**Fishery Data Series No. 23-18**

# Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River Near Eagle, Alaska, 2022


**by**

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**and**

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

## Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figures or figure captions.

**Weights and measures (metric)**

| | |
|---|---|
| centimeter | cm |
| deciliter | dL |
| gram | g |
| hectare | ha |
| kilogram | kg |
| kilometer | km |
| liter | L |
| meter | m |
| 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, $\chi^2$, 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 |

*FISHERY DATA SERIES NO. 23-18*

# SONAR ESTIMATION OF CHINOOK AND FALL CHUM SALMON PASSAGE IN THE YUKON RIVER NEAR EAGLE, ALASKA, 2022

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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 June 29 through October 6, 2022. A total of 12,025 (SE 119) Chinook salmon were estimated to have passed the sonar site from July 1 through August 21. The midpoint of the Chinook salmon migration occurred on July 29, which was 5 days later than the historical mean date. A total of 21,063 (SE 164) fall chum salmon were estimated to have passed the sonar site from August 22 through October 6. The fall chum salmon passage estimate was subsequently expanded to a total of 22,075 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 20, which was 3 days earlier 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 salmon, *Oncorhynchus tshawytscha*, 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, they are also 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 2022). 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: December 14, 2022).

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 (Morrill et al. 2022). Multi-beam imaging sonar, such as dual-frequency identification sonar (DIDSON) and adaptive resolution imaging sonar (ARIS), have been used at several sites, including the Kenai River (Key et al. 2018) and lower Yukon River near Pilot Station (Morrill et al. 2022), 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 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 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 T'eedriinjik (Chandalar) River drainages and various streams in the Yukon Territory, Canada, including the mainstem Yukon River.

In 2022, the project deployed split-beam and ARIS sonar to estimate Chinook and fall chum salmon migrating across the U.S./Canada border. Test 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 2022 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. 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:

3. Collect biological data from all fish captured in the test fisheries, including species, sex, length, and scales, as applicable.
4. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
5. 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 per 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 test 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 12 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 using 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 using a Simrad Controller program 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 using the counting software Echotastic (Version 3), 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 June 28 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 5.1 cm 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 AR2 Rotator and controlled by ARIScope software, which provided horizontal and vertical positioning (Figure 7). 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. 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 1 inch heavy-duty seine mesh supported by 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 first computing the passage rate for each sample ($p$) within each stratum and day as:

$$r_{dsp}= \frac{y_{dsp}}{h_{dsp}}, \tag{1}$$

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. The estimated passage was then computed by averaging the sampled hourly passage rates and then multiplying by the number of hours in a day as follows:

$$\hat{y}_{ds}= 24\cdot \frac{\sum_{p\text{-}1}^{n} r_{dsp}}{n_{ds}}, \tag{2}$$

and the total daily passage is then the sum of the estimated passage across all strata:

$$\hat{y}_{d}= \sum_{s} \hat{y}_{ds}\,. \tag{3}$$

Treating the systematically sampled sonar counts as a simple random sample could yield an overestimate of the variance because 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:

$$\widehat{Var}\left(\hat{y}_{ds}\right) = 24^2\, \frac{1\text{-}f_{ds}}{n_{ds}} \frac{\sum_{p=2}^{n_{ds}}\left(r_{dsp}\text{-}r_{ds,p\text{-}1}\right)^2}{2(n_{ds}\text{-}1)}, \tag{4}$$

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 $r_{dsp}$ is the hourly rate 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:

$$\widehat{Var}\,(\hat{y}) = \sum_d \sum_s \widehat{Var}\left(\hat{y}_{ds}\right). \tag{5}$$

## MISSING DATA

Estimating daily passage by multiplying the average hourly passage rates by 24 (Equation 2) compensates for missing data (either shortened or missing periods within a day) and is reflected in the variance (Equation 4) by reducing the number of samples and the fraction of the day sampled. If entire days were missed, then daily passage was interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

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

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 fishery managers via email each day. The estimates produced during the field season were further reviewed postseason and adjusted as necessary.

Because 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:

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

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 expanding for (October 18–October 6 = 12 days), and $x_i$ is the day number being estimated. Each bank was expanded separately and then summed to give the total expanded estimate for the day.

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 Distributions

Range distributions for Chinook and fall chum salmon were examined by importing text files containing all fish track information into *R*[2] where the 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, test fishery catches, and local subsistence harvest.

## Test Fishing

Test fisheries were implemented to monitor species composition and collect ASL and genetic samples: 1) a Chinook salmon test fishery from July 1 to 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 from August 1 to 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 to 1200 and 1300 to 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 in, 6.5 in, 7.5 in, and 8.5 in), drifted in a rotating schedule over the course of the Chinook salmon sample fishery to effectively capture all size classes present (Table 3). Nets were 25 fathoms long, approximately

[2] The R Project for statistical computing. R version 4.0.0 (Arbor Day). [released April 24, 2020; accessed: December 20, 2022]. Available for download from http://www.r-project.org/

8 m deep, and hung "even" at a 2:1 ratio of web to cork line (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:

$$t = SI - FO + \frac{FO\text{-}SO}{2} + \frac{FI\text{-}SI}{2}. \tag{8}$$

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

$$e_{dzlm} = \frac{25t_{dzlmj}}{60}. \tag{9}$$

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 test 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 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 (Berry and Larson 2021). 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

Inseason, the daily proportions of Chinook and fall chum salmon CPUE from the species composition test 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 9) 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 test fishery:

$$CPUE_{dbi} = \frac{\sum_g c_{dbig}}{\sum_g e_{dbg}}. \tag{10}$$

### 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*):

$$\hat{p}_{di} = \frac{CPUE_{di}}{\sum_i CPUE_{di}}. \tag{11}$$

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 hours 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). National Water Information System: Web Interface. USGS 15356000 Yukon River at Eagle Alaska. https://waterdata.usgs.gov/monitoring-location/15356000/#parameterCode=00065&startDT=2022-07-01&endDT=2022-10-06 (accessed: December 20, 2022).

# RESULTS AND DISCUSSION

## SONAR DEPLOYMENT

In 2022, 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. Overall, there were no significant problems with project operations. Both the left- and right-bank sonars operated from June 29 through October 6. The primary project objective of estimating Chinook and fall chum salmon passage through October 6 was achieved.

## CHINOOK AND FALL CHUM SALMON PASSAGE ESTIMATION

August 21 was determined to be the last day of the Chinook salmon migration based on CPUE from the species composition test fishery (Figures 10 and 11; Appendix A1). The total passage estimate for Chinook salmon was 12,025 (SE 119) from June 29 through August 21 (Table 5). The first quarter point of the run fell on July 24, the midpoint on July 29, and third quarter point on August 2 (Table 6). The midpoint of the Chinook salmon run occurred 5 days late compared to the 2005–2021[4] mean run timing (Figure 12). Chinook salmon passage peaked on July 30 with a daily estimate of 834 fish, and a total of 63 Chinook salmon were estimated to have passed the sonar on August 21, 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 between 19.8 hours and 60.4 hours (Table 7). Most time missed was due to generator failures, routine moving and re-aiming of the sonar because of changes in water level, and routine cleaning of the ARIS.

The total passage estimate for fall chum salmon was 21,063 (SE 164) fish from August 22 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 22,075 fish. Based on the expanded passage estimate, the first quarter point of the run fell on September 13, the midpoint on September 20, and the third quarter point on September 26 (Table 8). The midpoint of the fall chum salmon run occurred 3 days earlier than the 2006–2021[5] mean run timing (Figure 12). Fall chum salmon passage peaked on September 20 with a daily estimate of 1,227 fish, and a total of 288 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 between 12.0 hours and 24.4 hours (Table 9). Most time missed was due to generator failures, routine moving and re-aiming of the sonar 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 2022 season. Water levels and silt did not affect fish detection, and overall, the project ran smoothly with few breaks in operation.

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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 run was completed on the date the Chinook salmon run transitioned to fall chum salmon.

## 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 60 m of the transducer, and on the right bank, 95% of fish were detected within 15 m of the transducer. During the fall chum salmon migration, 95% of fish were detected within 20 m of the transducer on both banks. Approximately 66% (7,984) of Chinook salmon and 78% (17,305) 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 an increase in passage on the right bank from approximately 0600 to 1900 hours (Figure 17). When both banks were combined, this pattern was still evident but less pronounced.

## TEST FISHING

Chinook salmon test fishing occurred from July 1 through August 15. Species composition and fall chum salmon test fishing occurred from August 1 through September 30. A total of 133 Chinook salmon and 231 fall chum salmon were captured in drift gillnets between July 1 and September 30 (Table 10). A total of 1 humpback whitefish *Coregonus pidschian*; 8 sheefish *Stenodus leucichthys*; and 1 arctic grayling *Thymallus arcticus* were also captured in the test fisheries.

A total of 1,974 fathom-hours were fished in the Chinook salmon test fishery, and 2,132 fathom-hours were fished in the species-composition and fall chum salmon test fishery (Tables 11 and 12). The cumulative CPUE for both Chinook and fall chum salmon were well below the 2007–2021 means, and the cumulative CPUE for Chinook salmon was the lowest on record (Figure 18).

Chinook salmon sampled were made up of 73 (55%) males and 60 females. Fall chum salmon sampled were made up of 131 (57%) males and 100 females. Clipped adipose fins—an indication that fish hold coded wire tags from the hatchery in Whitehorse, Yukon Territory—were observed on no Chinook salmon.

A total of 133 Chinook and 231 fall chum salmon were sampled for complete ASL and genetic data. Of the scales collected, 119 (89%) Chinook and 209 (90%) fall chum salmon were analyzed as ageable[5]. Goals to collect biological data from all fish captured in the test 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 two-thirds of the season (Figure 19). The maximum water temperature observed was 17.4°C on July 9, and the minimum was 5.5°C on October 6. The water level was above the historical median (1995–2021) for most of the season except September 14 to

[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: December 20, 2022).

September 22, when it was near the historical median. (Figure 20). All goals to collect climatic and hydrologic measurements were achieved this season.

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# TABLES AND FIGURES

Table 1.–Split-beam sonar system settings at the Eagle sonar project on the Yukon River, 2022.

| 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 (µs) | All | 256 |
| | | | |
| | Ping rate (pps) | S1 | 8.33 |
| | | S2 | 4.16 |
| | | S3 | 16.66 |
| | | S4 | 8.33 |
| | | | |
| | Range (m)[a] | 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, 2022.

| 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 AR2 Rotator and ARIScope software.

Table 3.–Net schedule of mesh sizes in inches used for Chinook salmon test fishing and species composition and fall chum salmon test fishing for all zones at the Eagle sonar project on the Yukon River, 2022.

| | | Stretch mesh size 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 | 1 | 5.25 | 7.50 | NA |
| salmon samples | 2 | 7.50 | 5.25 | NA |

*Note*: NA means not applicable.

Table 4.–Specifications for drift gillnets used for test fishing at the Eagle sonar project on the Yukon River, 2022.

| | 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 monotwist (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, 2022.

| | | | | | 95% CI | |
|---|---|---|---|---|---|---|
| Species | Left bank | Right bank | Total passage | SE | Lower | Upper |
| Chinook | 7,984 | 4,041 | 12,025 | 119 | 11,792 | 12,258 |
| Fall chum (excluding expansion[a]) | 16,633 | 4,430 | 21,063 | 164 | 20,742 | 21,384 |
| Fall chum (including expansion[a,b]) | 17,305 | 4,770 | 22,075 | 164 | 21,754 | 22,396 |

[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.

[b] Standard error (SE) was only computed for the estimates during the period of sonar operation.

Table 6.–Estimated daily and cumulative Chinook salmon passage by bank at the Eagle sonar project on the Yukon River, 2022.

| | Daily | | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | SE | Left bank | Right bank | Total | Proportion |
| 06/29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 06/30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.000 |
| 07/01 | 0 | 11 | 11 | 5 | 0 | 11 | 11 | 0.001 |
| 07/02 | 0 | 11 | 11 | 5 | 0 | 22 | 22 | 0.002 |
| 07/03 | 0 | 17 | 17 | 6 | 0 | 39 | 39 | 0.003 |
| 07/04 | 4 | 8 | 12 | 4 | 4 | 47 | 51 | 0.004 |
| 07/05 | 6 | 17 | 23 | 5 | 10 | 64 | 74 | 0.006 |
| 07/06 | 16 | 39 | 55 | 8 | 26 | 103 | 129 | 0.011 |
| 07/07 | 14 | 28 | 42 | 5 | 40 | 131 | 171 | 0.014 |
| 07/08 | 12 | 46 | 58 | 7 | 52 | 177 | 229 | 0.019 |
| 07/09 | 40 | 47 | 87 | 6 | 92 | 224 | 316 | 0.026 |
| 07/10 | 62 | 58 | 120 | 13 | 154 | 282 | 436 | 0.036 |
| 07/11 | 64 | 86 | 150 | 14 | 218 | 368 | 586 | 0.049 |
| 07/12 | 92 | 58 | 150 | 16 | 310 | 426 | 736 | 0.061 |
| 07/13 | 98 | 79 | 177 | 15 | 408 | 505 | 913 | 0.076 |
| 07/14 | 96 | 71 | 167 | 14 | 504 | 576 | 1,080 | 0.090 |
| 07/15 | 112 | 84 | 196 | 17 | 616 | 660 | 1,276 | 0.106 |
| 07/16 | 136 | 64 | 200 | 13 | 752 | 724 | 1,476 | 0.123 |
| 07/17 | 130 | 88 | 218 | 15 | 882 | 812 | 1,694 | 0.141 |
| 07/18 | 154 | 70 | 224 | 18 | 1,036 | 882 | 1,918 | 0.160 |
| 07/19 | 124 | 70 | 194 | 16 | 1,160 | 952 | 2,112 | 0.176 |
| 07/20 | 144 | 50 | 194 | 12 | 1,304 | 1,002 | 2,306 | 0.192 |
| 07/21 | 108 | 67 | 175 | 12 | 1,412 | 1,069 | 2,481 | 0.206 |
| 07/22 | 142 | 81 | 223 | 14 | 1,554 | 1,150 | 2,704 | 0.225 |
| 07/23 | 126 | 117 | 243 | 14 | 1,680 | 1,267 | 2,947 | 0.245 |
| 07/24 | 209 | 84 | 293 | 17 | 1,889 | 1,351 | 3,240 | 0.269 |
| 07/25 | 246 | 209 | 455 | 20 | 2,135 | 1,560 | 3,695 | 0.307 |
| 07/26 | 294 | 216 | 510 | 21 | 2,429 | 1,776 | 4,205 | 0.350 |
| 07/27 | 373 | 188 | 561 | 31 | 2,802 | 1,964 | 4,766 | 0.396 |
| 07/28 | 470 | 256 | 726 | 29 | 3,272 | 2,220 | 5,492 | 0.457 |
| **07/29** | **599** | **179** | **778** | **29** | **3,871** | **2,399** | **6,270** | **0.521** |
| 07/30 | 702 | 132 | 834 | 33 | 4,573 | 2,531 | 7,104 | 0.591 |
| 07/31 | 600 | 176 | 776 | 32 | 5,173 | 2,707 | 7,880 | 0.655 |
| 08/01 | 430 | 198 | 628 | 32 | 5,603 | 2,905 | 8,508 | 0.708 |
| 08/02 | 431 | 145 | 576 | 24 | 6,034 | 3,050 | 9,084 | 0.755 |
| 08/03 | 342 | 178 | 520 | 29 | 6,376 | 3,228 | 9,604 | 0.799 |
| 08/04 | 292 | 168 | 460 | 19 | 6,668 | 3,396 | 10,064 | 0.837 |
| 08/05 | 270 | 137 | 407 | 23 | 6,938 | 3,533 | 10,471 | 0.871 |

