**Fishery Data Series No. 18-20**

# Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River near Eagle, Alaska, 2017

**by**

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**and**

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**June 2018**

**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 figure 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. 18-20*

# SONAR ESTIMATION OF CHINOOK AND FALL CHUM SALMON PASSAGE IN THE YUKON RIVER NEAR EAGLE, ALASKA, 2017

by
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June 2018

This investigation was partially financed by the U.S./Canada Treaty Implementation funds administered by the U.S. Fish and Wildlife Service, Agreement Award F13AP00954 and the Yukon River Restoration and Enhancement Fund (URE-16-17).

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 J. D. Lozori. 2018. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2017. Alaska Department of Fish and Game, Fishery Data Series No. 18-20, 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 to October 6, 2017. A total of 73,313 (SE 373) Chinook salmon were estimated to have passed the sonar site between July 1 and August 20. The midpoint of the Chinook salmon run occurred on July 22, which was 2 days early relative to the historical mean date. An estimated 407,166 (SE 1,566) fall chum salmon passed between August 21 and October 6. The sonar-estimated passage of fall chum salmon was subsequently expanded to a total passage estimate of 419,099 to include fish that may have passed after operations ceased. The midpoint of the expanded fall chum salmon estimate occurred on September 21, which was 2 days earlier than the historical mean date. Subtracting the preliminary subsistence catch upstream of the sonar site resulted in an estimated border passage of 71,815 Chinook salmon and 404,989 fall chum salmon. Drift gillnetting was conducted to collect age, sex, and length samples and tissue samples for genetic information. Species composition was also recorded to determine when the Chinook salmon run ended and the fall chum salmon run began.

Key words: Chinook *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 3,185 km.[1] It flows northwesterly from its origin in northwestern British Columbia through the Yukon Territory and Central Alaska to its mouth at the Bering Sea. Commercial and subsistence fisheries harvest Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta*, and coho salmon *O. kisutch* throughout most of the drainage. These fisheries are critical to the way of life and economy of people in dozens of communities along the river, in many instances providing the largest single source of food or income.

Fisheries management on the Yukon River is complex and difficult because of the number, diversity, and geographic range of fish stocks and user groups. Information upon which to base management decisions comes from several sources, each of which has unique strengths and weaknesses. Gillnet test fisheries provide inseason indices of run strength, but interpretation of these data are confounded by gillnet selectivity. In addition, the functional relationship between test fishery catches and abundance are poorly defined. Mark–recapture projects provide estimates of total abundance, but the information is typically not timely enough to make day-to-day management decisions. Sonar provides timely estimates of abundance but is limited in its ability to identify fish to species level.

Alaska is obligated to manage Canadian-origin Yukon River Chinook and fall chum salmon stocks according to precautionary, abundance-based harvest-sharing principles set by the *Yukon River Salmon Agreement* (Yukon River Panel 2004). The goal of bilateral, coordinated management is to meet negotiated escapement goals and provide for subsistence and commercial harvests of surplus, in both the United States and Canada. Timely estimates of abundance not only help managers adjust harvest inseason, they are crucial for postseason analysis to determine whether treaty obligations were met. The Canadian Department of Fisheries and Oceans (DFO) provided estimates of mainstem salmon passage through the U.S./Canada border using mark–recapture techniques from 1980 to 2008 (JTC 2014). Because of the highly turbid water of the Yukon River, and the width of the mainstem (approximately 400 m across at the study site),

[1] Yukoninfo. 2017. Yukon River. http://www.yukoninfo.com/yukon-river/ (accessed November 2017).

daily passage estimation methods that rely on visual observation, such as counting towers and weirs, are not feasible. Split-beam sonar technology was 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 (Schuman et al. 2017). Multi-beam imagining sonar (dual-frequency identification sonar DIDSON and adaptive resolution imaging sonar ARIS[2]) have been used at several sites, including the Anvik (Lozori 2017) and the 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, a number of problems were identified. Phase corruption was observed and was probably exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds causing the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed. A recommendation of these studies was to find a more appropriate site with smaller rocks and a uniform bottom profile (Johnston et al. 1993). Too many large rocks or obstructions in the profile can compromise fish detection by limiting how close to the bottom the hydroacoustic beam can be aimed. Similarly, an uneven bottom profile permits fish to pass undetected by the sonar.

In 2003, ADF&G carried out a study to identify a more suitable location to deploy hydroacoustic equipment to estimate salmon passage into Canada. A 45 km section of river from the DFO mark–recapture fish wheel project at White Rock, Yukon Territory to 19 km downriver from Eagle, Alaska was explored (Pfisterer and Huttunen 2004). This area was investigated because of its proximity to the DFO project and the U.S./Canada border. Desirable characteristics included 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 town of Eagle and immediately upstream of Shade Creek) was the most ideal site (Carroll et al. 2007a).

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

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

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 chum salmon passage. However, 2 genetically distinct runs of chum salmon enter the Yukon River, an early summer component and a later fall component (Estensen et al. 2013). Summer chum salmon spawn primarily in run-off streams in the lower 700 miles of the Yukon River drainage and in the Tanana River drainage. Fall chum salmon, which migrate past the Eagle sonar project, primarily spawn in the upper portion of the drainage in streams that are spring fed or have major upwelling features. Major fall chum salmon spawning areas include the Tanana, Porcupine, and Chandalar river drainages as well as various streams in the Yukon Territory, Canada, including the mainstem Yukon River.

In 2017, the project deployed split-beam and ARIS sonar to estimate Chinook and fall chum salmon passage migrating across the U.S./Canada border. Sample fisheries were conducted to determine the transition between Chinook and fall chum salmon runs as well as collect age, sex, and length (ASL) and tissue samples for stock identification. This report will describe the methods used to collect sonar and test fishery data, provide passage estimates, species distributions, run timing, climate observations, and hydrologic observations.

# OBJECTIVES

The goal of this project in 2017 was to provide daily inseason estimates of Chinook and fall chum salmon migrating across the U.S./Canada border to fishery managers. Primary objectives were as follows:

1. Begin field operations prior to the arrival of Chinook salmon, then operate continuously throughout the season until approximately October 6, when, historically, environmental conditions become unfavorable for field operations;
2. Operate side-looking split-beam and imaging sonar such that 95% of the migrating salmon detected are within three-quarters of the ensonified range; and
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 were as follows:

4. Collect a minimum of 160 Chinook salmon scale samples during each of 3 strata throughout the season to characterize the age, sex, and length (ASL) composition of Yukon River Chinook salmon passage, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$). Strata dates are determined by ADF&G fishery managers based on run timing, sample size, and fish pulses;
5. Collect a minimum of 160 fall chum salmon scale samples during each of 4 strata throughout the season to characterize the age, sex, and length (ASL) composition of Yukon River fall chum salmon passage, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$); and
6. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
7. Collect daily climatic and hydrologic measurements representative of the study area.

# METHODS

## STUDY AREA

The study area is 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 2). The Yukon River Basin is the fourth largest basin in North America, 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).

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

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

Digital files created by the ER60 software and the ARIS were reviewed using the echogram viewer program Echotastic (Version 3) to produce an estimate of fish passage (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

## SONAR DEPLOYMENT AND OPERATION

Each season, prior to transducer deployment, bottom profiles are checked to ensure the original sites remain acceptable for ensonification. Bottom profile data were collected from transects made from bank-to-bank using a boat-mounted Lowrance LCX-15 dual-frequency transducer (down-looking sonar) with a built-in Global Positioning System (GPS). A bottom profile was then generated using data files uploaded to a computer (Figure 3).

The split-beam transducer was attached to 2 Hydroacoustic Technology Incorporated (HTI) model 662H single-axis rotators, configured perpendicularly to provide dual-axis rotation. Aiming was performed remotely using an HTI model 660 remote control unit that provided horizontal and vertical positioning.

The split-beam sonar was deployed from July 1 through October 6 on the left bank, approximately 800 m downriver from the camp (Figure 2). The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore (Figure 4). Transducer height was adjusted by sliding a mounting bar up or down along riser pipes that extended above the water. The transducer was deployed at approximately 1.5 m depth and aimed perpendicular to the current, at a location with consistent flow and no slack water.

When counting Chinook salmon, the split-beam system was aimed to ensonify a range of approximately 150 m from the transducer and sampled 2 strata (S1: approximately 0–50 m and S2: approximately 50–150 m). When counting fall chum salmon, the split-beam system was aimed to ensonify a range of 75 m and sampled 2 strata (S3: approximately 0–25 m and S4: approximately 25–75 m) (Figure 5).

A portable tripod-style fish lead was constructed approximately 1.5 m downstream from the transducer to prevent fish passage inshore of the transducer and provide sufficient offshore distance for fish swimming upstream to be detected in the sonar beam. Freestanding lead sections were constructed of 2.0 in 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 a distance of 5–12 m beyond the transducer (Figure 6). The portability of this style of fish lead was important because of the gradual slope found on the left bank. As the water level rises and falls over the duration of the season, the transducer and lead require frequent relocation to maintain their depth in the water column.

The ARIS sonar was attached to a Sound Metrics ARIS Rotator AR2, and controlled by ARIScope software interface, which provided horizontal and vertical positioning. Aiming was performed remotely using a laptop computer.

The ARIS was deployed from July 1 through October 6 on the right bank, approximately 700 m downriver from the camp, and was aimed to ensonify approximately 40 m beginning at 0.7 m from the face of the transducer, with 2 sampling strata (S5: 0.7–20 m and S6: 20–40 m) (Figure 5). The transducer and rotator were mounted on a freestanding aluminum frame similar to the split-beam sonar (Figure 7). Operators were able to remotely adjust the aim by viewing the video image for each stratum. Proper aim was achieved when adequate bottom features appeared over a majority of the ensonified range.

A fish lead was constructed using 2 m steel "T" stakes. A lead line was strung through the bottom of the 1.2 m plastic snow fencing for weight (Figure 6). The fish lead was less than 1 m downstream from the transducer and extended 3 m offshore, beyond the transducer. This distance provided sufficient offshore diversion for fish swimming upstream to be detected in the sonar beam. A shorter lead was appropriate for this bank because of the steep slope and the shorter near field view of the ARIS.