-continued-

Table 6.–Page 2 of 2.

| | Daily | | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | SE | Left bank | Right bank | Total | Proportion |
| 08/06 | 176 | 69 | 245 | 16 | 7,114 | 3,602 | 10,716 | 0.891 |
| 08/07 | 146 | 56 | 202 | 14 | 7,260 | 3,658 | 10,918 | 0.908 |
| 08/08 | 100 | 52 | 152 | 13 | 7,360 | 3,710 | 11,070 | 0.921 |
| 08/09 | 112 | 27 | 139 | 14 | 7,472 | 3,737 | 11,209 | 0.932 |
| 08/10 | 84 | 26 | 110 | 9 | 7,556 | 3,763 | 11,319 | 0.941 |
| 08/11 | 86 | 52 | 138 | 12 | 7,642 | 3,815 | 11,457 | 0.953 |
| 08/12 | 68 | 34 | 102 | 10 | 7,710 | 3,849 | 11,559 | 0.961 |
| 08/13 | 50 | 21 | 71 | 9 | 7,760 | 3,870 | 11,630 | 0.967 |
| 08/14 | 34 | 14 | 48 | 8 | 7,794 | 3,884 | 11,678 | 0.971 |
| 08/15 | 17 | 24 | 41 | 6 | 7,811 | 3,908 | 11,719 | 0.975 |
| 08/16 | 32 | 10 | 42 | 7 | 7,843 | 3,918 | 11,761 | 0.978 |
| 08/17 | 22 | 22 | 44 | 6 | 7,865 | 3,940 | 11,805 | 0.982 |
| 08/18 | 19 | 20 | 39 | 7 | 7,884 | 3,960 | 11,844 | 0.985 |
| 08/19 | 48 | 18 | 66 | 9 | 7,932 | 3,978 | 11,910 | 0.990 |
| 08/20 | 26 | 26 | 52 | 8 | 7,958 | 4,004 | 11,962 | 0.995 |
| 08/21[b] | 26 | 37 | 63 | 9 | 7,984 | 4,041 | 12,025 | 1.000 |
| Total | 7,984 | 4,041 | 12,025 | | | | | |
| Var | 9,114 | 5,023 | 14,137 | | | | | |
| SE | 95 | 71 | 119 | | | | | |

*Note:* SE means standard error and Var means variance. 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] 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, 2022.

| | Left bank | | Right bank | |
|---|---|---|---|---|
| Date | Stratum 1 (0–50 m) | Stratum 2 (50–150 m) | Stratum 5 (0.7–20.7 m) | Stratum 6 (20.7–40.7 m) |
| 06/29 | 498 | 480 | 576 | 0 |
| 06/30 | 168 | 180 | 408 | 0 |
| 07/01 | 30 | 30 | 462 | 216 |
| 07/02 | 0 | 0 | 348 | 270 |
| 07/03 | 0 | 0 | 66 | 240 |
| 07/04 | 0 | 0 | 84 | 18 |
| 07/05 | 0 | 0 | 78 | 0 |
| 07/06 | 0 | 0 | 84 | 0 |
| 07/07 | 0 | 0 | 0 | 18 |
| 07/08 | 0 | 60 | 0 | 66 |
| 07/09 | 18 | 30 | 18 | 0 |
| 07/10 | 0 | 0 | 12 | 0 |
| 07/11 | 0 | 0 | 12 | 0 |
| 07/12 | 30 | 18 | 0 | 0 |
| 07/13 | 0 | 0 | 48 | 0 |
| 07/14 | 0 | 0 | 216 | 0 |
| 07/15 | 0 | 0 | 0 | 0 |
| 07/16 | 0 | 0 | 132 | 0 |
| 07/17 | 0 | 0 | 12 | 0 |
| 07/18 | 0 | 0 | 12 | 0 |
| 07/19 | 0 | 0 | 12 | 36 |
| 07/20 | 0 | 0 | 18 | 120 |
| 07/21 | 0 | 0 | 6 | 0 |
| 07/22 | 0 | 0 | 6 | 0 |
| 07/23 | 0 | 0 | 12 | 0 |
| 07/24 | 60 | 90 | 0 | 0 |
| 07/25 | 60 | 30 | 24 | 0 |
| 07/26 | 0 | 0 | 12 | 0 |
| 07/27 | 138 | 138 | 12 | 0 |
| 07/28 | 0 | 0 | 0 | 0 |
| 07/29 | 0 | 0 | 0 | 0 |
| 07/30 | 0 | 0 | 216 | 0 |
| 07/31 | 0 | 0 | 30 | 0 |
| 08/01 | 0 | 0 | 6 | 0 |
| 08/02 | 30 | 42 | 6 | 0 |
| 08/03 | 0 | 0 | 6 | 120 |

-continued-

Table 7.–Page 2 of 2.

| | Left bank | | Right bank | |
|---|---|---|---|---|
| Date | Stratum 1 (0–50 m) | Stratum 2 (50–150 m) | Stratum 5 (0.7–20.7 m) | Stratum 6 (20.7–40.7 m) |
| 08/04 | 0 | 0 | 6 | 330 |
| 08/05 | 0 | 0 | 168 | 324 |
| 08/06 | 0 | 0 | 6 | 0 |
| 08/07 | 0 | 0 | 0 | 0 |
| 08/08 | 0 | 0 | 12 | 0 |
| 08/09 | 0 | 0 | 204 | 0 |
| 08/10 | 0 | 0 | 6 | 0 |
| 08/11 | 0 | 0 | 0 | 0 |
| 08/12 | 0 | 0 | 0 | 0 |
| 08/13 | 0 | 0 | 54 | 0 |
| 08/14 | 0 | 0 | 0 | 60 |
| 08/15 | 30 | 0 | 0 | 0 |
| 08/16 | 0 | 0 | 150 | 0 |
| 08/17 | 0 | 0 | 0 | 0 |
| 08/18 | 120 | 108 | 6 | 0 |
| 08/19 | 0 | 0 | 0 | 0 |
| 08/20 | 0 | 0 | 0 | 0 |
| 08/21 | 6 | 0 | 78 | 0 |
| Total (min) | 1,188 | 1,206 | 3,624 | 1,818 |
| Total (h) | 19.8 | 20.1 | 60.4 | 30.3 |

Table 8.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project on the Yukon River, 2022.

| | Daily | | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | SE | Left bank | Right bank | Total | Proportion |
| 08/22[a] | 62 | 25 | 87 | 10 | 62 | 25 | 87 | 0.004 |
| 08/23 | 46 | 34 | 80 | 11 | 108 | 59 | 167 | 0.008 |
| 08/24 | 44 | 54 | 98 | 12 | 152 | 113 | 265 | 0.012 |
| 08/25 | 50 | 36 | 86 | 8 | 202 | 149 | 351 | 0.016 |
| 08/26 | 52 | 40 | 92 | 9 | 254 | 189 | 443 | 0.020 |
| 08/27 | 76 | 18 | 94 | 12 | 330 | 207 | 537 | 0.024 |
| 08/28 | 76 | 22 | 98 | 10 | 406 | 229 | 635 | 0.029 |
| 08/29 | 88 | 36 | 124 | 10 | 494 | 265 | 759 | 0.034 |
| 08/30 | 130 | 55 | 185 | 12 | 624 | 320 | 944 | 0.043 |
| 08/31 | 114 | 74 | 188 | 13 | 738 | 394 | 1,132 | 0.051 |
| 09/01 | 138 | 54 | 192 | 12 | 876 | 448 | 1,324 | 0.060 |
| 09/02 | 164 | 36 | 200 | 19 | 1,040 | 484 | 1,524 | 0.069 |
| 09/03 | 174 | 49 | 223 | 15 | 1,214 | 533 | 1,747 | 0.079 |
| 09/04 | 176 | 71 | 247 | 17 | 1,390 | 604 | 1,994 | 0.090 |
| 09/05 | 144 | 30 | 174 | 13 | 1,534 | 634 | 2,168 | 0.098 |
| 09/06 | 202 | 34 | 236 | 11 | 1,736 | 668 | 2,404 | 0.109 |
| 09/07 | 156 | 44 | 200 | 14 | 1,892 | 712 | 2,604 | 0.118 |
| 09/08 | 190 | 46 | 236 | 14 | 2,082 | 758 | 2,840 | 0.129 |
| 09/09 | 264 | 94 | 358 | 18 | 2,346 | 852 | 3,198 | 0.145 |
| 09/10 | 302 | 62 | 364 | 20 | 2,648 | 914 | 3,562 | 0.161 |
| 09/11 | 432 | 104 | 536 | 28 | 3,080 | 1,018 | 4,098 | 0.186 |
| 09/12 | 516 | 184 | 700 | 34 | 3,596 | 1,202 | 4,798 | 0.217 |
| 09/13 | 540 | 178 | 718 | 25 | 4,136 | 1,380 | 5,516 | 0.250 |
| 09/14 | 500 | 171 | 671 | 27 | 4,636 | 1,551 | 6,187 | 0.280 |
| 09/15 | 607 | 178 | 785 | 32 | 5,243 | 1,729 | 6,972 | 0.316 |
| 09/16 | 641 | 212 | 853 | 43 | 5,884 | 1,941 | 7,825 | 0.354 |
| 09/17 | 631 | 186 | 817 | 27 | 6,515 | 2,127 | 8,642 | 0.391 |
| 09/18 | 650 | 168 | 818 | 32 | 7,165 | 2,295 | 9,460 | 0.429 |
| 09/19 | 831 | 122 | 953 | 35 | 7,996 | 2,417 | 10,413 | 0.472 |
| **09/20** | **1,019** | **208** | **1,227** | **32** | **9,015** | **2,625** | **11,640** | **0.527** |
| 09/21 | 884 | 250 | 1,134 | 38 | 9,899 | 2,875 | 12,774 | 0.579 |
| 09/22 | 855 | 203 | 1,058 | 35 | 10,754 | 3,078 | 13,832 | 0.627 |
| 09/23 | 773 | 89 | 862 | 35 | 11,527 | 3,167 | 14,694 | 0.666 |
| 09/24 | 857 | 75 | 932 | 32 | 12,384 | 3,242 | 15,626 | 0.708 |
| 09/25 | 805 | 84 | 889 | 37 | 13,189 | 3,326 | 16,515 | 0.748 |
| 09/26 | 703 | 96 | 799 | 37 | 13,892 | 3,422 | 17,314 | 0.784 |

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Table 8.–Page 2 of 2.

| | Daily | | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | SE | Left bank | Right bank | Total | Proportion |
| 09/27 | 478 | 121 | 599 | 27 | 14,370 | 3,543 | 17,913 | 0.811 |
| 09/28 | 414 | 115 | 529 | 33 | 14,784 | 3,658 | 18,442 | 0.835 |
| 09/29 | 386 | 123 | 509 | 29 | 15,170 | 3,781 | 18,951 | 0.858 |
| 09/30 | 336 | 91 | 427 | 21 | 15,506 | 3,872 | 19,378 | 0.878 |
| 10/01 | 212 | 134 | 346 | 21 | 15,718 | 4,006 | 19,724 | 0.893 |
| 10/02 | 188 | 115 | 303 | 22 | 15,906 | 4,121 | 20,027 | 0.907 |
| 10/03 | 154 | 82 | 236 | 18 | 16,060 | 4,203 | 20,263 | 0.918 |
| 10/04 | 209 | 63 | 272 | 18 | 16,269 | 4,266 | 20,535 | 0.930 |
| 10/05 | 172 | 68 | 240 | 15 | 16,441 | 4,334 | 20,775 | 0.941 |
| 10/6[b] | 192 | 96 | 288 | 27 | 16,633 | 4,430 | 21,063 | 0.954 |
| 10/07[c] | 161 | 81 | 242 | NA | 16,794 | 4,511 | 21,305 | 0.965 |
| 10/08[c] | 133 | 67 | 200 | NA | 16,927 | 4,578 | 21,505 | 0.974 |
| 10/09[c] | 108 | 54 | 162 | NA | 17,035 | 4,632 | 21,667 | 0.982 |
| 10/10[c] | 85 | 43 | 128 | NA | 17,120 | 4,675 | 21,795 | 0.987 |
| 10/11[c] | 65 | 33 | 98 | NA | 17,185 | 4,708 | 21,893 | 0.992 |
| 10/12[c] | 48 | 24 | 72 | NA | 17,233 | 4,732 | 21,965 | 0.995 |
| 10/13[c] | 33 | 17 | 50 | NA | 17,266 | 4,749 | 22,015 | 0.997 |
| 10/14[c] | 21 | 11 | 32 | NA | 17,287 | 4,760 | 22,047 | 0.999 |
| 10/15[c] | 12 | 6 | 18 | NA | 17,299 | 4,766 | 22,065 | 1.000 |
| 10/16[c] | 5 | 3 | 8 | NA | 17,304 | 4,769 | 22,073 | 1.000 |
| 10/17[c] | 1 | 1 | 2 | NA | 17,305 | 4,770 | 22,075 | 1.000 |
| 10/18[d] | 0 | 0 | 0 | NA | 17,305 | 4,770 | 22,075 | 1.000 |
| Total | 17,305 | 4,770 | 22,075 | | | | | |
| Var[e] | 21,181 | 5,679 | 26,860 | | | | | |
| SE[e] | 146 | 75 | 164 | | | | | |

*Note:* SE means standard error and Var means variance. 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] Last day of the expanded passage.

[e] Variance (Var) and standard error (SE) 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, 2022.

| | 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) |
| 08/22 | 0 | 0 | 210 | 192 |
| 08/23 | 0 | 0 | 6 | 6 |
| 08/24 | 0 | 0 | 42 | 54 |
| 08/25 | 0 | 0 | 12 | 12 |
| 08/26 | 0 | 0 | 18 | 18 |
| 08/27 | 0 | 0 | 6 | 6 |
| 08/28 | 0 | 0 | 6 | 12 |
| 08/29 | 0 | 6 | 0 | 24 |
| 08/30 | 0 | 0 | 24 | 0 |
| 08/31 | 0 | 0 | 150 | 192 |
| 09/01 | 0 | 0 | 12 | 18 |
| 09/02 | 120 | 90 | 6 | 12 |
| 09/03 | 0 | 0 | 18 | 0 |
| 09/04 | 0 | 0 | 6 | 12 |
| 09/05 | 0 | 0 | 6 | 6 |
| 09/06 | 0 | 0 | 0 | 0 |
| 09/07 | 0 | 0 | 0 | 0 |
| 09/08 | 0 | 0 | 6 | 6 |
| 09/09 | 0 | 0 | 30 | 6 |
| 09/10 | 0 | 0 | 0 | 18 |
| 09/11 | 0 | 0 | 0 | 6 |
| 09/12 | 0 | 30 | 0 | 18 |
| 09/13 | 0 | 0 | 12 | 18 |
| 09/14 | 0 | 0 | 12 | 24 |
| 09/15 | 0 | 0 | 6 | 12 |
| 09/16 | 0 | 0 | 12 | 6 |
| 09/17 | 0 | 0 | 0 | 24 |
| 09/18 | 0 | 0 | 0 | 12 |
| 09/19 | 0 | 0 | 6 | 42 |
| 09/20 | 0 | 0 | 0 | 36 |
| 09/21 | 198 | 234 | 12 | 6 |
| 09/22 | 0 | 0 | 6 | 30 |
| 09/23 | 0 | 0 | 6 | 6 |
| 09/24 | 0 | 0 | 6 | 12 |
| 09/25 | 0 | 0 | 12 | 6 |
| 09/26 | 0 | 0 | 18 | 6 |
| 09/27 | 0 | 0 | 6 | 6 |
| 09/28 | 0 | 0 | 120 | 108 |
| 09/29 | 0 | 0 | 6 | 6 |
| 09/30 | 0 | 0 | 12 | 12 |
| 10/01 | 0 | 0 | 0 | 24 |
| 10/02 | 0 | 0 | 18 | 12 |
| 10/03 | 0 | 0 | 18 | 42 |

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Table 9.–Page 2 of 2.

| | 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) |
| 10/04 | 30 | 30 | 24 | 24 |
| 10/05 | 12 | 0 | 12 | 12 |
| 10/06 | 360 | 360 | 360 | 360 |
| Total (min) | 720 | 750 | 1,242 | 1,464 |
| Total (h) | 12.0 | 12.5 | 20.7 | 24.4 |

Table 10.–Fish caught using gillnets at the Eagle sonar project on the Yukon River, 2022.

| | Sampling purpose | | |
|---|---|---|---|
| Species | Species composition and fall chum salmon samples | Chinook salmon samples | Total |
| Chinook salmon | 53 | 80 | 133 |
| Fall chum salmon | 231 | 0 | 231 |
| Humpback whitefish | 1 | 0 | 1 |
| Sheefish | 8 | 0 | 8 |
| Arctic grayling | 1 | 0 | 1 |
| Total | 294 | 80 | 374 |

Table 11.–Fishing effort, catch, and proportion by zone and mesh size for Chinook and fall chum salmon in the Chinook salmon test fishery at the Eagle sonar project on the Yukon River, 2022.

| | Mesh size | Fishing effort | Chinook salmon | | Fall chum salmon | |
|---|---|---|---|---|---|---|
| Zone[a] | (in) | (fathom-hours) | Catch | Proportion | Catch | Proportion |
| LBN | 5.25 | 170 | 24 | 0.300 | 0 | 0.000 |
| | 6.50 | 171 | 13 | 0.163 | 0 | 0.000 |
| | 7.50 | 166 | 20 | 0.250 | 0 | 0.000 |
| | 8.50 | 153 | 14 | 0.175 | 0 | 0.000 |
| Total | | 659 | 71 | 0.888 | 0 | 0.000 |
| RBN | 5.25 | 172 | 1 | 0.013 | 0 | 0.000 |
| | 6.50 | 175 | 1 | 0.013 | 0 | 0.000 |
| | 7.50 | 163 | 2 | 0.025 | 0 | 0.000 |
| | 8.50 | 157 | 0 | 0.000 | 0 | 0.000 |
| Total | | 667 | 4 | 0.050 | 0 | 0.000 |
| LBF | 5.25 | 164 | 1 | 0.013 | 0 | 0.000 |
| | 6.50 | 170 | 1 | 0.013 | 0 | 0.000 |
| | 7.50 | 163 | 0 | 0.000 | 0 | 0.000 |
| | 8.50 | 151 | 3 | 0.038 | 0 | 0.000 |
| Total | | 648 | 5 | 0.063 | 0 | 0.000 |
| Grand total | | 1,974 | 80 | 1.000 | 0 | 0.000 |

[a] Gillnets were drifted through 3 zones: left bank nearshore (LBN) was located approximately 1 net length from shore; left bank offshore (LBF) was located approximately 2 net lengths from shore; and right bank nearshore (RBN) was 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 test fishery at the Eagle sonar project on the Yukon River, 2022.

| | Mesh size | Fishing effort | Chinook salmon | | Fall chum salmon | |
|---|---|---|---|---|---|---|
| Zone[a] | (in) | (fathom-hours) | Catch | Proportion | Catch | Proportion |
| LBI | 5.25 | 376 | 6 | 0.113 | 167 | 0.723 |
| | 7.50 | 341 | 9 | 0.170 | 6 | 0.026 |
| Total | | 716 | 15 | 0.283 | 173 | 0.749 |
| LBN | 5.25 | 359 | 12 | 0.226 | 42 | 0.182 |
| | 7.50 | 354 | 21 | 0.396 | 11 | 0.048 |
| Total | | 713 | 33 | 0.623 | 53 | 0.229 |
| LBF | 5.25 | 351 | 4 | 0.075 | 3 | 0.013 |
| | 7.50 | 351 | 1 | 0.019 | 2 | 0.009 |
| Total | | 703 | 5 | 0.094 | 5 | 0.022 |
| Grand total | | 2,132 | 53 | 1.000 | 231 | 1.000 |

[a] Gillnets were drifted through 3 zones on the left bank: on the left bank inshore (LBI) 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.

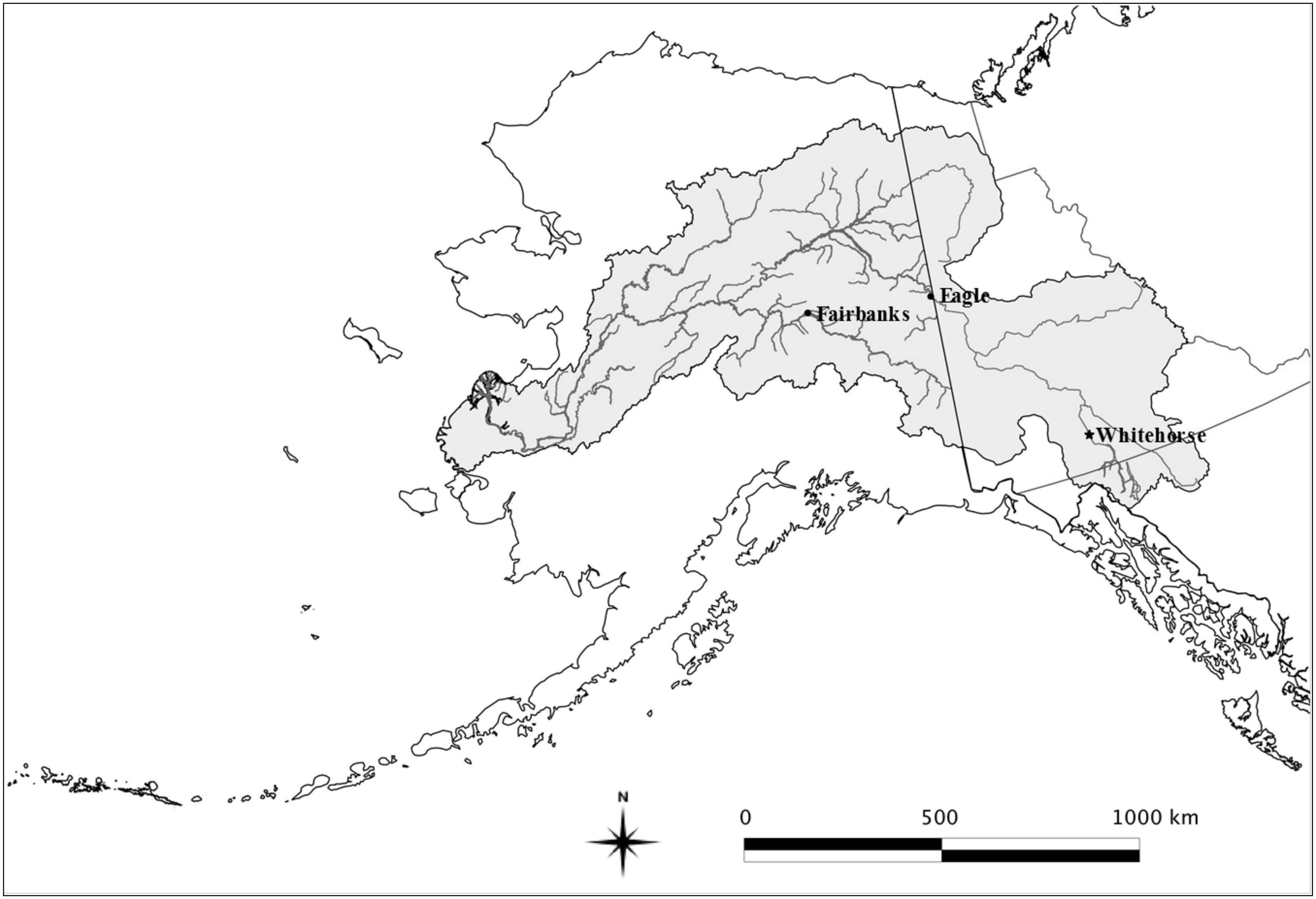


Figure 1.–Yukon River drainage.

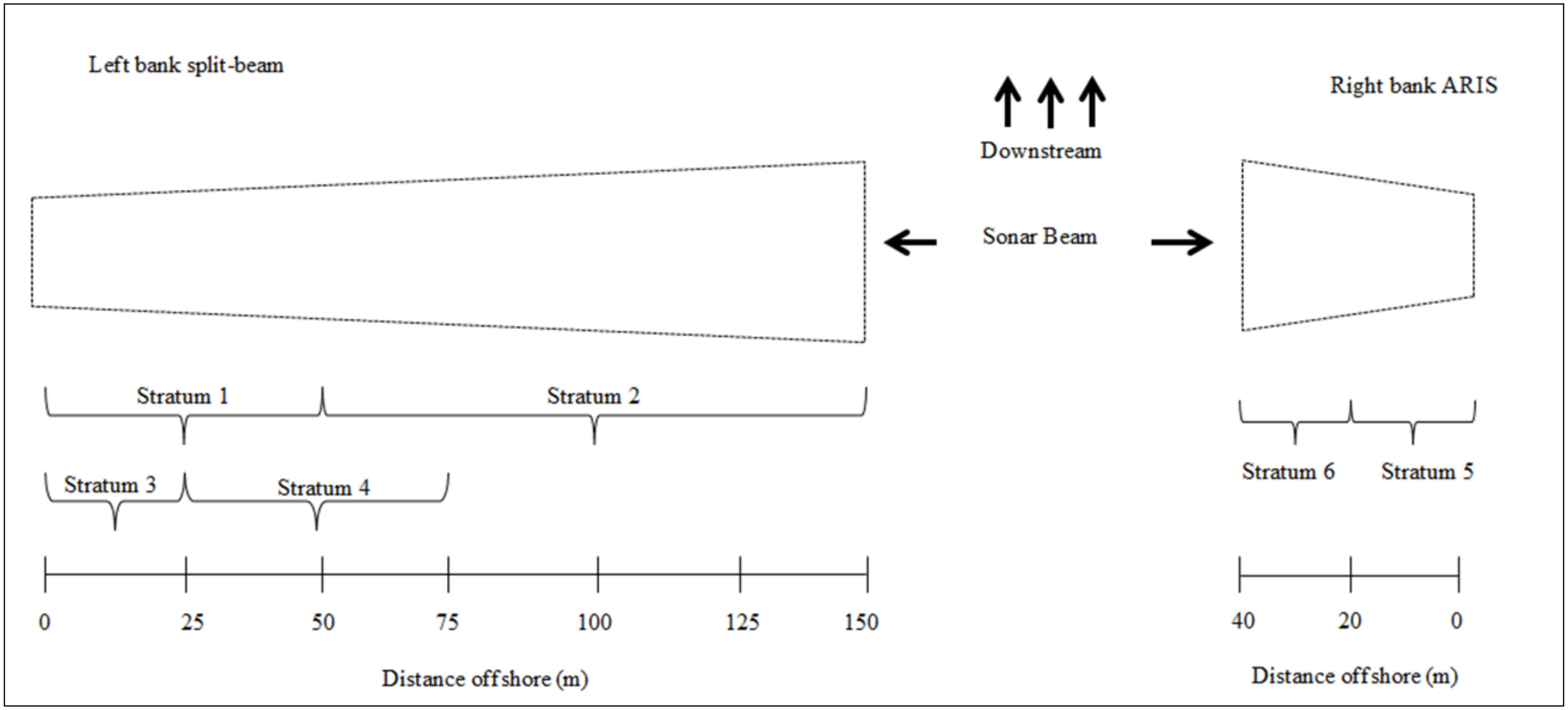


Figure 2.–Illustration of strata and approximate sonar ranges (not to scale) at the Eagle sonar project on the Yukon River, 2022.

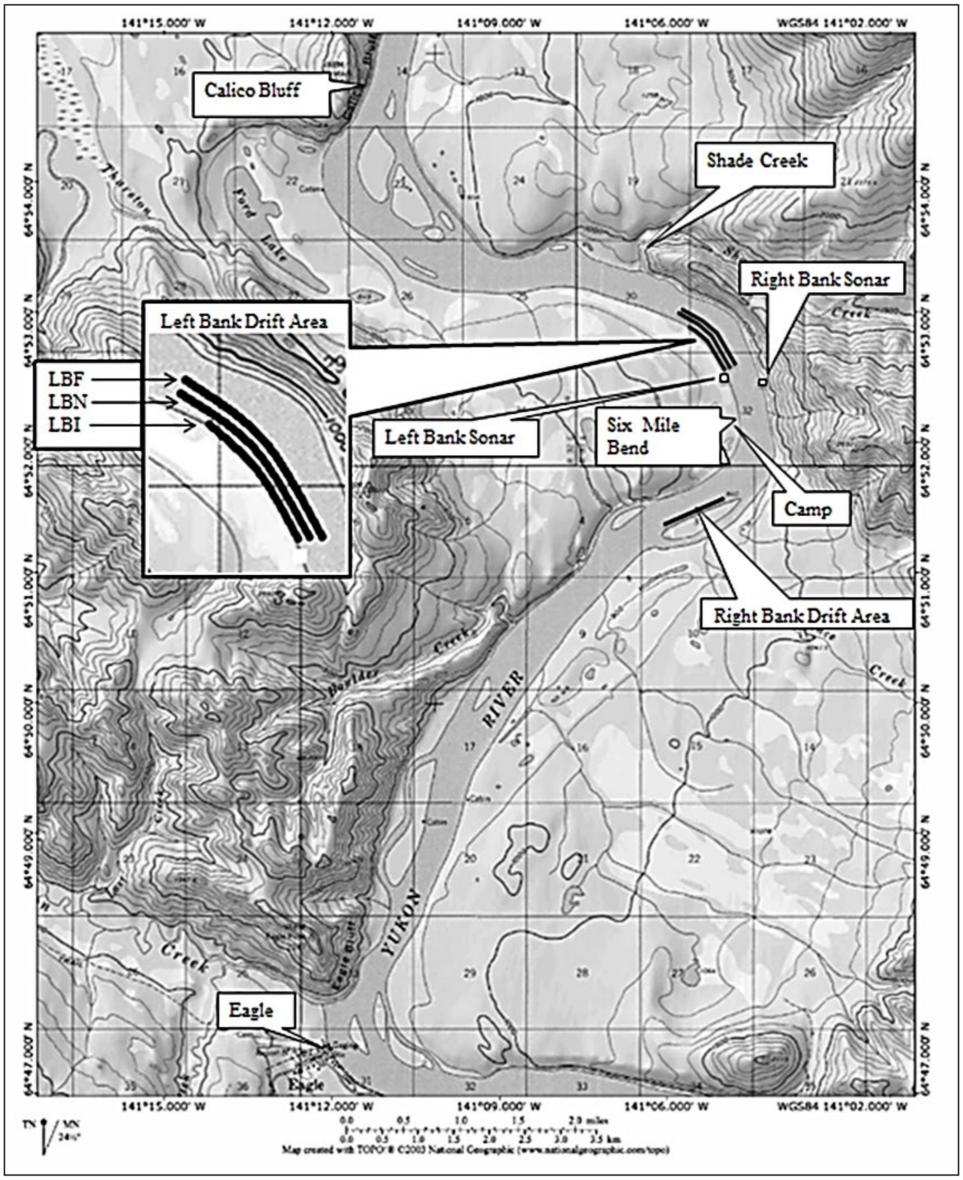


Figure 3.–Eagle sonar project site at Six Mile Bend on the Yukon River showing sonar and drift gillnet fishing locations, 2022.