## SONAR DATA PROCESSING AND PASSAGE ESTIMATION

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

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

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

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 of the total because sonar counts can be highly autocorrelated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed (Wolter 1985). The variance for the passage estimate for stratum ($s$) on day ($d$) is estimated as:

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

where $n_{ds}$ is the number of samples in the day (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 ($p$). Because the passage estimates are assumed independent between strata and among days, the total variance was estimated as the sum of the variances:

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

## MISSING DATA

Estimating daily passage by multiplying the average hourly passage rates by 24 (Equation 1) compensates for missing data (either shortened or missing periods within a day) and was reflected in the variance (Equation 2) by reducing the number of samples and the fraction of the day sampled. If 1 or multiple days were missed, daily passage was interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

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

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.

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

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

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

,

where $y_i$ is the daily passage estimate on the $i^{th}$ day of expansion, $L$ is the count on the last day of sonar operation, $d$ is the total number of days expanding for, and $x_i$ is the day number estimated. October 18 was chosen based on what was considered the most likely run timing scenario derived from 1982 to 2008 historical data collected at the DFO mark–recapture fish wheel project near the U.S./Canada border.

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

## Spatial and Temporal Distributions

Fish range distributions for Chinook and fall chum salmon were examined by importing text files containing all fish track information into *R* (*R* Development Core Team 2015) and 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. Run timing of Chinook and fall chum salmon was examined inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

## Sample Fishing

Two specific test fisheries were implemented to monitor species composition, and collect ASL and genetic samples: 1) a Chinook salmon sample fishery (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 (August 1 to September 30) to determine the transition date between the Chinook and fall chum salmon runs, and to collect fall chum salmon ASL data.

The Chinook salmon sample fishery occurred twice daily from July1 through August 1, from approximately 0800 to 1200 hours and approximately 1300 to 1700 hours. The fishery specifically targeted Chinook salmon, which are the predominant species during the months of June and July. Chinook salmon sample fishing was conducted once per day between 1300 and 1700 hours from August 1 to August 15.

Genetic and ASL samples were collected using 4 different mesh sizes (5.25-, 6.5-, 7.5-, and 8.5-inch), which were drifted in a rotating schedule (Table 3) over the course of the Chinook salmon run to effectively capture all size classes present. Nets were 25 fathoms long, approximately 25 ft deep, and hung “even” at a 2:1 ratio of web to corkline (Table 4). Nets were drifted for approximately 6 minutes each within the left bank nearshore (LBN), left bank offshore (LBF), and right bank nearshore (RBN) 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 2). This resulted in 9 drifts during the Chinook salmon sample fishing period.

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

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \qquad (6)$$

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:

$$e_{dzlm} = \frac{25t_{dzlmj}}{60} \qquad (7)$$

Fishing for species composition and ASL collection was conducted once daily from August 1 to September 30 between approximately 0800 and 1200 hours on the left bank. During the sampling period, both 5.25-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 2) for a total of 12 drifts. Nets were hung the same as for the Chinook salmon sample fishery, with the exception that 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 to limit catches and prevent mortalities during times of high fish passage. LBI drifts were referred to as "beach walks" (Fleischman et al. 1995) where 1 person held onto the shore end of the net and led it downstream along the beach while a boat drifted with the offshore end. The nearshore zone started approximately 1 net length from shore and the offshore zone started approximately 2 net lengths from shore. The order of drifts was 1) LBI, 2) LBN, and 3) LBF, and 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).

For standard ASL samples, length was measured mideye to tail fork (METF) to the nearest 1 mm. Sex was determined by visually examining features such as development of the kype, roundness of the belly, presence or absence of an ovipositor, and overall size. This was similar to the sampling routine used on the Kuskokwim River (Molyneaux et al. 2010). Four 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 and mounted on gum cards to be aged by ADF&G ASL lab in Anchorage.

For genetic stock identification (GSI), an axillary process was clipped from each salmon. Chinook salmon samples were stored individually in a vial of ethanol and fall chum salmon samples were stored in bulk collections of up to 200 samples. All samples were sent to ADF&G genetics laboratory and then forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing. Non-salmon species were measured from nose to tail fork but were not sampled for other data. Captured fish were handled in a manner that minimized mortalities.

## SPECIES DETERMINATION

Although Chinook and fall chum salmon migrations are considered discrete in time, some temporal overlap does occur. Inseason, a tentative date was chosen to represent the last day of the Chinook salmon migration, based on the daily proportions of Chinook and fall chum salmon CPUE. The remainder of the passage estimates for the season was then classified as fall chum salmon

### CPUE 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 on the catch (*c*) and effort (*e*) (calculated in Equation 7) of the large mesh gillnet (7.5 inch); fall chum salmon CPUE was calculated on the catch and effort of the small mesh gillnet (5.25 inch). Because all nets were 25 fathoms (45.7 m) in length, CPUE estimates (in catch per fathom hour) for each species (*i*) were made daily for the left bank species composition test fishery.

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

### Determination of Chinook and fall chum salmon separation date

The separation date between Chinook and fall chum salmon was determined using daily left bank CPUE values for Chinook and fall chum salmon. The daily CPUE values were smoothed using the function *supsmu* in *R* with the default span (*R* Development Core Team 2015; Friedman 1984). The smoothed values were used to compute the estimated daily proportions ( $\hat{p}$ ) for the 2 species:

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

Because there are only 2 species, and because fall chum salmon increase as Chinook salmon decrease, the crossover is the date at which the proportion of fall chum salmon is greater than or equal to 0.5.

## CLIMATE AND HYDROLOGIC OBSERVATIONS

Climatic and hydrologic observations were collected at approximately 1800 hours daily. Reported stream levels are taken from the U.S. Geological Survey's gaging station at Eagle[3], although water levels were monitored at the sonar site as well. Surface water temperature was measured approximately 30 cm below the surface with a HOBO U22 water temperature data logger. Data loggers were attached to the sonar transducer stands on each bank and set to record every hour. Air temperature, wind velocity, and wind direction were measured daily using a portable weather station set up near the sonar tent site. Other daily observations included occurrence of precipitation and percent cloud cover.

[3] USGS (U.S. Geological Survey). 2014. National Water Information System: Web Interface. USGS 15356000 Yukon River at Eagle Alaska. http://waterdata.usgs.gov/ak/nwis/inventory/?site_no=15356000&agency_cd=USGS& (Accessed November 2017).

# RESULTS

## SONAR DEPLOYMENT

In 2017, both the right and left bank transducers were deployed in approximately the same locations that have been used in recent years (Figure 2). The left bank profile was linear, extending approximately 300 m to the thalweg at a 2.9° slope. The right bank profile was less linear, shorter, and steeper, extending approximately 100 m to the thalweg at a 9.1° slope (Figure 3). The substrate at Six Mile Bend was large cobble to small boulder on the right bank and small to medium sized cobble and silt on the left bank.

## CHINOOK AND FALL CHUM SALMON PASSAGE ESTIMATION

Inseason, August 20 was determined to be the last day of the Chinook salmon run based on relatively low sonar counts and catches from the species composition test fishery (Figure 10). Postseason analysis of CPUE data for both the large and small mesh nets (7.50 inch and 5.25 inch) from the species composition test fishery were plotted by day, and the relationship between the variables summarized using Friedman's supersmoother algorithm (Figure 11; Appendix A1). The plot also suggested that the last day of the Chinook salmon run was August 20.

The total Chinook salmon passage estimate at the Eagle sonar site was 73,313 (SE 373) from July 1 through August 20. The first quarter point was July 16, the midpoint was July 22, and third-quarter point was July 28 (Table 5). Peak daily passage estimate of 3,695 Chinook salmon occurred on July 23 and 158 fish passed on August 20, which was the last day of the Chinook salmon season (Figure 12). Compared to the 2005–2016 historical mean run timing, the midpoint of the Chinook salmon run occurred 2 days early (Figure 13)[4]. Sampling time missed during this period varied by stratum, and totals ranged between 13.8 hours and 60.9 hours (Table 6). Time missed was generally due to wireless connection failures, time adjusting weir panels, and re-aiming or cleaning the sonars. Because of problems with the wireless network, there were no right bank sonar estimates on August 20 (the last day of Chinook salmon passage). Passage estimates for this day were interpolated by averaging passage estimates from the day before and day after the missing day (Equation 4).

The preliminary subsistence harvest from the Eagle area upstream of the sonar was 1,498 Chinook salmon (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Postseason, adjustment for subsistence Chinook salmon harvest produced a border passage estimate of 71,815 Chinook salmon (Table 7). This estimate was above the upper end of the preseason projection and the interim management escapement goal (IMEG)[5] of 42,500–55,000. The total fall chum salmon sonar passage estimate was 407,166 (SE 1,566) fish from August 21 through October 6. Approximately 0.83% (3,396 fish) of the total fall chum salmon passage occurred on October 6, which was the last day of operation (Table 8). Because fall chum salmon passage continued after the project was terminated, the sonar estimate was expanded and adjusted to 419,099 fish (Figure 12). The first quarter point of the run was

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

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

September 17, the midpoint was September 21, and the third quarter point was September 25. These quartiles were calculated using the expanded passage estimate after the sonar project was terminated (Table 8). Fall chum salmon passage peaked on September 21 and the daily estimate was 28,748 fish (Figure 12). Compared to the 2006–2016 historical mean run timing, the midpoint of the fall chum salmon run occurred 2 days earlier than the historic mean date (Figure 13). Sampling time missed during the fall chum migration varied by stratum, and totals ranged between 19.8 hours and 26.0 hours (Table 9).

The preliminary fall chum salmon subsistence harvest from the Eagle area was 14,110 fish (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Postseason, adjusting for subsistence harvest produced a border passage estimate of 404,989 fish (Table 7). After accounting for preliminary Canadian harvest from both the First Nation and Canadian Commercial/Domestic (approximately 3,500) fisheries[6], total fall chum salmon escapement was estimated to be 401,489[7] in the mainstem Yukon River in Canada. This exceeded the IMEG range of 70,000–104,000 fish and provided for harvest under the sharing agreement.

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

## SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore oriented on both banks (Figures 14 and 15). On the left bank, during the Chinook salmon migration, approximately 95% of the fish were detected within 60 m of the transducer and 99% within 80 m. On the right bank, 95% of the fish were detected within 15 m of the transducer and 99% within 25 m.

During the fall chum salmon migration, approximately 95% of the fish were detected within 20 m of the transducer and 99% within 30 m on the left bank. On the right bank, approximately 95% of the fish were detected within 6 m of the transducer and 99% within 8 m. Approximately 83% of Chinook salmon and 51% of fall chum salmon passed on the left bank.