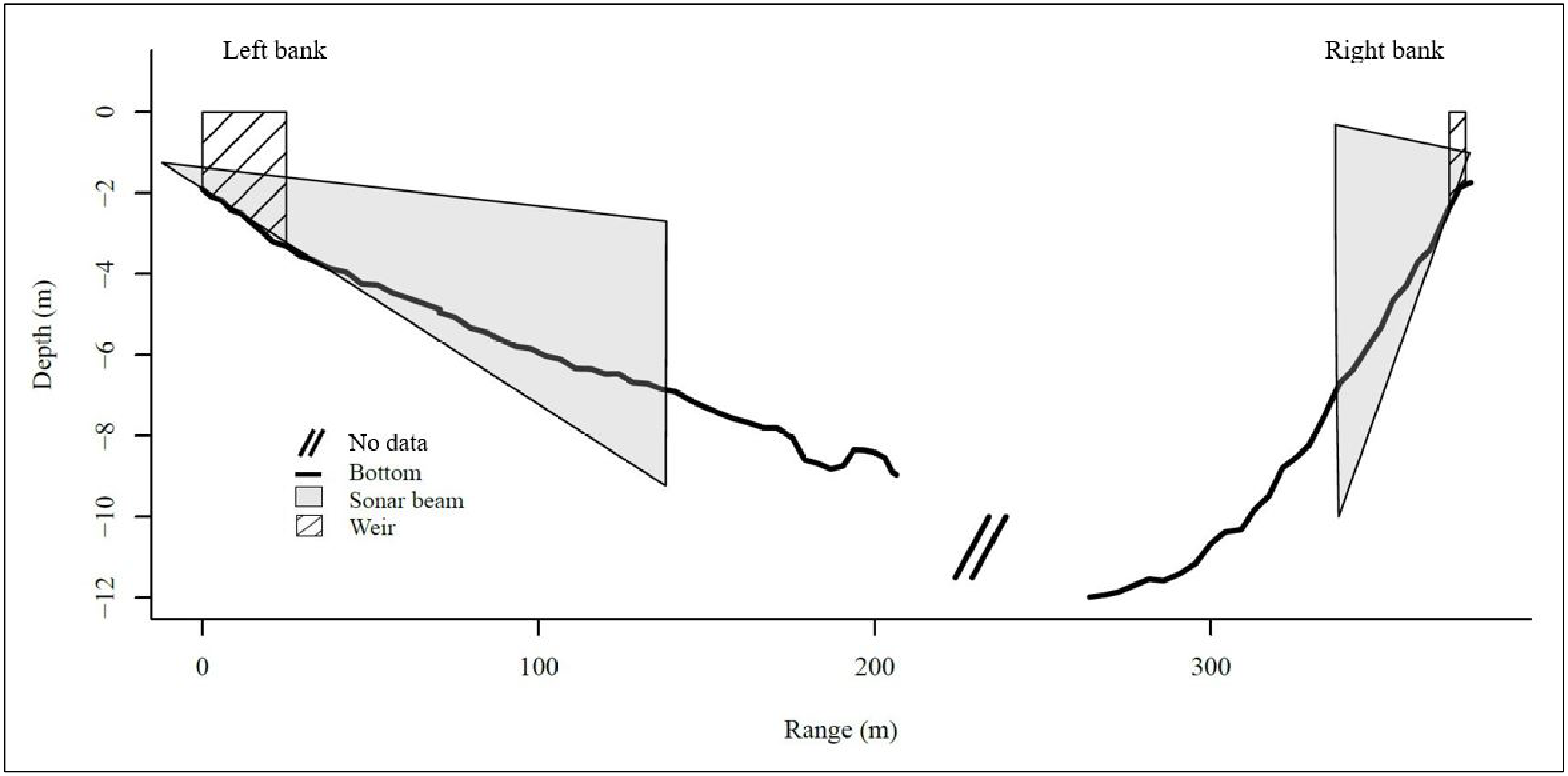


Figure 4.–Depth profile of the Yukon River in front of transducers (looking downstream) and approximate sonar coverage at the Eagle sonar project, 2022.

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

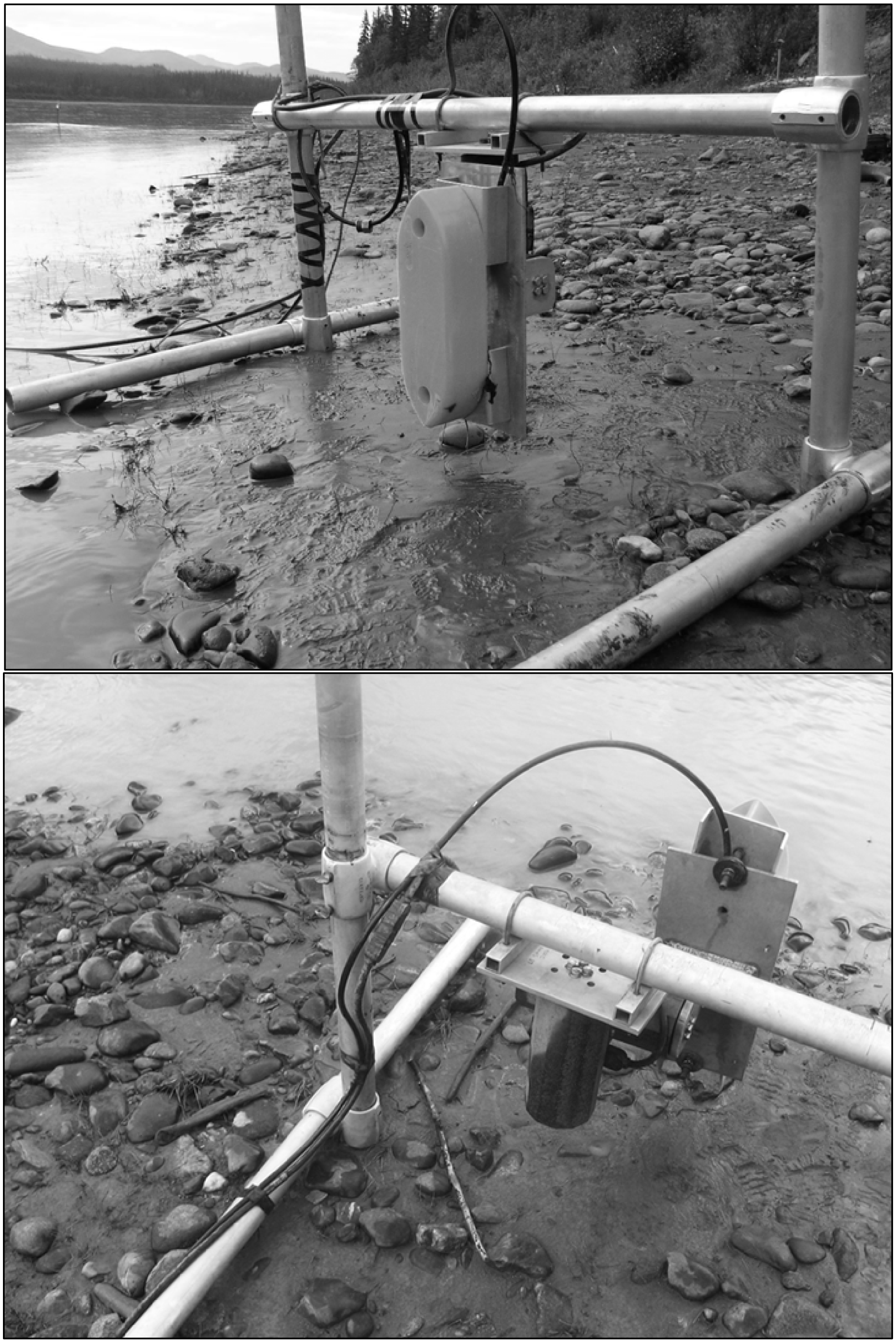

Figure 5.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single-axis automated rotators (bottom) used on the left bank at the Eagle sonar project on the Yukon River, 2022.

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, 2022.

Figure 7.–ARIS imaging sonar and AR2 Rotator mounted to an aluminum H-mount (top) and close-up view of rotator mount (bottom) at the Eagle sonar project on the Yukon River, 2022.

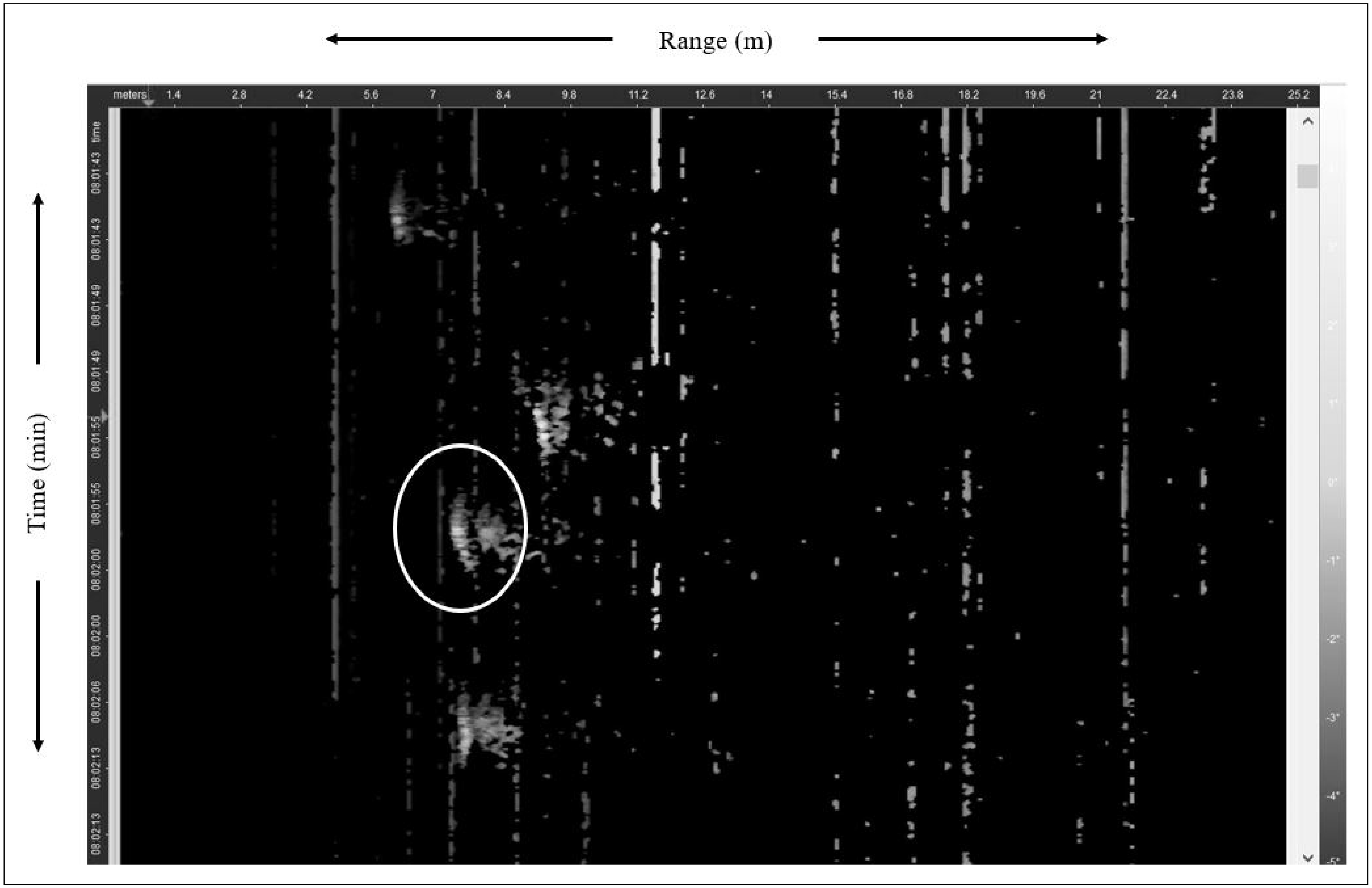


Figure 8.–Screenshot of an echogram from a split-beam sonar data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

*Note*: Ellipse encompasses typical upstream migrating salmon.

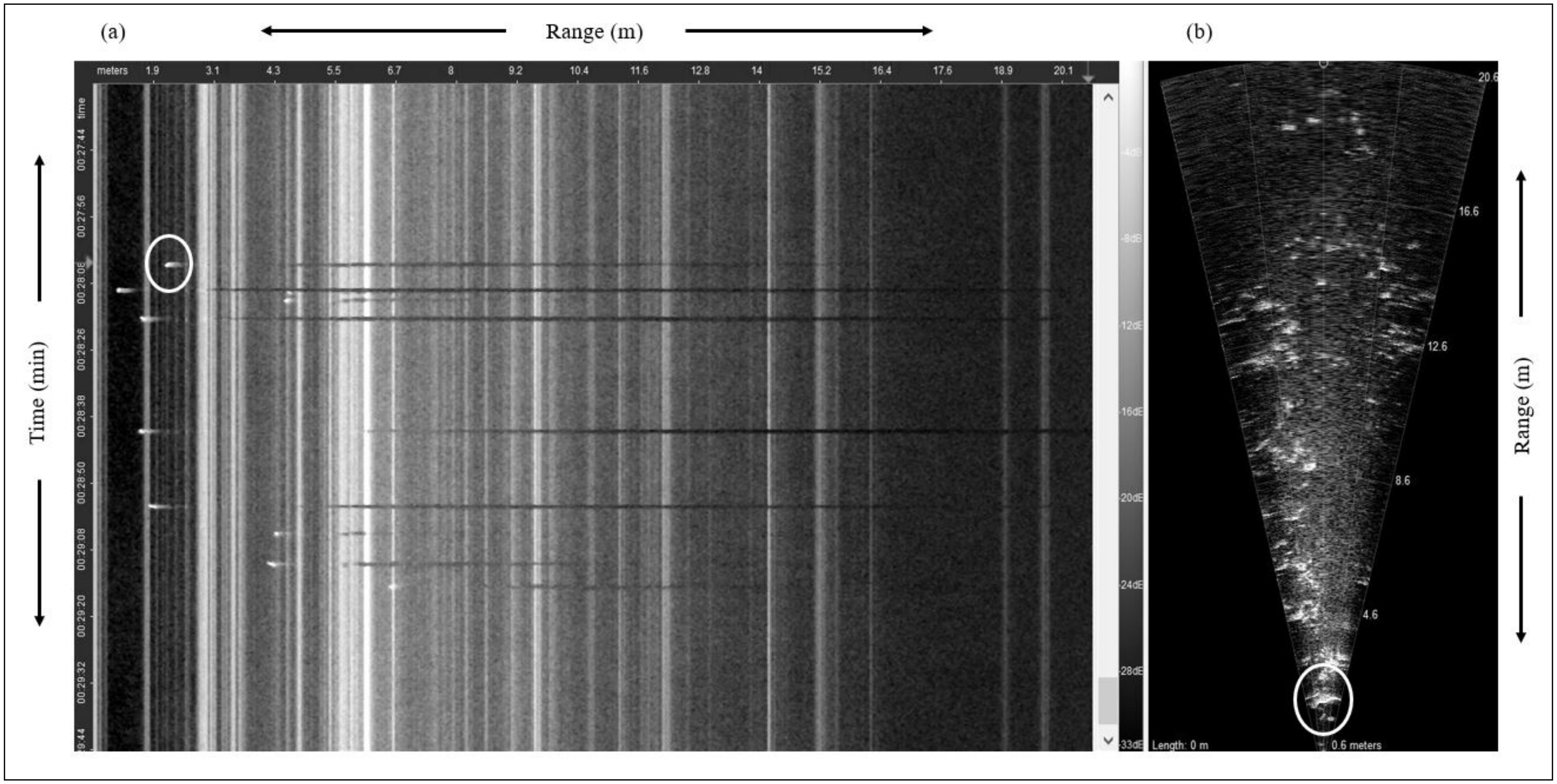


Figure 9.–Screenshots of an echogram (a) and video (b) from an ARIS data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

*Note*: Ellipse encompasses typical upstream migrating salmon.

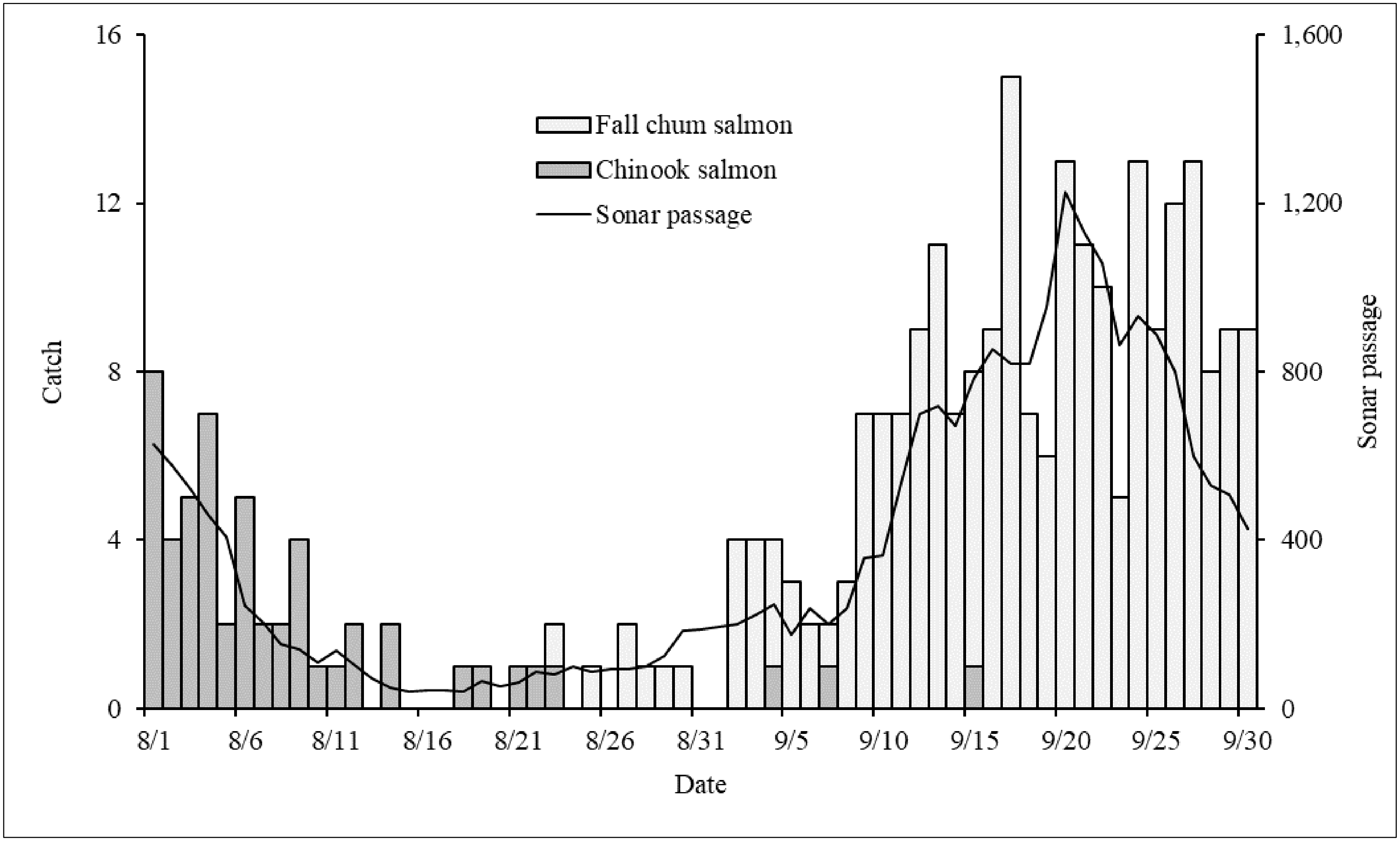


Figure 10.–Daily catch during species composition fishing and sonar passage estimates at the Eagle sonar project on the Yukon River, 2022.

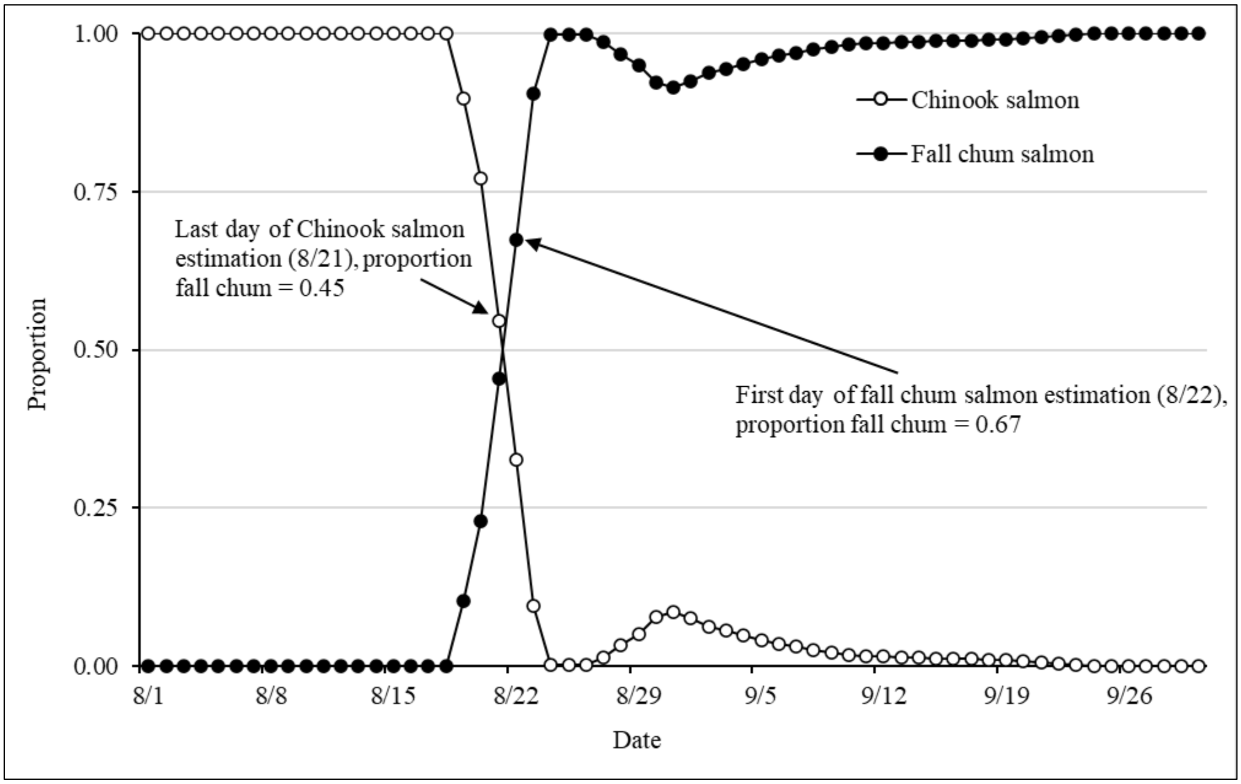


Figure 11.–Proportion of catch based on smoothed Chinook and fall chum salmon species composition CPUE data at the Eagle sonar project on the Yukon River, 2022.

*Note*: Species transition date (August 22) is 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.

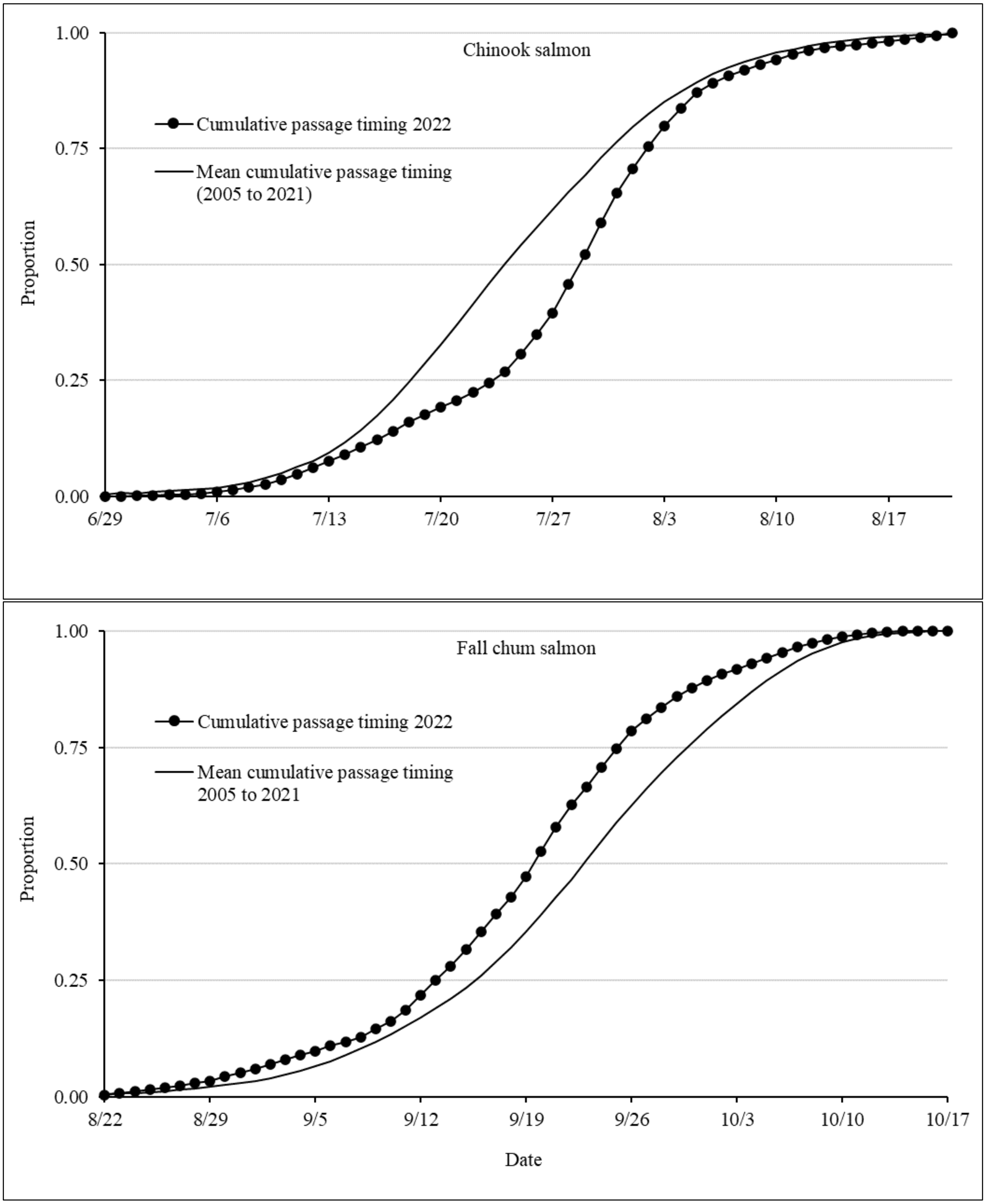


Figure 12.–2022 Chinook (top) and fall chum (bottom) salmon daily cumulative passage timing compared to the 2005–2022 (Chinook salmon) and 2006–2022 (fall chum salmon) mean passage timing at the Eagle sonar project on the Yukon River.

*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.

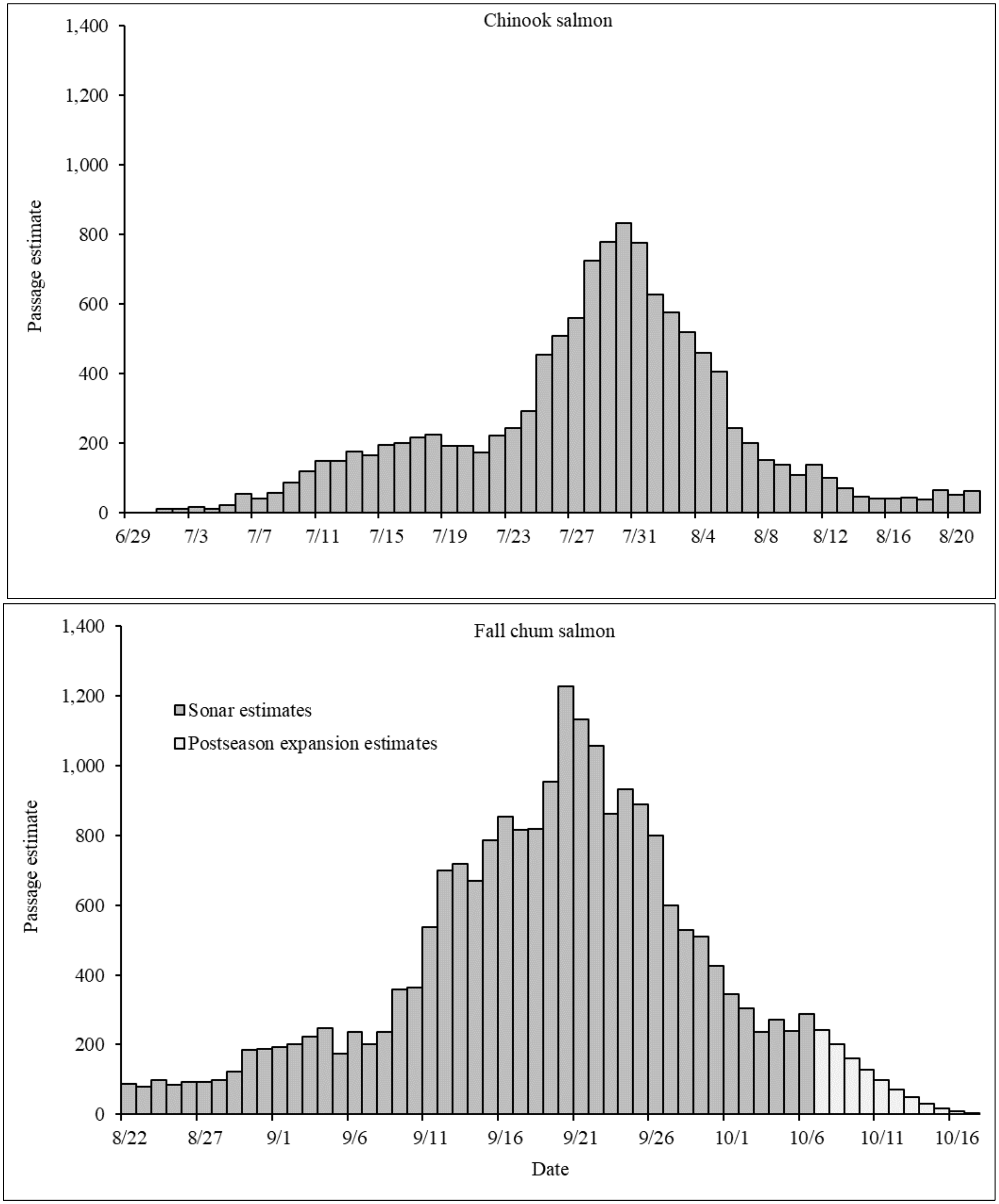


Figure 13.–Daily sonar passage estimates for Chinook salmon (top) from June 29 through August 21 and fall chum salmon (bottom) from August 22 through October 17 at the Eagle sonar project on the Yukon River, 2022.