Although the overall Chinook salmon migration (both banks combined) past the sonar does not suggest a distinct diel migration pattern, a decrease in passage on the right bank was evident between 0900 and 1700 hours (Figure 16). Contrary to the Chinook salmon passage, fall chum salmon passage increased on the right bank at approximately 0700 hours and decreased during the night hours (Figure 17). Overall (both banks combined), fall chum salmon also did not suggest a distinct diel migration pattern.

## SAMPLE FISHING

A total of 825 Chinook and 827 fall chum salmon were captured in drift gillnets between July 1 and September 30 (Table 10). Fishing for species composition and sample collection occurred from August 1 to September 30, and additional Chinook salmon sample fishing occurred from July 1 to August 15. Three sheefish *Stenodus leucichthys*, 4 arctic grayling *Thymallus arcticus*, 2

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6 2017 Canadian Yukon River Salmon Management: Joint Technical Committee of the Yukon River Panel, October 30- November 2, 2017, Fairbanks, Alaska; Power Point Presentation.

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

burbot *Lota lota*, and 2 broad whitefish *Coregonus nasus* were captured. The number of Chinook and fall chum salmon captured in drift gillnets by sampling purpose (species composition sampling or Chinook salmon sampling) are summarized in Tables 11 and 12.

Cumulative CPUE for both Chinook and fall chum salmon were above the historical (2007–2016) mean (Figure 18). There was 1 known Chinook and zero known fall chum salmon capture mortalities. Five Chinook salmon had clipped adipose fins, which indicated that they held coded wire tags from the hatchery in Whitehorse, Yukon Territory. Fish with adipose fin clips were noted in the field data and released after sampling.

Chinook salmon sampled were composed of 392 (49%) males and 411 females. Fall chum salmon were composed of 520 (64%) males and 288 females. ASL samples from all Chinook and fall chum salmon (unless recaptured) were collected and sent to the ADF&G age determination laboratory in Anchorage for processing. Genetic samples from Chinook and fall chum salmon were collected and sent to the ADF&G Genetics Laboratory in Anchorage, Alaska and then forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia for processing.

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

### CLIMATE AND HYDROLOGIC OBSERVATIONS

Weather and water observations were recorded at the sonar site daily (Appendix B). Water temperature on the left bank decreased over the course of the season; the maximum observed was 20.0°C on August 10, and the minimum was 5.0°C on October 6 (Figure 19). The water level was below the historic median (1995–2016) on July 1 when sonar operations began. Water levels remained below the median until July 14 when the level increased and remained above the median until August 13, and remained below the historical median for the rest of the season (Figure 20). All goals to collect climatic and hydrologic measurements were achieved this season.

# DISCUSSION

Overall there were no significant problems with project operations and both sonars performed well the entire season. Occasionally, rapid water level fluctuations and substantial debris did make it necessary to frequently move the transducers and fish leads to deeper or shallower water, however this is not uncommon and did not affect sonar operation.

This season problems were encountered drifting test fish nets through the left bank nearshore zone because of a snag which could not be removed. The nearshore zone was relocated from the traditional area in front of the sonar site (McDougall and Lozori 2017), upriver approximately 1 kilometer near the field camp (Figure 2). The new site proved to be suitable for drift gillnetting, had few snags, and a moderate current. When comparing percentages of Chinook salmon catches from the left bank nearshore zone to the overall catch from all zones combined (2016 and 2017), 81% of the total catch was observed in this zone for both years. Similarly, fall chum salmon catches in the nearshore zone contributed 13% of the overall catch compared to 10% in 2016. Granted water levels, passage numbers, as well as other environmental conditions can influence distribution and catchability of fish at a given site, but the new site proved feasible this season as far as collecting samples to characterize the (ASL) composition of Yukon River Chinook and fall chum salmon passage past the sonar site.

# ACKNOWLEDGMENTS

The authors wish to acknowledge the field camp personnel: technicians Melvin Besharah (DFO), Denny Bohmer (DFO), Kate McGivney (DFO), Bill Mosher (ADF&G), Kelcy Tousignant (DFO), Barry Westphal (ADF&G), Keela Wiglesworth (ADF&G), and Rebecca Zimmerman (DFO) for collecting most of the data used in this report, as well as contributing to the successful operation of the project this season. Participation of DFO personnel was greatly appreciated, and we hope that bilateral collaboration at the Eagle Sonar project will continue. 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, who allowed us to store project equipment and boats at their facility, as well as Toshihide Hamazaki and Carl Pfisterer 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 F13AP00954, the Yukon River Restoration and Enhancement Fund (URE-16-17), and ADF&G general funding.

# REFERENCES CITED

Brabets, T. P., B. Wang, and R. H. Meade. 2000. Environmental and hydrologic overview of the Yukon River Basin, Alaska and Canada. U.S. Geological Survey Water-Resources Investigations Report 99-4204, Anchorage.

Carroll, H. C., R. D. Dunbar, and C. T. Pfisterer. 2007a. Evaluation of hydroacoustic site on the Yukon River near Eagle, Alaska for monitoring passage of salmon across the U.S./Canada border, 2004. Alaska Department of Fish and Game Fishery Data Series No. 07-10, Anchorage.

Carroll, H. C., R. D. Dunbar, and C. T. Pfisterer. 2007b. Sonar estimation of Chinook salmon in the Yukon River near Eagle, Alaska, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 07-82, Anchorage.

Clutter, R. I., and L. E. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin of the International Pacific Salmon Fisheries Commission 9, Vancouver, British Columbia.

Estensen, J. L., S. J. Hayes, B. M. Borba, S. N. Schmidt, D. L. Green, D. M. Jallen, E. J. Newland, and A. C. Wiese. 2013. Annual management report for the Yukon and Northern Areas, 2011. Alaska Department of Fish and Game, Fishery Management Report No. 13-52, Anchorage.

Fleischman, S. J., D. C. Mesiar, and P. A. Skvorc, II. 1995. Lower Yukon River sonar project report 1993. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A95-33, Anchorage.

Friedman, J. H. 1984. A variable span smoother. Technical Report No. 5, Laboratory for Computational Statistics, Department of Statistics, Stanford.

Huttunen, D. C., and P. A. Skvorc, II. 1994. 1992 Yukon River border sonar progress report. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 3A94-16, Anchorage.

Johnston, S. V., B. H. Ransom, and K. K. Kumagai. 1993. Hydroacoustic evaluation of adult Chinook and chum salmon migrations in the Yukon River during 1992. Hydroacoustic Technology, Inc. Seattle, WA, 98105 USA.

# REFERENCES CITED (Continued)


JTC (Joint Technical Committee of the Yukon River U.S./Canada Panel). 2014. Yukon River salmon 2013 season summary and 2014 season outlook. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A14-01, Anchorage.

Konte, M. D., D. C. Huttunen, and P. A. Skvorc, II. 1996. 1994 Yukon River border sonar progress report. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 3A96-26, Anchorage.

Lozori, J. D. 2017. Sonar estimation of summer chum and pink salmon passage in the Anvik River, Alaska, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 17-26, Anchorage.

McDougall, M. J., and J. D. Lozori. 2017. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2016. Alaska Department of Fish and Game, Fishery Data Series No. 17-28, Anchorage.

Mercer, B. 2016. 2015 Teslin River Chinook sonar project. Project number: CRE-01N-15, March 2016, Whitehorse Yukon. Prepared for the Yukon River Panel Restoration and Enhancement Fund, Whitehorse, Yukon.

Molyneaux, D. B., A. R. Brodersen, and C. A. Sheldon. 2010. Salmon age, sex, and length catalog for the Kuskokwim Area, 2009. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A10-05, Anchorage.

Pfisterer, C. T., and D. C Huttunen. 2004. Evaluation of hydroacoustic site on the Yukon River to monitor passage of salmon across the U.S./Canada border, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A 04-18, Anchorage.

R Development Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available for download: http://www.R-project.org.

Schuman K. J., B. C. McIntosh, and B. P. Gray. 2017. Sonar estimation of salmon passage in the Yukon River near Pilot Station, 2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-32, Anchorage.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

Yukon River Panel. 2004. Yukon River Panel reference manual, The Yukon River Salmon Agreement. Yukon River Panel, Whitehorse, Yukon Territory.

# TABLES AND FIGURES

Table 1.–Split-beam sonar system settings at the Eagle sonar site on the Yukon River, 2017.

| Component | Setting | Stratum [a] | Value |
|---|---|---|---|
| Transducer | Beam size (h x w) | All | 2.5º x 10.0º |
| | | | |
| Echosounder | Power output (W) | All | 500 |
| | Pulse width (µ) | All | 256 |
| | | | |
| | Ping rate (pps) | S1 | 8.33 |
| | | S2 | 4.16 |
| | | S3 | 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 was aimed to ensonify a range of approximately 150 m from the transducer, and sampled 2 strata, (S1: approximately 0–50 m and S2: approximately 50–150 m). When counting fall chum salmon, the split-beam system was aimed to ensonify 2 strata (S3: approximately 0–25, and S4: approximately 25–75 m).

Table 2.–Technical specifications and settings for the adaptive resolution imaging sonar (ARIS) at the Eagle sonar site on the Yukon River, 2017.

| Setting | Stratum[a] | Value |
|---|---|---|
| Mode | S5 | Identification |
| | S6 | Detection |
| Frequency (MHz) | S5 | 1.20 |
| | S6 | 0.70 |
| Number of beams | S5 | 48 |
| | S6 | 48 |
| Start range (m) | S5 | 0.7 |
| | S6 | 20 |
| End range (m) | S5 | 20.0 |
| | S6 | 40.0 |
| Frame rate | S5 | 6 frames/s |
| | S6 | 4 frames/s |
| Duration in minutes | S5, S6 | 30 |
| Field of view | S5, S6 | 28° |

[a] The 2 ARIS sampling strata (S5: 0.7–20 m and S6: 20–40 m) were independently aimed using a Sound Metrics AR2 Rotator and ARIScope software.

Table 3.–Net schedule of mesh sizes (inches) for species composition and additional Chinook salmon samples, all zones, at the Eagle sonar project on the Yukon River, 2017.

| | | Net order | | |
|---|---|---|---|---|
| Sampling purpose | Day | 1 | 2 | 3 |
| Species composition | 1 | 5.25 | 7.50 | NA |
| | 2 | 7.50 | 5.25 | NA |
| Additional Chinook salmon samples | 1 | 5.25 | 6.50 | 7.50 |
| | 2 | 7.50 | 8.50 | 6.50 |
| | 3 | 6.50 | 5.25 | 8.50 |
| | 4 | 8.50 | 7.50 | 5.25 |

Table 4.–Specifications for drift gillnets used for test fishing at the Eagle sonar project on the Yukon River, 2017.

| | Stretch mesh size | | Mesh diameter | Meshes deep | Depth |
|---|---|---|---|---|---|
| Method | (inch) | (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.–Estimated daily and cumulative Chinook salmon passage by bank at the Eagle sonar project on the Yukon River, 2017.

| | Daily | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | Left bank | Right bank | Total | Proportion of total passage |
| 7/01 [a] | 66 | 53 | 119 | 66 | 53 | 119 | 0.002 |
| 7/02 | 54 | 40 | 94 | 120 | 93 | 213 | 0.003 |
| 7/03 | 113 | 54 | 167 | 233 | 147 | 380 | 0.005 |
| 7/04 | 154 | 44 | 198 | 387 | 191 | 578 | 0.008 |
| 7/05 | 202 | 98 | 300 | 589 | 289 | 878 | 0.012 |
| 7/06 | 276 | 140 | 416 | 865 | 429 | 1,294 | 0.018 |
| 7/07 | 485 | 211 | 696 | 1,350 | 640 | 1,990 | 0.027 |
| 7/08 | 612 | 302 | 914 | 1,962 | 942 | 2,904 | 0.040 |
| 7/09 | 954 | 206 | 1,160 | 2,916 | 1,148 | 4,064 | 0.055 |
| 7/10 | 1,258 | 204 | 1,462 | 4,174 | 1,352 | 5,526 | 0.075 |
| 7/11 | 1,633 | 268 | 1,901 | 5,807 | 1,620 | 7,427 | 0.101 |
| 7/12 | 1,848 | 184 | 2,032 | 7,655 | 1,804 | 9,459 | 0.129 |
| 7/13 | 2,030 | 324 | 2,354 | 9,685 | 2,128 | 11,813 | 0.161 |
| 7/14 | 1,884 | 478 | 2,362 | 11,569 | 2,606 | 14,175 | 0.193 |
| 7/15 | 2,329 | 285 | 2,614 | 13,898 | 2,891 | 16,789 | 0.229 |
| 7/16 | 2,622 | 386 | 3,008 | 16,520 | 3,277 | 19,797 | 0.270 |
| 7/17 | 2,878 | 327 | 3,205 | 19,398 | 3,604 | 23,002 | 0.314 |
| 7/18 | 2,650 | 402 | 3,052 | 22,048 | 4,006 | 26,054 | 0.355 |
| 7/19 | 2,403 | 716 | 3,119 | 24,451 | 4,722 | 29,173 | 0.398 |
| 7/20 | 2,568 | 861 | 3,429 | 27,019 | 5,583 | 32,602 | 0.445 |
| 7/21 | 2,892 | 720 | 3,612 | 29,911 | 6,303 | 36,214 | 0.494 |
| 7/22 | 2,958 | 655 | 3,613 | 32,869 | 6,958 | 39,827 | 0.543 |
| 7/23 | 3,218 | 477 | 3,695 | 36,087 | 7,435 | 43,522 | 0.594 |
| 7/24 | 2,682 | 376 | 3,058 | 38,769 | 7,811 | 46,580 | 0.635 |
| 7/25 | 2,554 | 502 | 3,056 | 41,323 | 8,313 | 49,636 | 0.677 |
| 7/26 | 2,366 | 440 | 2,806 | 43,689 | 8,753 | 52,422 | 0.715 |
| 7/27 | 2,035 | 345 | 2,380 | 45,724 | 9,098 | 54,822 | 0.748 |
| 7/28 | 2,044 | 292 | 2,336 | 47,768 | 9,390 | 57,158 | 0.780 |
| 7/29 | 1,622 | 286 | 1,908 | 49,390 | 9,676 | 59,066 | 0.806 |
| 7/30 | 1,454 | 330 | 1,784 | 50,844 | 10,006 | 60,850 | 0.830 |
| 7/31 | 1,430 | 299 | 1,729 | 52,274 | 10,305 | 62,579 | 0.854 |
| 8/01 | 1,120 | 366 | 1,486 | 53,394 | 10,671 | 64,065 | 0.874 |
| 8/02 | 976 | 231 | 1,207 | 54,370 | 10,902 | 65,272 | 0.890 |
| 8/03 | 944 | 210 | 1,154 | 55,314 | 11,112 | 66,426 | 0.906 |
| 8/04 | 754 | 206 | 960 | 56,068 | 11,318 | 67,386 | 0.919 |
| 8/05 | 716 | 158 | 874 | 56,784 | 11,476 | 68,260 | 0.931 |
| 8/06 | 625 | 192 | 817 | 57,409 | 11,668 | 69,077 | 0.942 |

-continued-

Table 5.–Page 2 of 2.

| | Daily | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | Left bank | Right bank | Total | Proportion of total passage |
| 8/07 | 476 | 136 | 612 | 57,885 | 11,804 | 69,689 | 0.951 |
| 8/08 | 509 | 116 | 625 | 58,394 | 11,920 | 70,314 | 0.959 |
| 8/09 | 310 | 87 | 397 | 58,704 | 12,007 | 70,711 | 0.965 |
| 8/10 | 296 | 123 | 419 | 59,000 | 12,130 | 71,130 | 0.970 |
| 8/11 | 242 | 104 | 346 | 59,242 | 12,234 | 71,476 | 0.975 |
| 8/12 | 238 | 66 | 304 | 59,480 | 12,300 | 71,780 | 0.979 |
| 8/13 | 224 | 94 | 318 | 59,704 | 12,394 | 72,098 | 0.983 |
| 8/14 | 178 | 60 | 238 | 59,882 | 12,454 | 72,336 | 0.987 |
| 8/15 | 140 | 82 | 222 | 60,022 | 12,536 | 72,558 | 0.990 |
| 8/16 | 131 | 48 | 179 | 60,153 | 12,584 | 72,737 | 0.992 |
| 8/17 | 116 | 42 | 158 | 60,269 | 12,626 | 72,895 | 0.994 |
| 8/18 | 86 | 44 | 130 | 60,355 | 12,670 | 73,025 | 0.996 |
| 8/19 | 90 | 40 | 130 | 60,445 | 12,710 | 73,155 | 0.998 |
| 8/20 [b] | 113 | 45 | 158 | 60,558 | 12,755 | 73,313 | 1.000 |
| Var | | | | 114,274 | 24,749 | 139,023 | |
| SE | | | | 338 | 157 | 373 | |

*Note*: The outside box identifies the second and third quartile of run, the inside box identifies median day of passage.

[a] Sonar operational on both banks.

[b] Last day of Chinook salmon estimation.

Table 6.–Sampling time, in minutes, missed by bank, zone, and date during Chinook salmon sampling at the Eagle sonar project on the Yukon River, 2017.

| | Left bank | | Right bank | |
|---|---|---|---|---|
| Date | 0–50 m | 50–150 m | 0–20 m | 20–40 m |
| 7/01 | 330 | 330 | 450 | 420 |
| 7/02 | 0 | 0 | 0 | 0 |
| 7/03 | 30 | 0 | 30 | 12 |
| 7/04 | 0 | 0 | 0 | 0 |
| 7/05 | 0 | 0 | 0 | 0 |
| 7/06 | 0 | 0 | 0 | 0 |
| 7/07 | 0 | 30 | 0 | 30 |
| 7/08 | 0 | 0 | 0 | 0 |
| 7/09 | 0 | 0 | 6 | 6 |
| 7/10 | 0 | 0 | 0 | 0 |
| 7/11 | 6 | 0 | 30 | 0 |
| 7/12 | 0 | 0 | 0 | 0 |
| 7/13 | 6 | 0 | 30 | 30 |
| 7/14 | 0 | 0 | 192 | 180 |
| 7/15 | 6 | 0 | 186 | 144 |
| 7/16 | 0 | 0 | 0 | 0 |
| 7/17 | 0 | 0 | 54 | 36 |
| 7/18 | 0 | 0 | 0 | 6 |
| 7/19 | 0 | 12 | 60 | 60 |
| 7/20 | 0 | 0 | 390 | 102 |
| 7/21 | 0 | 0 | 0 | 0 |
| 7/22 | 0 | 0 | 12 | 60 |
| 7/23 | 0 | 12 | 72 | 90 |
| 7/24 | 0 | 0 | 0 | 0 |
| 7/25 | 60 | 30 | 0 | 0 |
| 7/26 | 0 | 0 | 0 | 0 |
| 7/27 | 0 | 6 | 12 | 6 |
| 7/28 | 0 | 0 | 108 | 90 |
| 7/29 | 0 | 0 | 0 | 0 |
| 7/30 | 0 | 0 | 0 | 0 |
| 7/31 | 12 | 0 | 90 | 78 |
| 8/01 | 0 | 0 | 0 | 0 |
| 8/02 | 30 | 0 | 60 | 30 |
| 8/03 | 0 | 0 | 96 | 66 |
| 8/04 | 0 | 12 | 12 | 12 |
| 8/05 | 0 | 0 | 0 | 0 |
| 8/06 | 60 | 30 | 0 | 0 |
| 8/07 | 0 | 0 | 0 | 0 |
| 8/08 | 0 | 30 | 30 | 6 |
| 8/09 | 60 | 66 | 60 | 48 |
| 8/10 | 0 | 0 | 30 | 0 |
| 8/11 | 0 | 0 | 36 | 12 |
| 8/12 | 0 | 6 | 0 | 30 |
| 8/13 | 0 | 0 | 0 | 0 |
| 8/14 | 0 | 0 | 6 | 0 |
| 8/15 | 0 | 0 | 0 | 0 |
| 8/16 | 12 | 0 | 12 | 24 |
| 8/17 | 60 | 30 | 0 | 0 |
| 8/18 | 0 | 30 | 330 | 360 |
| 8/19 | 18 | 60 | 540 | 540 |
| 8/20 | 138 | 132 | 720 | 720 |
| Total min | 828 | 816 | 3,654 | 3,198 |
| Total hours | 13.8 | 13.6 | 60.9 | 53.3 |

Table 7.–Eagle sonar estimate, Eagle area subsistence harvest, and border passage estimates, 2005–2017.