*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.

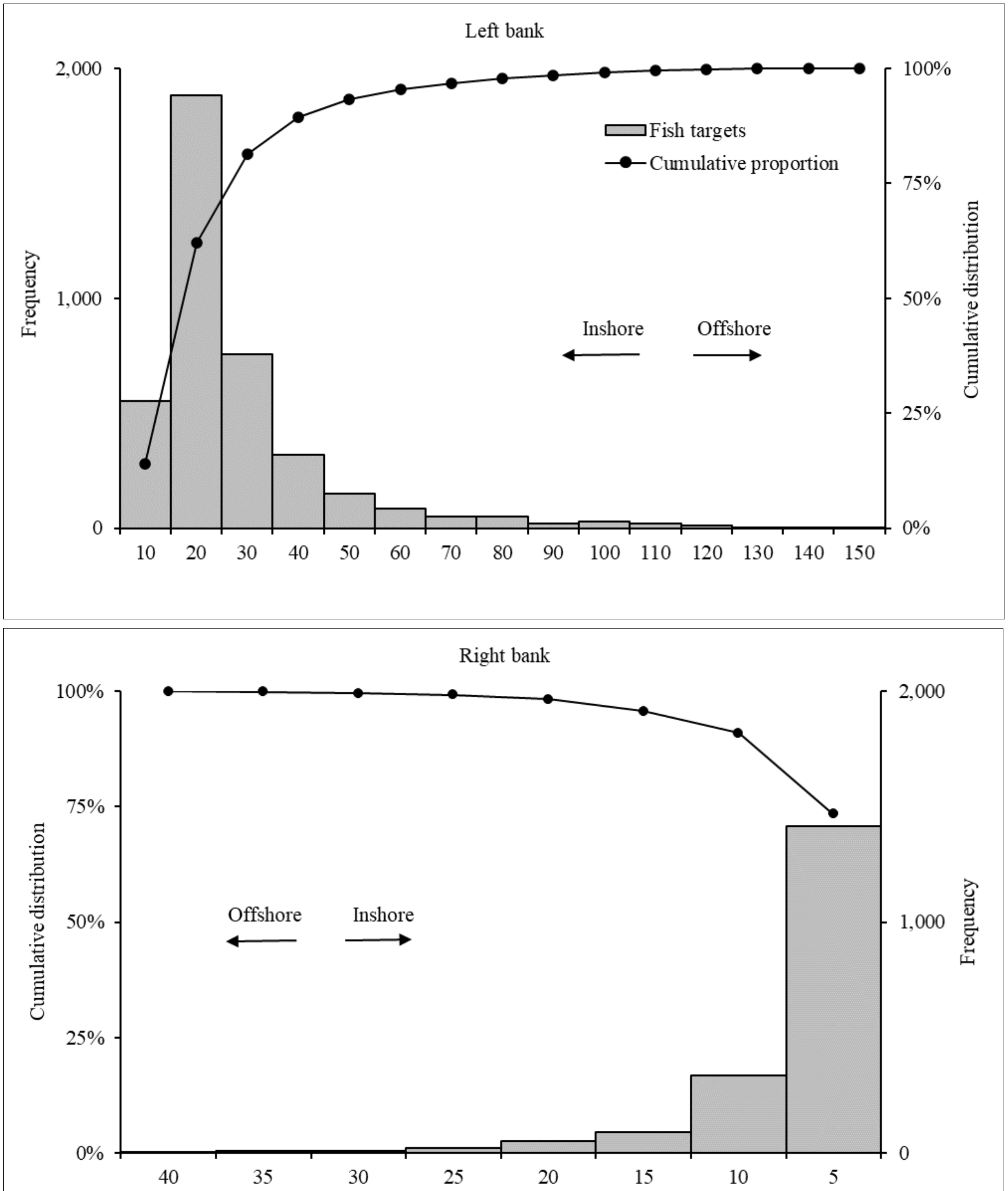


Figure 14.–Left- and right-bank horizontal distribution of upstream migrating Chinook salmon from June 29 through August 21 at the Eagle sonar project on the Yukon River, 2022.

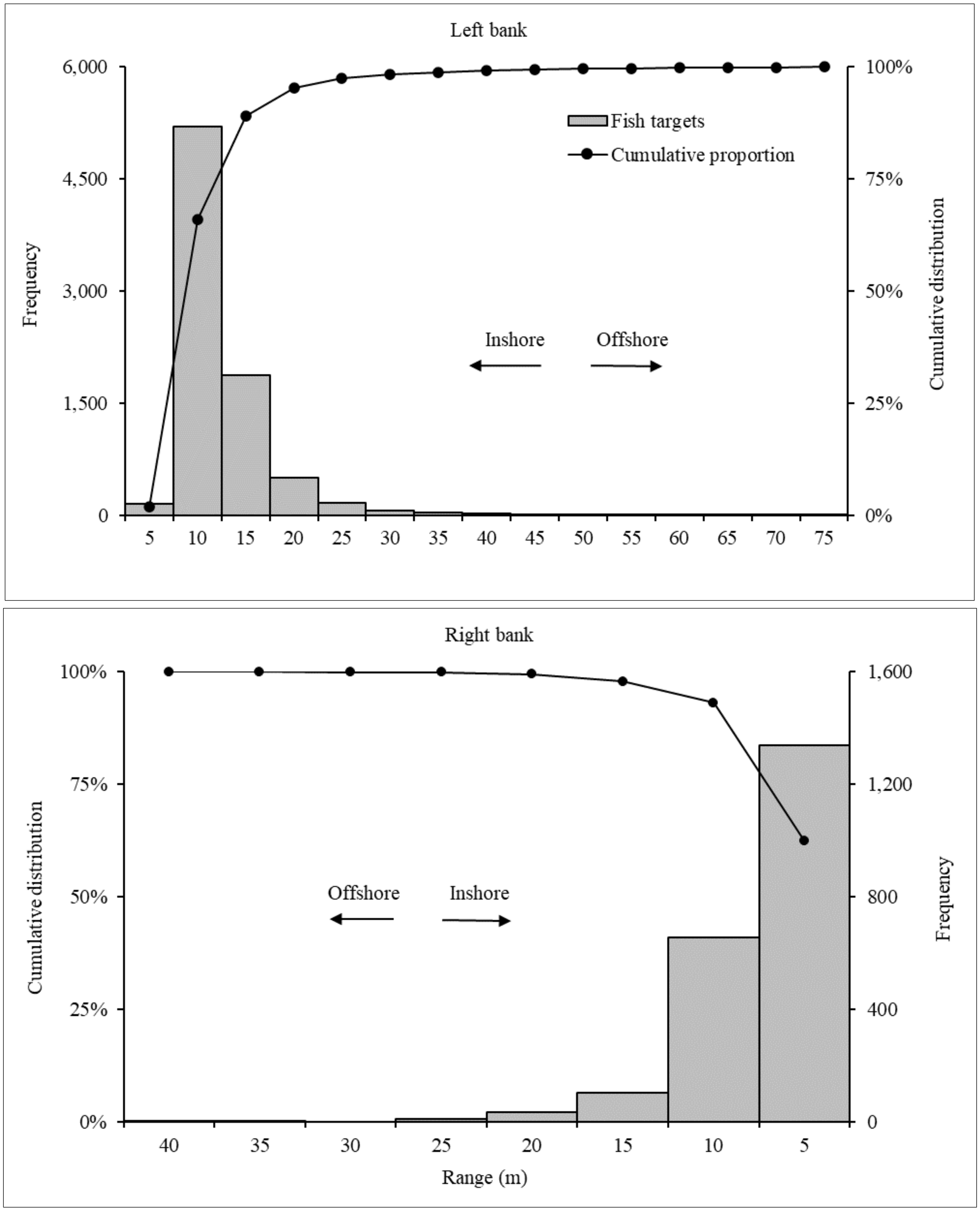


Figure 15.–Left- and right-bank horizontal distribution of upstream migrating fall chum salmon from August 22 through October 6 at the Eagle sonar project on the Yukon River, 2022.

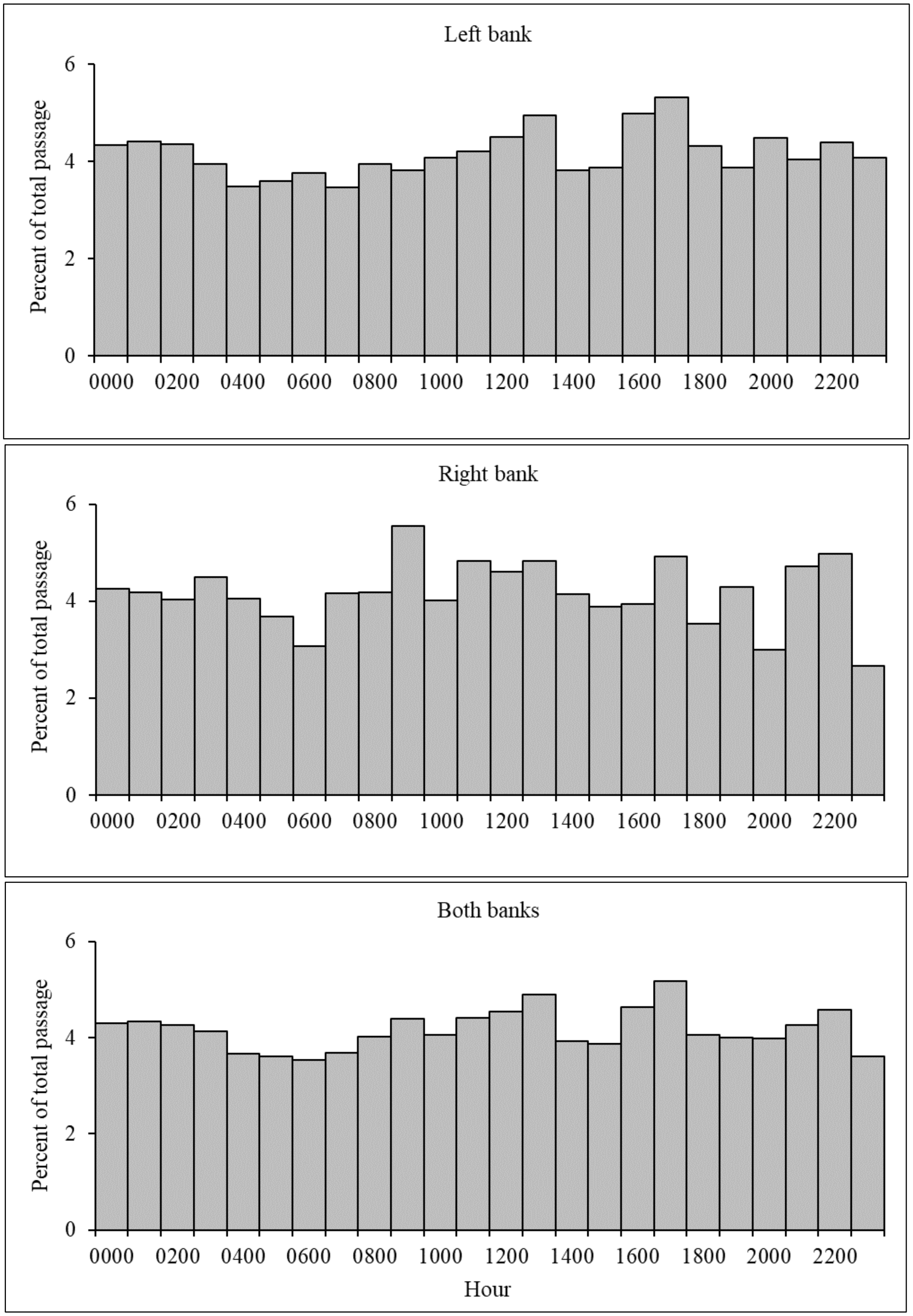


Figure 16.–Percent of total Chinook salmon passage, by hour, observed on the left bank, right bank, and both banks combined from June 29 through August 21 at the Eagle sonar project on the Yukon River, 2022.

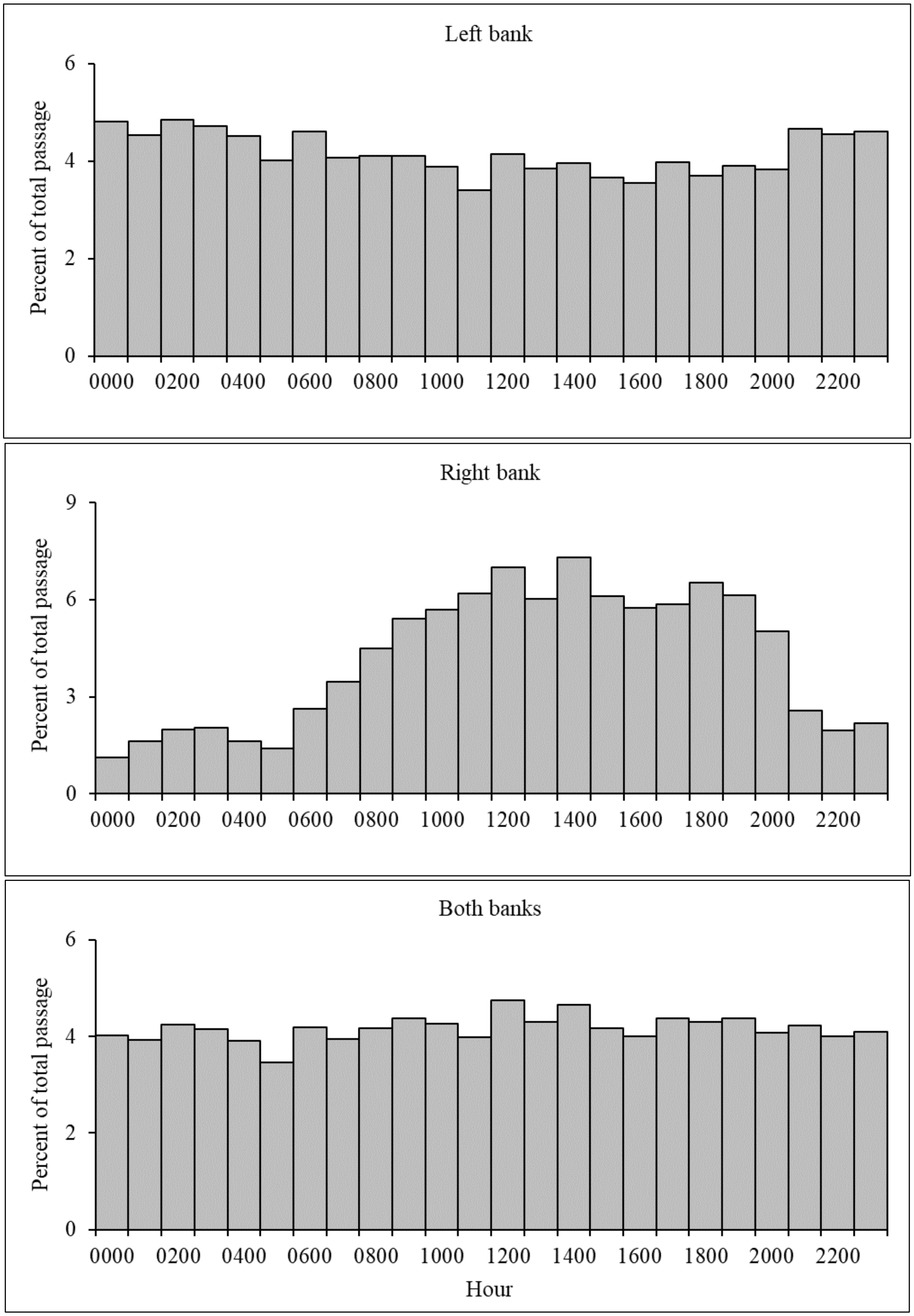


Figure 17.–Percent of total fall chum salmon passage, by hour, observed on the left bank, right bank, and both banks combined from August 22 through October 6 at the Eagle sonar project on the Yukon River, 2022.