| | Sonar estimate | | Subsistence harvest | | Border passage estimate | |
|---|---|---|---|---|---|---|
| Date | Chinook | Fall chum | Chinook | Fall chum | Chinook | Fall chum |
| 2005 | 81,528 | ND | 2,566 | ND | 78,962 | ND |
| 2006 | 73,691 | 236,386 | 2,303 | 17,775 | 71,388 | 218,611 |
| 2007 | 41,697 | 265,008 [a] | 1,999 | 18,691 | 39,698 | 246,317 |
| 2008 | 38,097 | 185,409 [a] | 815 | 11,381 | 37,282 | 174,028 |
| 2009 | 69,957 | 101,734 [a] | 382 | 6,995 | 69,575 | 94,739 |
| 2010 | 35,074 | 133,413 [a] | 604 | 11,432 | 34,470 | 121,498 |
| 2011 | 51,271 | 224,355 [a] | 370 | 12,477 | 50,901 | 211,878 |
| 2012 | 34,747 | 153,248 [a] | 91 | 11,681 | 34,656 | 141,567 |
| 2013 | 30,725 | 216,794 [a] | 152 [b] | 12,692 [b] | 30,573 | 204,102 |
| 2014 | 63,482 | 172,887 [a] | 55 [b] | 13,575 [b] | 63,427 | 159,312 |
| 2015 | 84,015 | 125,095 [a] | 341 [b] | 12,540 [b] | 83,674 | 112,555 |
| 2016 | 72,329 | 161,025 [a] | 755 [b] | 12,954 [b] | 71,574 | 148,071 |
| 2017 | 73,313 | 419,099 | 1,498 | 14,110 | 71,815 | 404,989 |

*Note*: ND indicates that data was not collected. Estimates for subsistence salmon caught between the sonar site and border (Eagle area) prior to 2008 include an unknown portion caught below the sonar site. This number was probably in the hundreds for Chinook salmon, and a few thousand for fall chum salmon. Starting in 2008, the estimates for subsistence salmon only include salmon harvested between the sonar site and the U.S./Canada border.

[a] Expanded sonar estimate includes expansion for fish that may have passed after sonar operations ceased.

[b] Subsistence estimates are preliminary.

Table 8.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project, on the Yukon River, 2017.

| | Daily | | | Cumulative | | | |
|---|---|---|---|---|---|---|---|
| Date | Left bank | Right bank | Total | Left bank | Right bank | Total | Proportion of total passage |
| 8/21 [a] | 104 | 54 | 158 | 104 | 54 | 158 | 0.000 |
| 8/22 | 172 | 42 | 214 | 276 | 96 | 372 | 0.001 |
| 8/23 | 244 | 56 | 300 | 520 | 152 | 672 | 0.002 |
| 8/24 | 387 | 66 | 453 | 907 | 218 | 1,125 | 0.003 |
| 8/25 | 518 | 183 | 701 | 1,425 | 401 | 1,826 | 0.004 |
| 8/26 | 646 | 204 | 850 | 2,071 | 605 | 2,676 | 0.006 |
| 8/27 | 901 | 160 | 1,061 | 2,972 | 765 | 3,737 | 0.009 |
| 8/28 | 1,062 | 124 | 1,186 | 4,034 | 889 | 4,923 | 0.012 |
| 8/29 | 1,249 | 143 | 1,392 | 5,283 | 1,032 | 6,315 | 0.015 |
| 8/30 | 1,510 | 162 | 1,672 | 6,739 | 1,194 | 7,987 | 0.019 |
| 8/31 | 1,876 | 236 | 2,112 | 8,669 | 1,430 | 10,099 | 0.024 |
| 9/01 | 1,974 | 444 | 2,418 | 10,643 | 1,874 | 12,517 | 0.030 |
| 9/02 | 3,000 | 504 | 3,504 | 13,643 | 2,378 | 16,021 | 0.038 |
| 9/03 | 3,576 | 723 | 4,299 | 17,219 | 3,101 | 20,320 | 0.048 |
| 9/04 | 3,814 | 246 | 4,060 | 21,033 | 3,347 | 24,380 | 0.058 |
| 9/05 | 3,214 | 625 | 3,839 | 24,247 | 3,972 | 28,219 | 0.067 |
| 9/06 | 3,008 | 606 | 3,614 | 27,255 | 4,578 | 31,833 | 0.076 |
| 9/07 | 2,682 | 670 | 3,352 | 29,937 | 5,248 | 35,185 | 0.084 |
| 9/08 | 2,300 | 878 | 3,178 | 32,237 | 6,126 | 38,363 | 0.092 |
| 9/09 | 1,714 | 854 | 2,568 | 33,951 | 6,980 | 40,931 | 0.098 |
| 9/10 | 1,714 | 539 | 2,253 | 35,665 | 7,519 | 43,184 | 0.103 |
| 9/11 | 1,932 | 580 | 2,512 | 37,597 | 8,099 | 45,696 | 0.109 |
| 9/12 | 2,502 | 776 | 3,278 | 40,099 | 8,875 | 48,974 | 0.117 |
| 9/13 | 4,214 | 1,128 | 5,342 | 44,313 | 10,003 | 54,316 | 0.130 |
| 9/14 | 7,520 | 2,247 | 9,767 | 51,833 | 12,250 | 64,083 | 0.153 |
| 9/15 | 12,468 | 2,090 | 14,558 | 64,301 | 14,340 | 78,641 | 0.188 |
| 9/16 | 13,498 | 5,590 | 19,088 | 77,799 | 19,930 | 97,729 | 0.233 |
| 9/17 | 14,791 | 8,486 | 23,277 | 92,590 | 28,416 | 121,066 | 0.289 |
| 9/18 | 12,656 | 11,196 | 23,852 | 105,246 | 39,612 | 144,858 | 0.346 |
| 9/19 | 10,488 | 16,138 | 26,626 | 115,734 | 55,750 | 171,484 | 0.409 |
| 9/20 | 12,006 | 15,628 | 27,634 | 127,740 | 71,378 | 199,118 | 0.475 |
| 9/21 | 10,804 | 17,944 | 28,748 | 138,544 | 89,322 | 227,866 | 0.544 |
| 9/22 | 9,914 | 15,900 | 25,814 | 148,458 | 105,222 | 253,680 | 0.605 |
| 9/23 | 8,732 | 15,338 | 24,070 | 157,190 | 120,560 | 277,750 | 0.663 |
| 9/24 | 8,444 | 13,810 | 22,254 | 165,634 | 134,370 | 300,004 | 0.716 |
| 9/25 | 7,464 | 11,568 | 19,032 | 173,098 | 145,938 | 319,036 | 0.761 |
| 9/26 | 6,418 | 9,547 | 15,965 | 179,516 | 155,485 | 335,001 | 0.799 |
| 9/27 | 5,883 | 8,270 | 14,153 | 185,399 | 163,755 | 349,154 | 0.833 |
| 9/28 | 3,850 | 7,470 | 11,320 | 189,249 | 171,225 | 360,474 | 0.860 |
| 9/29 | 4,016 | 5,254 | 9,270 | 193,265 | 176,479 | 369,744 | 0.882 |
| 9/30 | 2,954 | 5,084 | 8,038 | 196,219 | 181,563 | 377,782 | 0.901 |
| 10/01 | 2,918 | 4,344 | 7,262 | 199,137 | 185,907 | 385,044 | 0.919 |

-continued-

Table 8.–Page 2 of 2.

| Date | Daily Left bank | Daily Right bank | Daily Total | Cumulative Left bank | Cumulative Right bank | Cumulative Total | Proportion of total passage |
|---|---|---|---|---|---|---|---|
| 10/02 | 2,460 | 3,059 | 5,519 | 201,597 | 188,966 | 390,563 | 0.932 |
| 10/03 | 1,864 | 2,992 | 4,856 | 203,461 | 191,958 | 395,419 | 0.943 |
| 10/04 | 1,768 | 2,778 | 4,546 | 205,229 | 194,736 | 399,965 | 0.954 |
| 10/05 | 2,138 | 1,667 | 3,805 | 207,367 | 196,403 | 403,770 | 0.963 |
| 10/06 [b] | 2,336 | 1,060 | 3,396 | 209,703 | 197,463 | 407,166 | 0.972 |
| 10/07 [c] | 1,963 | 891 | 2,854 | 211,666 | 198,354 | 410,020 | 0.978 |
| 10/08 [c] | 1,622 | 736 | 2,358 | 213,288 | 199,090 | 412,378 | 0.984 |
| 10/09 [c] | 1,314 | 596 | 1,910 | 214,602 | 199,686 | 414,288 | 0.989 |
| 10/10 [c] | 1,038 | 471 | 1,509 | 215,640 | 200,157 | 415,798 | 0.992 |
| 10/11 [c] | 795 | 361 | 1,156 | 216,435 | 200,518 | 416,953 | 0.995 |
| 10/12 [c] | 584 | 265 | 849 | 217,019 | 200,783 | 417,820 | 0.997 |
| 10/13 [c] | 406 | 184 | 590 | 217,425 | 200,967 | 418,392 | 0.998 |
| 10/14 [c] | 260 | 118 | 377 | 217,684 | 201,085 | 418,769 | 0.999 |
| 10/15 [c] | 146 | 66 | 212 | 217,830 | 201,151 | 418,981 | 1.000 |
| 10/16 [c] | 65 | 29 | 94 | 217,895 | 201,180 | 419,076 | 1.000 |
| 10/17 [c] | 16 | 7 | 24 | 217,911 | 201,188 | 419,099 | 1.000 |
| 10/18 [c] | 0 | 0 | 0 | 217,911 | 201,188 | 419,099 | 1.000 |
| Var [d] | | | | 822,040 | 1,631,236 | 2,453,276 | |
| SE [d] | | | | 907 | 1,277 | 1,566 | |

*Note*: The median is based on inseason sonar estimates and does not include postseason expansion. The outside box identifies the second and third quartile of run, including the expanded estimate. The inside box identifies median day of passage, including the expanded estimate.

[a] First day of fall chum salmon counts.

[b] Last day of sonar operation.

[c] Expanded passage estimate.

[d] Variance and standard error are calculated to October 6, which was the last day of sonar operation.

Table 9.–Sampling time, in minutes, missed by bank, zone, and date during Chinook salmon sampling at the Eagle sonar project on the Yukon River, 2017.

| | Left bank | | Right bank | |
|---|---|---|---|---|
| Date | 0–50 m | 50–150 m | 0–20 m | 20–40 m |
| 8/21 | 102 | 90 | 324 | 300 |
| 8/22 | 0 | 0 | 0 | 0 |
| 8/23 | 0 | 0 | 0 | 0 |
| 8/24 | 72 | 60 | 0 | 0 |
| 8/25 | 0 | 30 | 12 | 36 |
| 8/26 | 0 | 0 | 0 | 0 |
| 8/27 | 6 | 0 | 0 | 0 |
| 8/28 | 12 | 0 | 24 | 6 |
| 8/29 | 30 | 0 | 12 | 18 |
| 8/30 | 0 | 0 | 0 | 0 |
| 8/31 | 0 | 0 | 0 | 0 |
| 9/01 | 0 | 0 | 0 | 30 |
| 9/02 | 18 | 48 | 18 | 60 |
| 9/03 | 210 | 216 | 228 | 240 |
| 9/04 | 0 | 0 | 48 | 30 |
| 9/05 | 0 | 0 | 6 | 12 |
| 9/06 | 0 | 6 | 18 | 30 |
| 9/07 | 0 | 0 | 30 | 0 |
| 9/08 | 0 | 0 | 0 | 0 |
| 9/09 | 0 | 0 | 0 | 30 |
| 9/10 | 30 | 0 | 42 | 6 |
| 9/11 | 0 | 0 | 0 | 0 |
| 9/12 | 0 | 0 | 0 | 0 |
| 9/13 | 0 | 0 | 0 | 0 |
| 9/14 | 12 | 0 | 30 | 6 |
| 9/15 | 0 | 0 | 0 | 0 |
| 9/16 | 0 | 0 | 0 | 0 |
| 9/17 | 30 | 36 | 30 | 30 |
| 9/18 | 30 | 30 | 30 | 12 |
| 9/19 | 0 | 0 | 0 | 0 |
| 9/20 | 0 | 0 | 0 | 0 |
| 9/21 | 0 | 0 | 12 | 0 |
| 9/22 | 0 | 18 | 18 | 30 |
| 9/23 | 0 | 30 | 0 | 6 |
| 9/24 | 0 | 0 | 0 | 0 |
| 9/25 | 0 | 0 | 0 | 0 |
| 9/26 | 6 | 0 | 18 | 6 |
| 9/27 | 252 | 270 | 210 | 198 |
| 9/28 | 0 | 0 | 0 | 0 |
| 9/29 | 0 | 0 | 0 | 0 |
| 9/30 | 0 | 0 | 0 | 0 |
| 10/01 | 0 | 24 | 0 | 30 |
| 10/02 | 0 | 0 | 54 | 72 |
| 10/03 | 0 | 0 | 0 | 12 |
| 10/04 | 0 | 0 | 0 | 0 |
| 10/05 | 18 | 0 | 24 | 0 |
| 10/06 | 360 | 360 | 360 | 360 |
| Total min | 1,188 | 1,218 | 1,548 | 1,560 |
| Total hours | 19.8 | 20.3 | 25.8 | 26.0 |

Table 10.–Fish caught with gillnets at the Eagle sonar project, on the Yukon River, 2017.

| Species | Species composition | Chinook sampling | Total [a] |
|---|---|---|---|
| Chinook salmon | 124 | 701 | 825 |
| fall chum salmon | 827 | 0 | 827 |
| sheefish | 3 | 0 | 3 |
| broad whitefish | 2 | 0 | 2 |
| burbot | 2 | 0 | 2 |
| grayling | 4 | 0 | 4 |
| Total | 1,036 | 685 | 1,663 |

[a] Totals include any recaptures.

Table 11.–Species composition fishing effort, catch, and percentage by zone and mesh for Chinook and fall chum salmon, at the Eagle sonar project, on the Yukon River, 2017.

| | Mesh size | Effort | Chinook salmon | | Fall chum salmon | |
|---|---|---|---|---|---|---|
| Zone[a] | (inches) | (fathom hours) | Catch | Proportion | Catch | Proportion |
| LBI | 5.25 | 332.2 | 28 | 0.23 | 562 | 0.68 |
| | 7.50 | 321.8 | 9 | 0.07 | 175 | 0.21 |
| Total | | 654.0 | 37 | 0.30 | 737 | 0.88 |
| LBN | 5.25 | 351.5 | 29 | 0.23 | 66 | 0.08 |
| | 7.50 | 351.0 | 51 | 0.41 | 22 | 0.03 |
| Total | | 702.5 | 80 | 0.65 | 88 | 0.11 |
| LBF | 5.25 | 339.2 | 4 | 0.03 | 1 | 0.00 |
| | 7.50 | 336.2 | 3 | 0.02 | 1 | 0.00 |
| Total | | 675.4 | 7 | 0.06 | 2 | 0.00 |
| | Grand total | 2031.9 | 124 | 1.00 | 827 | 1.00 |

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

Table 12.–Chinook salmon sample fishing effort, catch, and percentage for Chinook and fall chum salmon, Eagle sonar project, on the Yukon River, 2017.

| | Mesh size | Effort | Chinook salmon | | Fall chum salmon | |
|---|---|---|---|---|---|---|
| Zone[a] | (inches) | (fathom hours) | Catch | Proportion | Catch | Proportion |
| LBN | 5.25 | 173.9 | 134 | 0.19 | 0 | 0.00 |
| | 6.50 | 186.5 | 176 | 0.25 | 0 | 0.00 |
| | 7.50 | 176.4 | 174 | 0.25 | 0 | 0.00 |
| | 8.50 | 174.1 | 99 | 0.14 | 0 | 0.00 |
| Total | | 710.9 | 583 | 0.83 | 0 | 0.00 |
| RBN | 5.25 | 165.0 | 23 | 0.03 | 0 | 0.00 |
| | 6.50 | 162.9 | 17 | 0.02 | 0 | 0.00 |
| | 7.50 | 161.5 | 38 | 0.05 | 0 | 0.00 |
| | 8.50 | 165.6 | 17 | 0.02 | 0 | 0.00 |
| Total | | 655.0 | 95 | 0.14 | 0 | 0.00 |
| LBF | 5.25 | 155.5 | 5 | 0.01 | 0 | 0.00 |
| | 6.50 | 160.2 | 2 | 0.00 | 0 | 0.00 |
| | 7.50 | 162.2 | 9 | 0.01 | 0 | 0.00 |
| | 8.50 | 185.8 | 7 | 0.01 | 0 | 0.00 |
| Total | | 663.7 | 23 | 0.03 | 0 | 0.00 |
| Grand total | | 2029.6 | 701 | 1.00 | 0 | 0.00 |

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

Table 13.–Number of salmon scales sampled at the ADF&G age determination laboratory, by stratum dates, to characterize age, sex, and length (ASL) composition at the Eagle sonar project, on the Yukon River, 2017.

| Stratum dates [a] | Chinook salmon | Fall chum salmon |
|---|---|---|
| 7/01–7/17 | 209 | NA |
| 7/18–8/02 | 469 | NA |
| 8/03–8/20 | 120 | |
| | | |
| 8/21–8/31 | NA | 53 |
| 9/01–9/11 | NA | 183 |
| 9/12–9/22 | NA | 348 |
| 9/23–9/30[b] | NA | 165 |
| Total | 798 | 749 |

[a] Stratum dates are based on the species crossover date (August 17). This table does not represent total catch or samples by species.

[b] Last day of sample fishing.

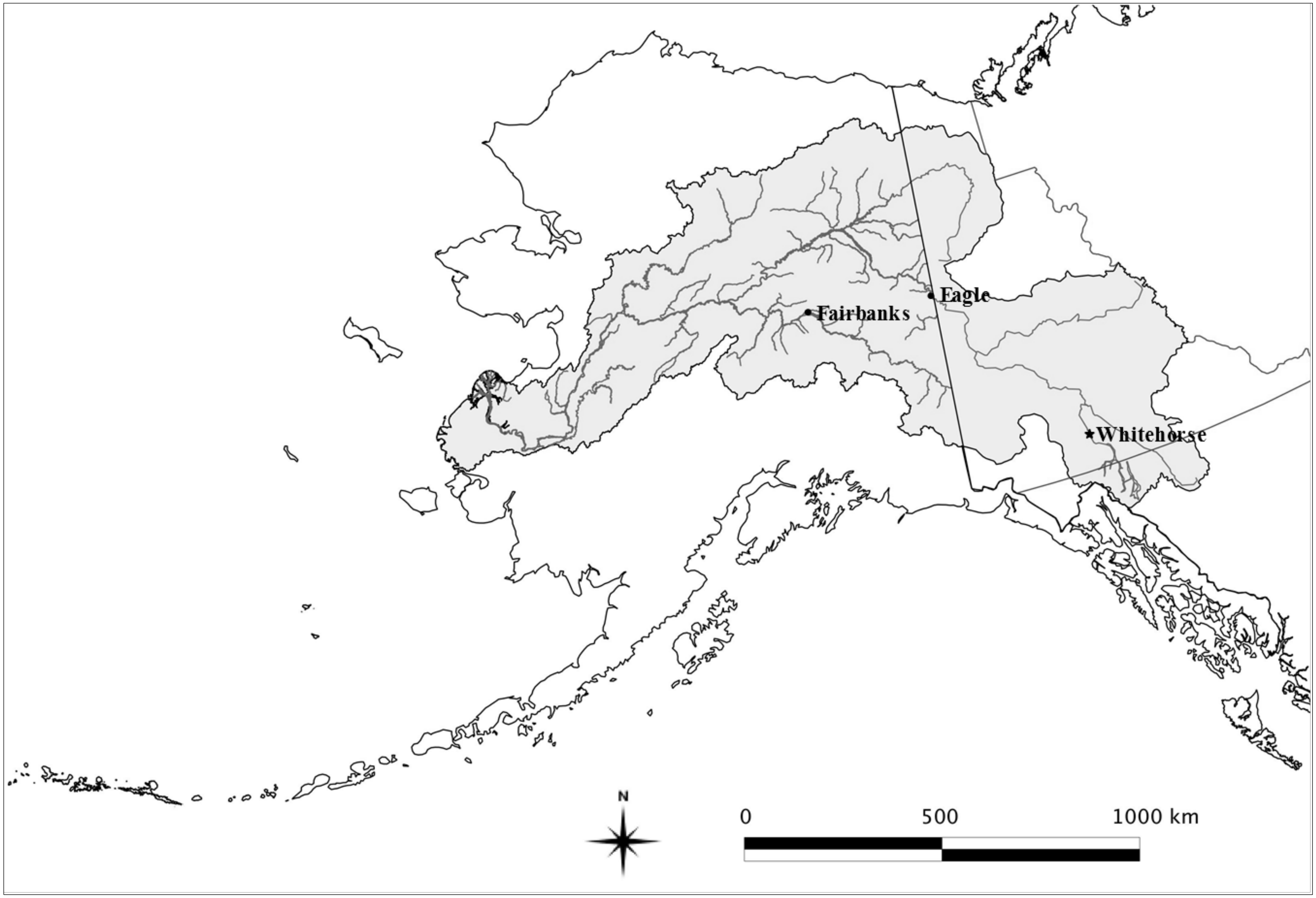



Figure 1.–Yukon River drainage.