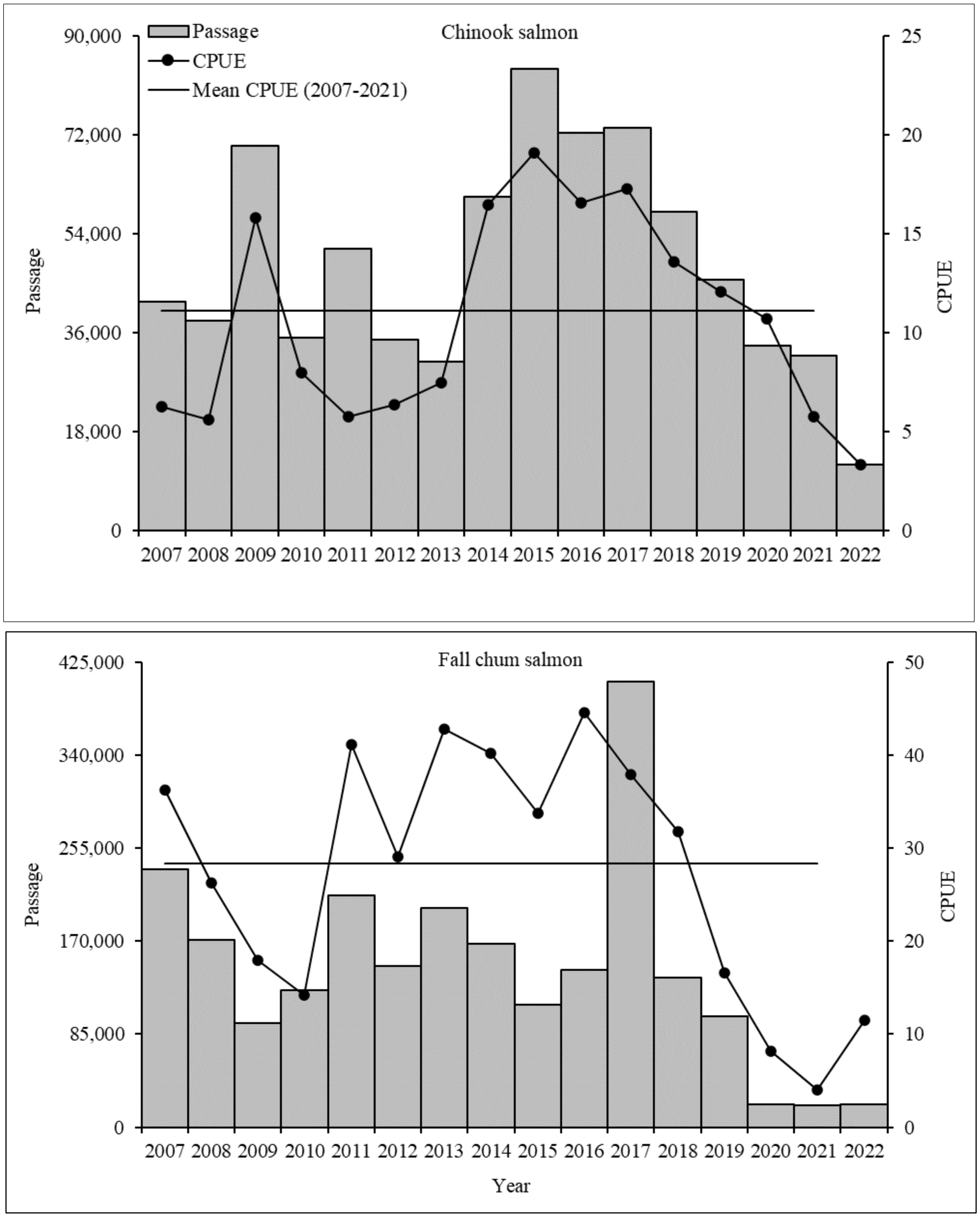


Figure 18.–Chinook and fall chum salmon passage, total cumulative catch per unit effort (CPUE) by year and mean total cumulative CPUE (2007–2021) at the Eagle sonar project on the Yukon River, 2022.

*Note*: Test fishing methodologies were not consistent until 2007; therefore, CPUE data prior to 2007 are not included in this figure. Because test fishing sites on the right bank changed several times throughout the project history, CPUE calculations are derived from left-bank drifts only. Prior to 2013, fish were occasionally released without being sampled to avoid mortalities. For these years, the CPUE only represents fish sampled.

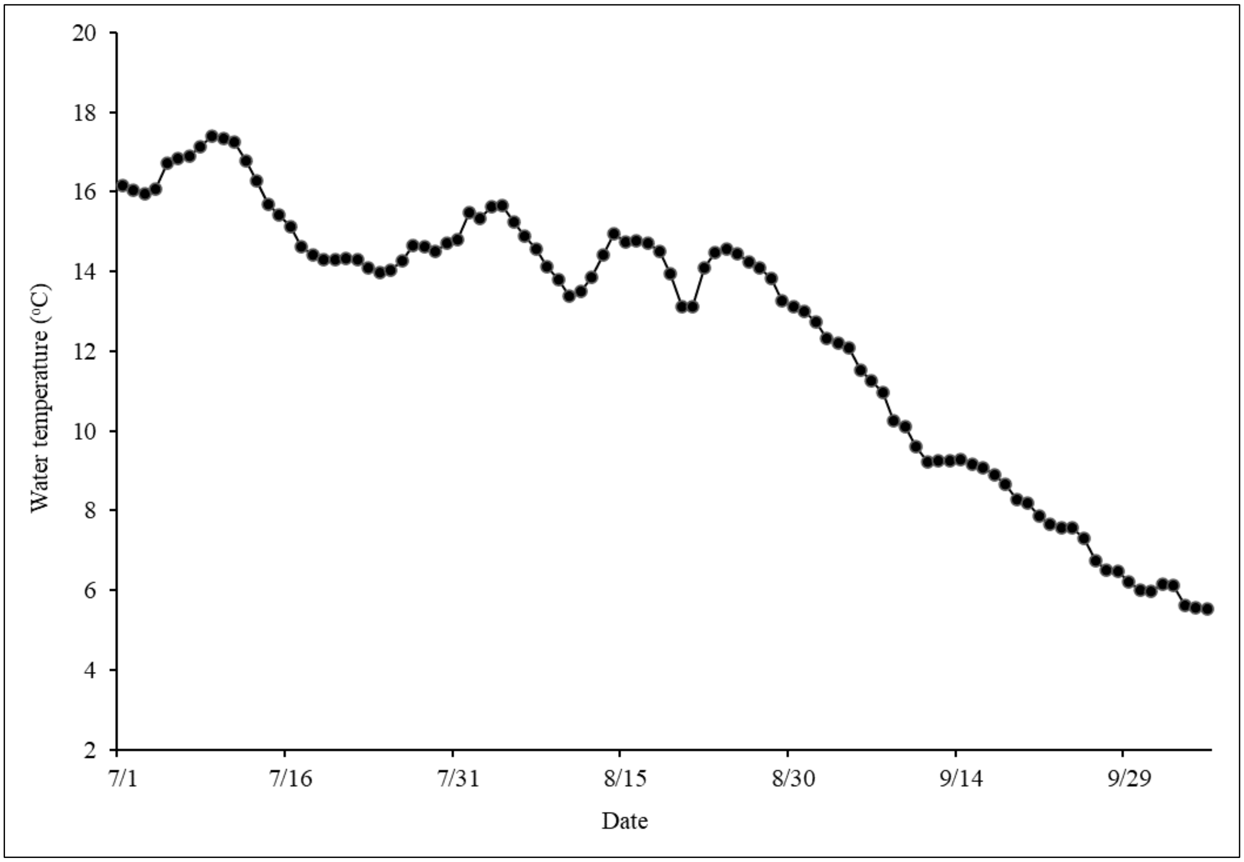


Figure 19.–Median daily water temperature recorded from July 1 through October 6 on the left bank at the Eagle sonar project on the Yukon River, 2022.

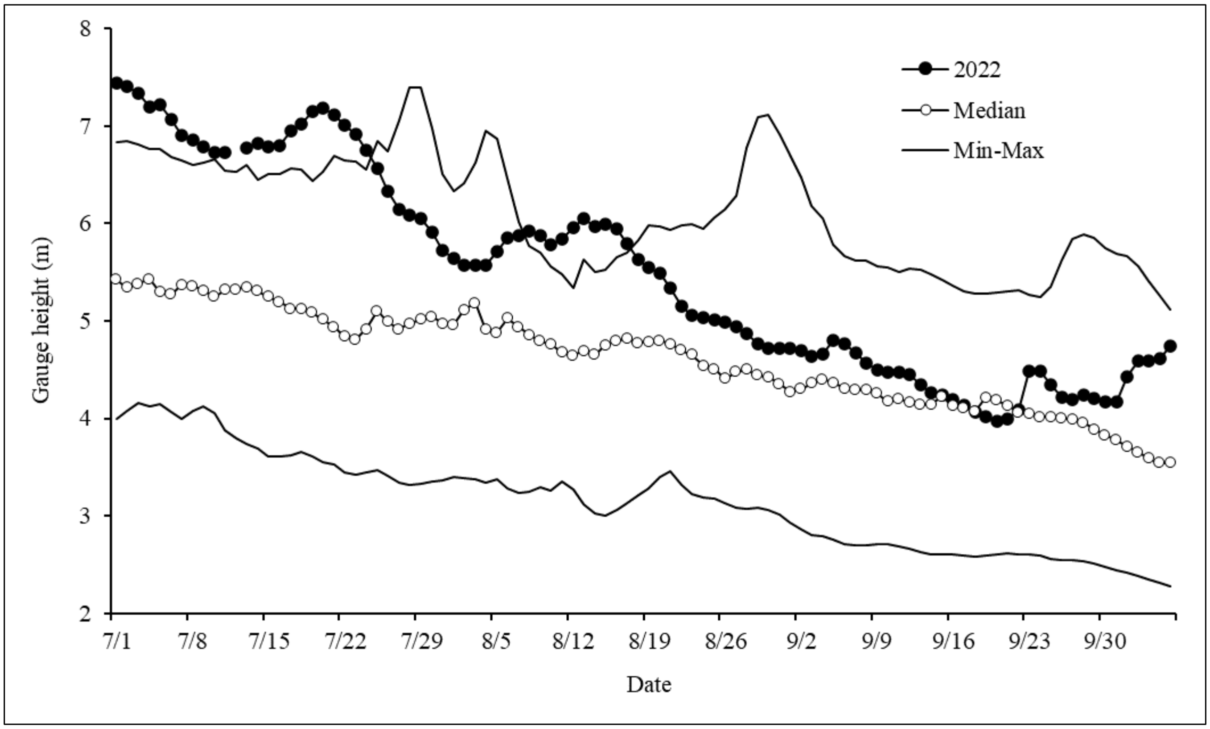


Figure 20.–Yukon River water level recorded daily at 1800 during the 2022 season at the city of Eagle, compared to minimum, maximum, and median gauge height from 1995 to 2022.

*Source*: United States Geological Survey (USGS). 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, 2022.

| | 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 | 17.78 | 2 | 0.11 | 2.55 | 0.14 | 17.99 | 0 | 0.00 | 0.00 | 0.00 |
| 08/02 | 17.84 | 3 | 0.17 | 2.48 | 0.14 | 17.55 | 0 | 0.00 | 0.00 | 0.00 |
| 08/03 | 18.08 | 4 | 0.22 | 2.40 | 0.13 | 18.01 | 0 | 0.00 | 0.00 | 0.00 |
| 08/04 | 18.93 | 6 | 0.32 | 2.31 | 0.13 | 17.84 | 0 | 0.00 | 0.00 | 0.00 |
| 08/05 | 17.51 | 2 | 0.11 | 2.21 | 0.12 | 17.36 | 0 | 0.00 | 0.00 | 0.00 |
| 08/06 | 17.89 | 1 | 0.06 | 2.10 | 0.12 | 18.17 | 0 | 0.00 | 0.00 | 0.00 |
| 08/07 | 17.59 | 0 | 0.00 | 1.96 | 0.11 | 17.23 | 0 | 0.00 | 0.00 | 0.00 |
| 08/08 | 19.16 | 2 | 0.10 | 1.77 | 0.10 | 18.96 | 0 | 0.00 | 0.00 | 0.00 |
| 08/09 | 18.71 | 3 | 0.16 | 1.52 | 0.08 | 17.66 | 0 | 0.00 | 0.00 | 0.00 |
| 08/10 | 18.55 | 1 | 0.05 | 1.27 | 0.07 | 18.25 | 0 | 0.00 | 0.00 | 0.00 |
| 08/11 | 17.67 | 1 | 0.06 | 1.02 | 0.06 | 18.04 | 0 | 0.00 | 0.00 | 0.00 |
| 08/12 | 17.10 | 1 | 0.06 | 0.78 | 0.04 | 17.55 | 0 | 0.00 | 0.00 | 0.00 |
| 08/13 | 17.16 | 0 | 0.00 | 0.55 | 0.03 | 17.40 | 0 | 0.00 | 0.00 | 0.00 |
| 08/14 | 17.06 | 0 | 0.00 | 0.43 | 0.02 | 17.52 | 0 | 0.00 | 0.00 | 0.00 |
| 08/15 | 17.41 | 0 | 0.00 | 0.36 | 0.02 | 18.05 | 0 | 0.00 | 0.00 | 0.00 |
| 08/16 | 16.73 | 0 | 0.00 | 0.32 | 0.02 | 16.92 | 0 | 0.00 | 0.00 | 0.00 |
| 08/17 | 17.08 | 0 | 0.00 | 0.32 | 0.02 | 17.24 | 0 | 0.00 | 0.00 | 0.00 |
| 08/18 | 17.67 | 1 | 0.06 | 0.35 | 0.02 | 16.81 | 0 | 0.00 | 0.00 | 0.00 |
| 08/19 | 17.17 | 1 | 0.06 | 0.34 | 0.02 | 16.72 | 0 | 0.00 | 0.04 | 0.00 |
| 08/20 | 17.02 | 0 | 0.00 | 0.27 | 0.02 | 17.04 | 0 | 0.00 | 0.08 | 0.00 |
| 08/21 | 17.86 | 0 | 0.00 | 0.19 | 0.01 | 17.45 | 0 | 0.00 | 0.16 | 0.01 |
| 08/22 | 16.53 | 0 | 0.00 | 0.12 | 0.01 | 16.92 | 0 | 0.00 | 0.24 | 0.01 |
| 08/23 | 16.39 | 0 | 0.00 | 0.04 | 0.00 | 17.08 | 1 | 0.06 | 0.40 | 0.02 |
| 08/24 | 16.45 | 0 | 0.00 | 0.00 | 0.00 | 16.43 | 0 | 0.00 | 0.52 | 0.03 |