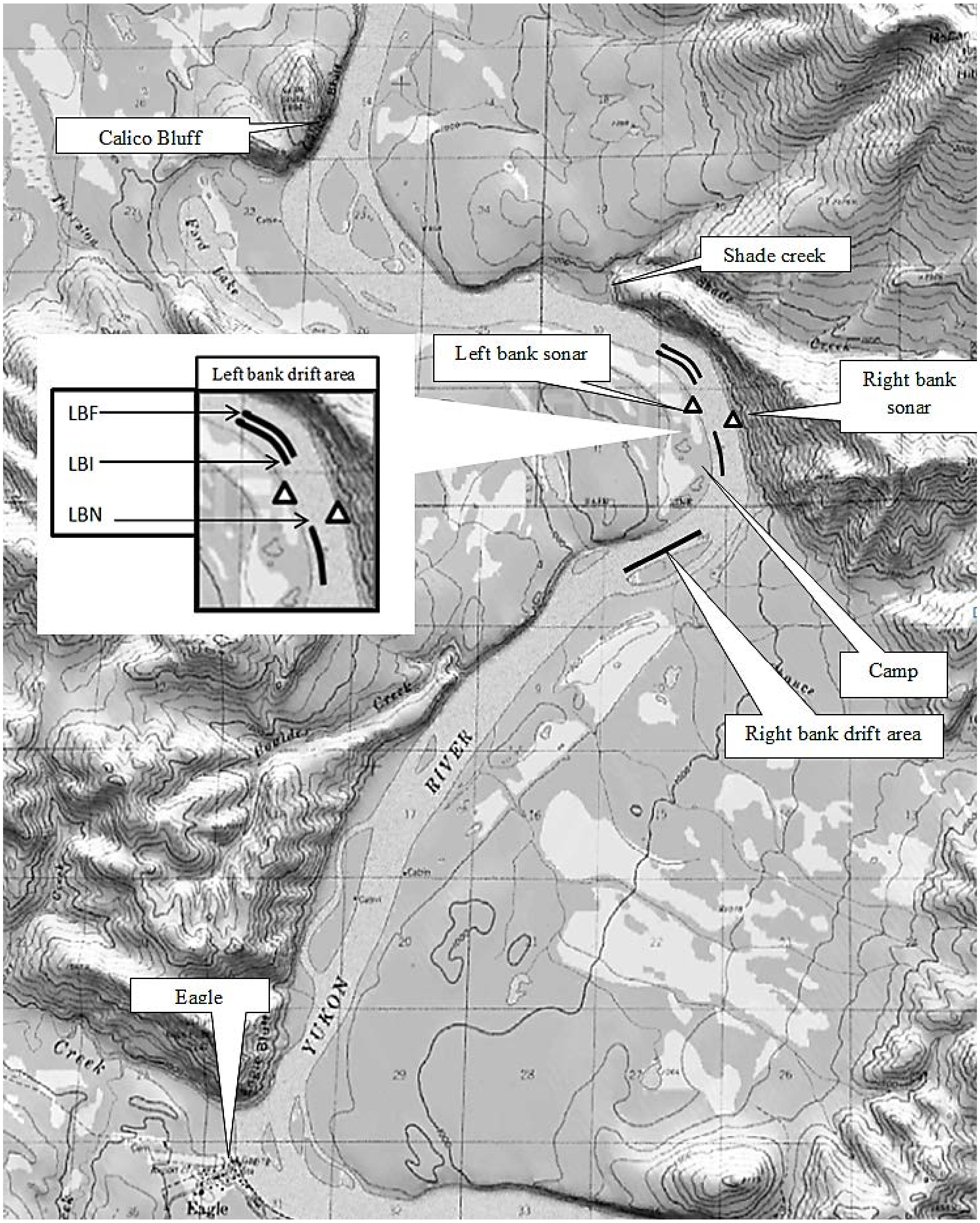



Figure 2.–Eagle sonar project site at Six Mile Bend on the Yukon River, showing sonar and drift gillnet fishing locations, 2017.

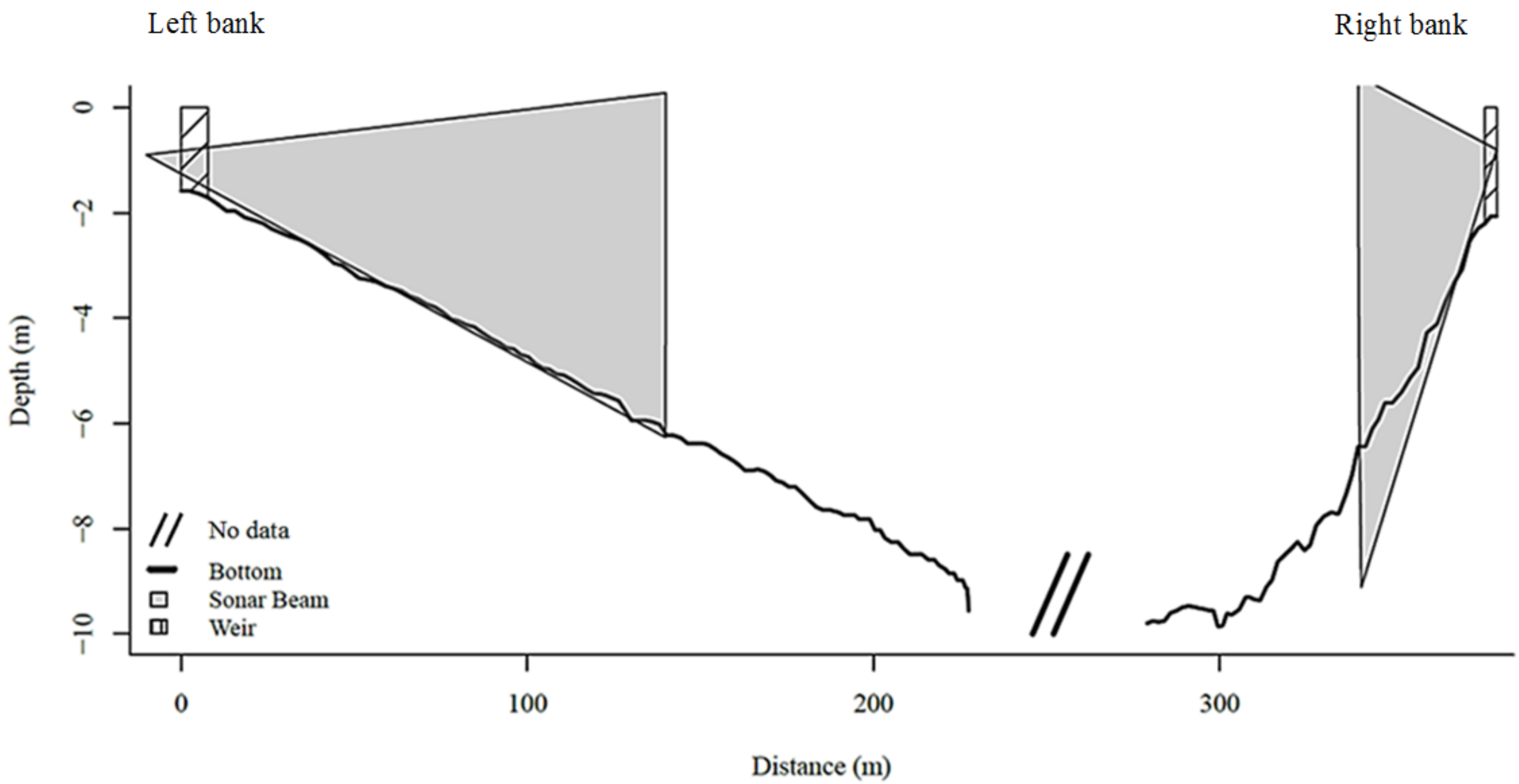



Figure 3.–Depth profile of Yukon River in front of the transducers and approximate sonar coverage at the Eagle sonar project, 2017.