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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 |
| 08/25 | 16.40 | 0 | 0.00 | 0.00 | 0.00 | 16.42 | 1 | 0.06 | 0.68 | 0.04 |
| 08/26 | 16.83 | 0 | 0.00 | 0.00 | 0.00 | 17.49 | 0 | 0.00 | 0.76 | 0.04 |
| 08/27 | 16.52 | 0 | 0.00 | 0.01 | 0.00 | 18.02 | 2 | 0.11 | 0.84 | 0.05 |
| 08/28 | 16.96 | 0 | 0.00 | 0.02 | 0.00 | 17.05 | 1 | 0.06 | 0.76 | 0.04 |
| 08/29 | 16.54 | 0 | 0.00 | 0.04 | 0.00 | 17.08 | 1 | 0.06 | 0.80 | 0.05 |
| 08/30 | 17.34 | 0 | 0.00 | 0.07 | 0.00 | 17.61 | 0 | 0.00 | 0.92 | 0.05 |
| 08/31 | 16.58 | 0 | 0.00 | 0.10 | 0.01 | 17.29 | 0 | 0.00 | 1.20 | 0.07 |
| 09/01 | 16.93 | 0 | 0.00 | 0.12 | 0.01 | 17.10 | 0 | 0.00 | 1.60 | 0.09 |
| 09/02 | 16.54 | 0 | 0.00 | 0.13 | 0.01 | 18.09 | 4 | 0.22 | 2.16 | 0.12 |
| 09/03 | 16.47 | 0 | 0.00 | 0.14 | 0.01 | 17.84 | 4 | 0.22 | 2.49 | 0.14 |
| 09/04 | 16.93 | 1 | 0.06 | 0.13 | 0.01 | 17.24 | 3 | 0.17 | 2.69 | 0.15 |
| 09/05 | 16.70 | 0 | 0.00 | 0.12 | 0.01 | 18.24 | 3 | 0.16 | 2.96 | 0.17 |
| 09/06 | 16.52 | 0 | 0.00 | 0.11 | 0.01 | 17.23 | 2 | 0.12 | 3.24 | 0.18 |
| 09/07 | 17.52 | 1 | 0.06 | 0.11 | 0.01 | 17.13 | 1 | 0.06 | 3.60 | 0.20 |
| 09/08 | 16.56 | 0 | 0.00 | 0.10 | 0.01 | 17.02 | 3 | 0.18 | 4.30 | 0.24 |
| 09/09 | 16.81 | 0 | 0.00 | 0.10 | 0.01 | 18.13 | 7 | 0.39 | 5.24 | 0.29 |
| 09/10 | 16.81 | 0 | 0.00 | 0.10 | 0.01 | 18.22 | 6 | 0.33 | 5.99 | 0.32 |
| 09/11 | 17.61 | 0 | 0.00 | 0.10 | 0.01 | 18.98 | 7 | 0.37 | 6.61 | 0.35 |
| 09/12 | 16.80 | 0 | 0.00 | 0.10 | 0.01 | 19.54 | 9 | 0.46 | 7.17 | 0.38 |
| 09/13 | 16.60 | 0 | 0.00 | 0.10 | 0.01 | 19.68 | 11 | 0.56 | 7.58 | 0.41 |
| 09/14 | 16.51 | 0 | 0.00 | 0.09 | 0.01 | 17.80 | 7 | 0.39 | 7.77 | 0.42 |
| 09/15 | 16.93 | 1 | 0.06 | 0.09 | 0.01 | 17.73 | 7 | 0.40 | 7.91 | 0.42 |
| 09/16 | 17.32 | 0 | 0.00 | 0.09 | 0.01 | 19.46 | 9 | 0.46 | 8.08 | 0.43 |
| 09/17 | 16.96 | 0 | 0.00 | 0.08 | 0.00 | 18.83 | 15 | 0.80 | 8.13 | 0.44 |
| 09/18 | 17.14 | 0 | 0.00 | 0.08 | 0.00 | 17.69 | 5 | 0.28 | 8.14 | 0.44 |
| 09/19 | 17.50 | 0 | 0.00 | 0.07 | 0.00 | 17.43 | 3 | 0.17 | 8.20 | 0.44 |

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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 | 16.92 | 0 | 0.00 | 0.06 | 0.00 | 19.16 | 12 | 0.63 | 8.35 | 0.45 |
| 09/21 | 16.83 | 0 | 0.00 | 0.04 | 0.00 | 18.30 | 10 | 0.55 | 8.47 | 0.46 |
| 09/22 | 17.47 | 0 | 0.00 | 0.03 | 0.00 | 18.20 | 10 | 0.55 | 8.57 | 0.46 |
| 09/23 | 17.05 | 0 | 0.00 | 0.02 | 0.00 | 17.55 | 3 | 0.17 | 8.68 | 0.47 |
| 09/24 | 17.47 | 0 | 0.00 | 0.00 | 0.00 | 18.86 | 11 | 0.58 | 8.76 | 0.48 |
| 09/25 | 17.36 | 0 | 0.00 | 0.00 | 0.00 | 17.52 | 5 | 0.29 | 8.85 | 0.48 |
| 09/26 | 17.20 | 0 | 0.00 | 0.00 | 0.00 | 19.09 | 11 | 0.58 | 8.97 | 0.49 |
| 09/27 | 16.81 | 0 | 0.00 | 0.00 | 0.00 | 18.76 | 12 | 0.64 | 9.15 | 0.50 |
| 09/28 | 16.60 | 0 | 0.00 | 0.00 | 0.00 | 18.22 | 8 | 0.44 | 9.26 | 0.51 |
| 09/29 | 16.46 | 0 | 0.00 | 0.00 | 0.00 | 18.11 | 9 | 0.50 | 9.36 | 0.52 |
| 09/30 | 16.43 | 0 | 0.00 | 0.00 | 0.00 | 17.50 | 9 | 0.51 | 9.46 | 0.53 |

# 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, 2022.

| | | Wind | | | Temperature (°C) | |
|---|---|---|---|---|---|---|
| Date | Precipitation (code)[a] | Direction[b] | Velocity (kph) | Sky (code)[c] | Air | Water[d] |
| 07/02 | A | NW | 9.7 | O | 21.7 | 15.5 |
| 07/03 | A | NA | 0.0 | B | 21.6 | 16.0 |
| 07/04 | A | NW | 17.1 | B | 24.2 | 16.5 |
| 07/05 | A | NA | 0.0 | O | 26.5 | 17.0 |
| 07/06 | A | NA | 0.0 | F | 24.3 | 17.0 |
| 07/07 | A | N | 9.0 | B | 25.3 | 17.3 |
| 07/08 | C | NA | 0.0 | O | 15.5 | 17.3 |
| 07/09 | A | S | 3.9 | O | 21.3 | 18.0 |
| 07/10 | A | SE | 4.3 | B | 21.0 | 18.0 |
| 07/11 | A | NA | 0.0 | B | 25.1 | 18.0 |
| 07/12 | A | N | 8.5 | B | 25.5 | 16.0 |
| 07/13 | A | NA | 0.0 | O | 17.7 | 16.0 |
| 07/14 | A | W | 4.2 | B | 20.5 | 16.0 |
| 07/15 | A | SE | 17.2 | B | 21.2 | 15.0 |
| 07/16 | C | NA | 0.0 | B | 18.6 | 15.0 |
| 07/17 | A | NW | 5.5 | B | 18.5 | 15.0 |
| 07/18 | B | NA | 0.0 | B | 19.6 | 15.0 |
| 07/19 | A | NA | 0.0 | B | 20.6 | 14.5 |
| 07/20 | A | NA | 0.0 | B | 20.5 | 14.5 |
| 07/21 | A | SE | 16.3 | B | 21.2 | 14.5 |
| 07/22 | B | NA | 0.0 | B | 16.3 | 14.5 |
| 07/23 | A | SE | 4.2 | S | 15.7 | 14.0 |
| 07/24 | A | SE | 5.3 | B | 15.5 | 14.5 |
| 07/25 | A | SE | 15.6 | O | 22.0 | 14.5 |
| 07/26 | A | W | 10.9 | S | 16.0 | 14.0 |
| 07/27 | A | E | 8.9 | B | 18.5 | 15.0 |
| 07/28 | A | NW | 6.6 | C | 20.5 | 15.0 |
| 07/29 | A | NW | 3.5 | S | 18.5 | 15.0 |
| 07/30 | A | NA | 0.0 | B | 22.6 | 16.0 |
| 07/31 | A | NW | 8.4 | O | 19.6 | 16.0 |
| 08/01 | A | NA | 0.0 | C | 27.0 | 17.0 |
| 08/02 | C | SW | 5.6 | O | 18.5 | 16.0 |
| 08/03 | A | W | 13.2 | C | 21.3 | 17.0 |
| 08/04 | A | W | 17.7 | C | 25.1 | 17.0 |
| 08/05 | B | NA | 0.0 | S | 15.0 | 15.0 |
| 08/06 | A | SE | 6.4 | O | 15.0 | 15.0 |
| 08/07 | A | SE | 2.9 | B | 18.8 | 15.0 |

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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 | SE | 3.4 | O | 16.7 | 14.5 |
| 08/09 | A | NA | 0.0 | S | 16.2 | 14.0 |
| 08/10 | A | SE | 18.0 | C | 18.8 | 14.0 |
| 08/11 | A | NE | 15.8 | C | 22.0 | 14.5 |
| 08/12 | A | S | 4.5 | S | 31.2 | 15.5 |
| 08/13 | A | NA | 0.0 | B | 22.0 | 15.0 |
| 08/14 | A | NW | 3.1 | S | 17.9 | 15.0 |
| 08/15 | B | W | 4.5 | C | 17.6 | 15.0 |
| 08/16 | A | E | 2.1 | B | 20.5 | 15.0 |
| 08/17 | A | NA | 0.0 | O | 17.5 | 15.0 |
| 08/18 | A | E | 24.1 | S | 18.8 | 15.0 |
| 08/19 | A | NA | 0.0 | C | 15.1 | 14.0 |
| 08/20 | A | NA | 0.0 | O | 16.1 | 13.0 |
| 08/21 | A | NA | 0.0 | B | 22.9 | 14.0 |
| 08/22 | A | NW | 3.7 | B | 21.1 | 15.0 |
| 08/23 | B | E | 3.2 | O | 19.5 | 15.0 |
| 08/24 | B | E | 3.2 | 9 | 19.0 | 14.0 |
| 08/25 | A | NE | 16.9 | B | 18.6 | 15.0 |
| 08/26 | A | NE | 21.2 | B | 18.1 | 14.0 |
| 08/27 | A | SW | 7.2 | B | 17.1 | 15.0 |
| 08/28 | A | SW | 4.8 | B | 17.8 | 15.0 |
| 08/29 | A | SW | 7.9 | B | 17.5 | 15.0 |
| 08/30 | A | E | 8.4 | B | 17.0 | 14.0 |
| 08/31 | A | SE | 24.1 | B | 18.3 | 14.5 |
| 09/01 | A | NA | 0.0 | B | 16.7 | 13.0 |
| 09/02 | B | S | 2.7 | O | 13.8 | 12.5 |
| 09/03 | A | NA | 0.0 | S | 15.8 | 13.0 |
| 09/04 | B | NA | 0.0 | O | 13.3 | 12.5 |
| 09/05 | A | NA | 0.0 | B | 14.2 | 12.0 |
| 09/06 | A | NA | 0.0 | C | 14.5 | 12.0 |
| 09/07 | A | E | 3.4 | B | 14.4 | 12.0 |
| 09/08 | B | E | 28.8 | O | 12.0 | 12.0 |
| 09/09 | C | SE | 3.7 | B | 10.1 | 9.5 |
| 09/10 | B | S | 5.0 | S | 14.4 | 10.5 |
| 09/11 | A | SE | 9.0 | S | 15.2 | 10.5 |
| 09/12 | A | NA | 0.0 | O | 16.4 | 10.0 |
| 09/13 | A | NA | 0.0 | O | 15.3 | 10.0 |
| 09/14 | B | NA | 0.0 | B | 14.7 | 9.5 |
| 09/15 | A | SE | 14.6 | B | 13.6 | 9.5 |
| 09/16 | A | NW | 11.7 | C | 14.8 | 10.0 |

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| Date | Precipitation (code)[a] | Wind | | Sky (code)[c] | Temperature (°C) | |
|---|---|---|---|---|---|---|
| | | Direction[b] | Velocity (kph) | | Air | Water[d] |
| 09/17 | C | NW | 23.0 | O | 8.6 | 9.0 |
| 09/18 | A | W | 4.2 | S | 11.9 | 9.0 |
| 09/19 | A | E | 2.9 | B | 11.1 | 8.5 |
| 09/20 | A | NA | 0.0 | O | 11.1 | 8.0 |
| 09/21 | B | W | 2.4 | O | 5.3 | 7.5 |
| 09/22 | A | W | 4.5 | S | 6.3 | 7.5 |
| 09/23 | A | W | 2.1 | B | 8.8 | 7.5 |
| 09/24 | A | SE | 7.1 | B | 12.2 | 8.0 |
| 09/25 | A | NA | 0.0 | B | 16.0 | 8.0 |
| 09/26 | C | NA | 0.0 | O | 6.4 | 6.0 |
| 09/27 | A | W | 2.1 | B | 16.4 | 7.0 |
| 09/28 | A | E | 6.9 | O | 10.6 | 7.0 |
| 09/29 | A | E | 7.1 | C | 14.7 | 7.0 |
| 09/30 | A | NE | 5.0 | S | 15.9 | 7.0 |
| 10/01 | A | S | 9.8 | O | 9.3 | 6.0 |
| 10/02 | A | N | 6.0 | O | 14.0 | 7.0 |
| 10/03 | A | W | 8.7 | S | 5.4 | 6.0 |
| 10/04 | A | NA | 0.0 | C | 13.0 | 6.0 |
| 10/05 | A | S | 20.9 | C | 12.5 | 7.0 |
| 10/06[e] | A | SE | 28.6 | S | 11.6 | 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.

[e] Observations taken at 12:00.