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

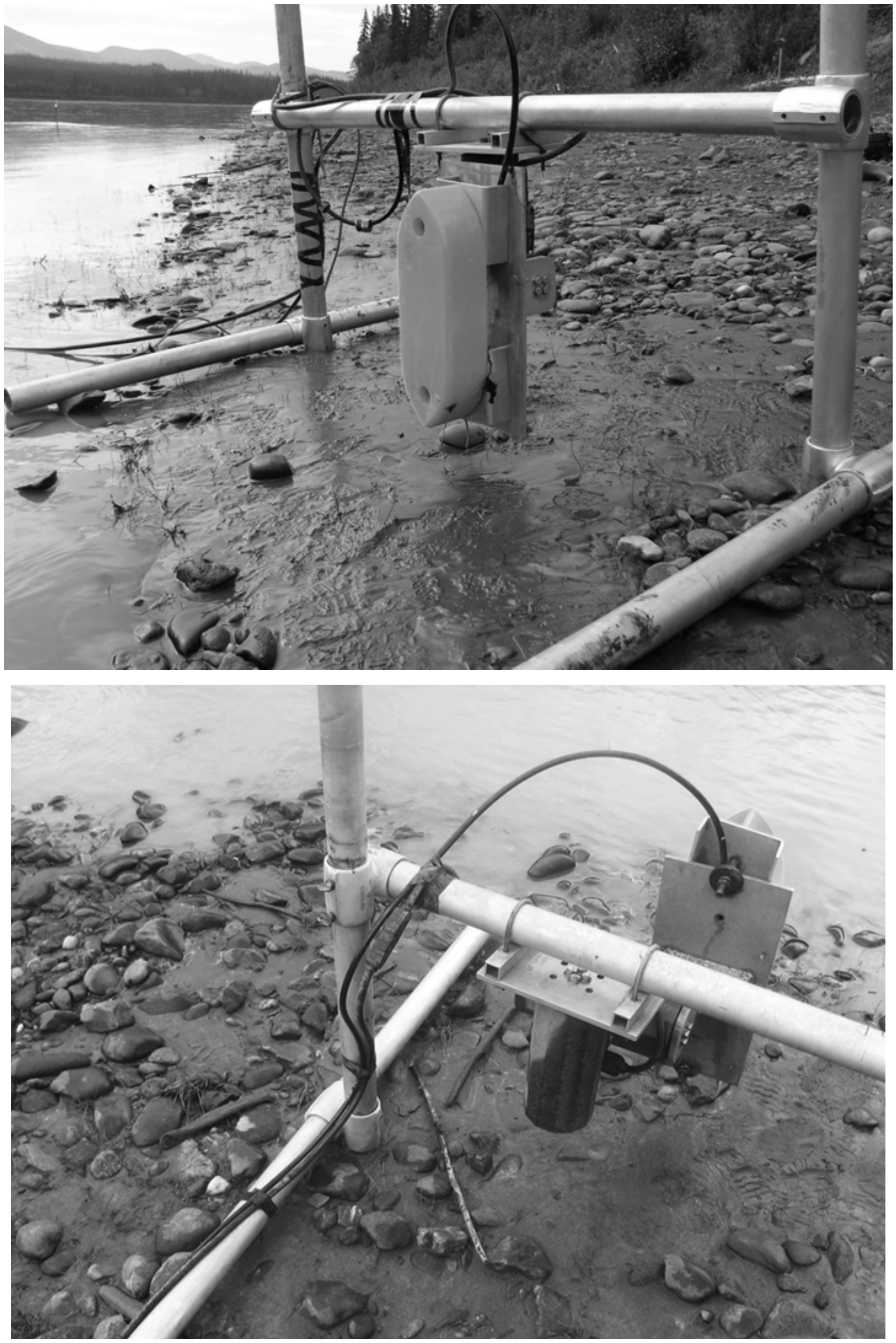


Figure 4.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single-axis automated rotators (bottom), used on the left bank at the Eagle sonar project, on the Yukon River, 2017.

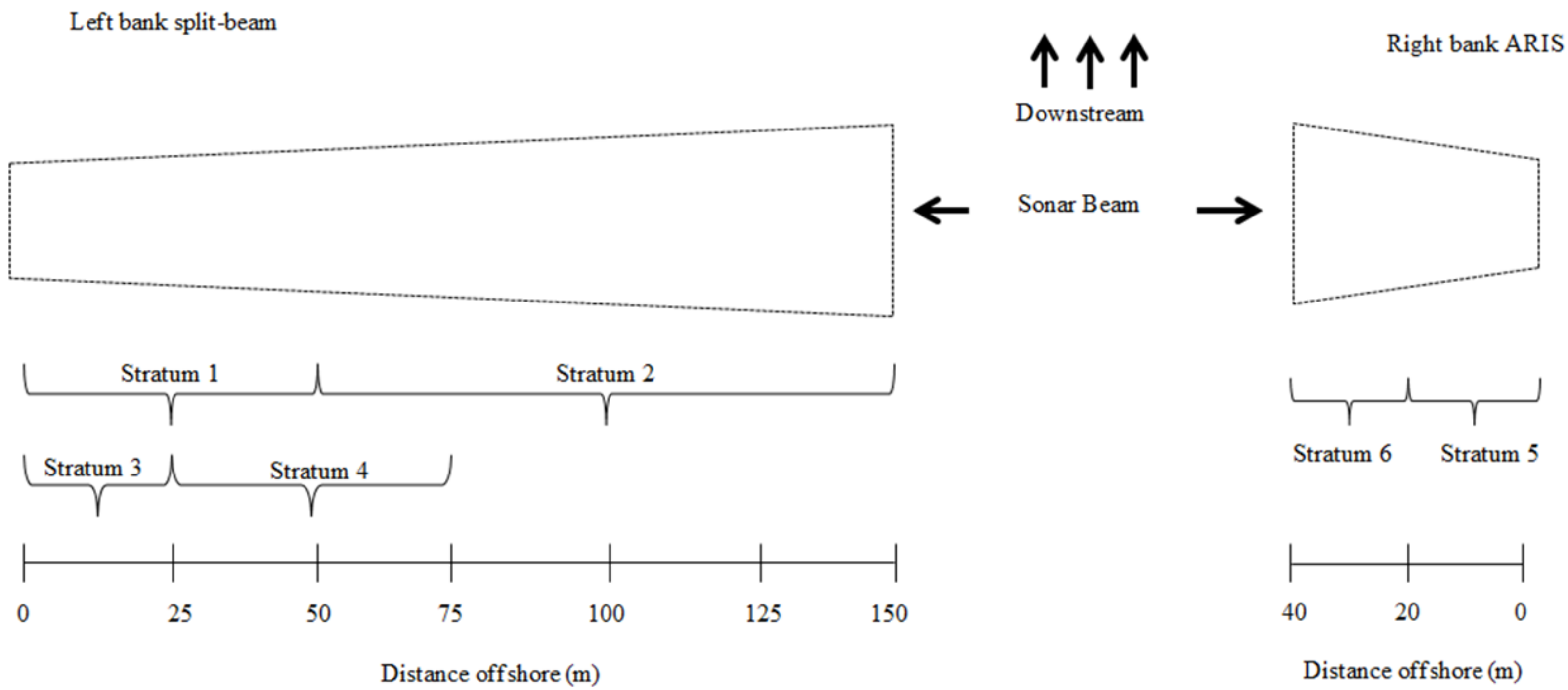



Figure 5.–Illustration of strata and approximate sonar ranges (not to scale) at the Eagle sonar project, on the Yukon River, 2017.

Figure 6.–Portable tripod-style fish lead used on the left bank (top) and plastic snow fencing used on the right bank at the Eagle sonar project, on the Yukon River, 2017.

Figure 7.–View of ARIS imaging sonar and AR2 rotator mounted to an aluminum H mount (top), and closeup view of mount for rotator (bottom), at the Eagle sonar project on the Yukon River, 2017.

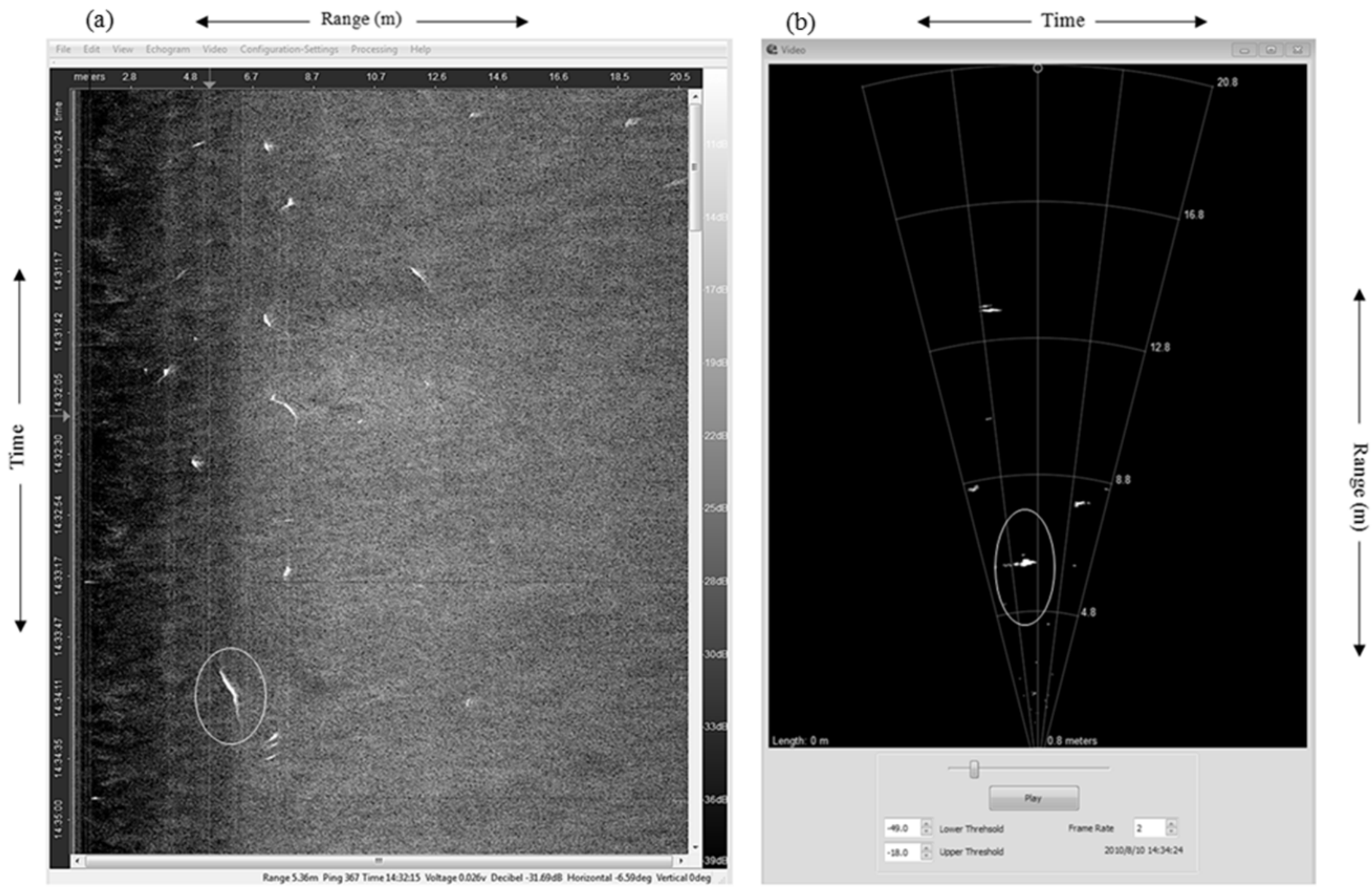



Figure 8.–Screenshots of echogram (a) and video (b) used to count and determine direction of travel from ARIS data files at the Eagle sonar project on the Yukon River, 2017.

*Note*: Ellipse encompasses typical upstream migrating salmon.

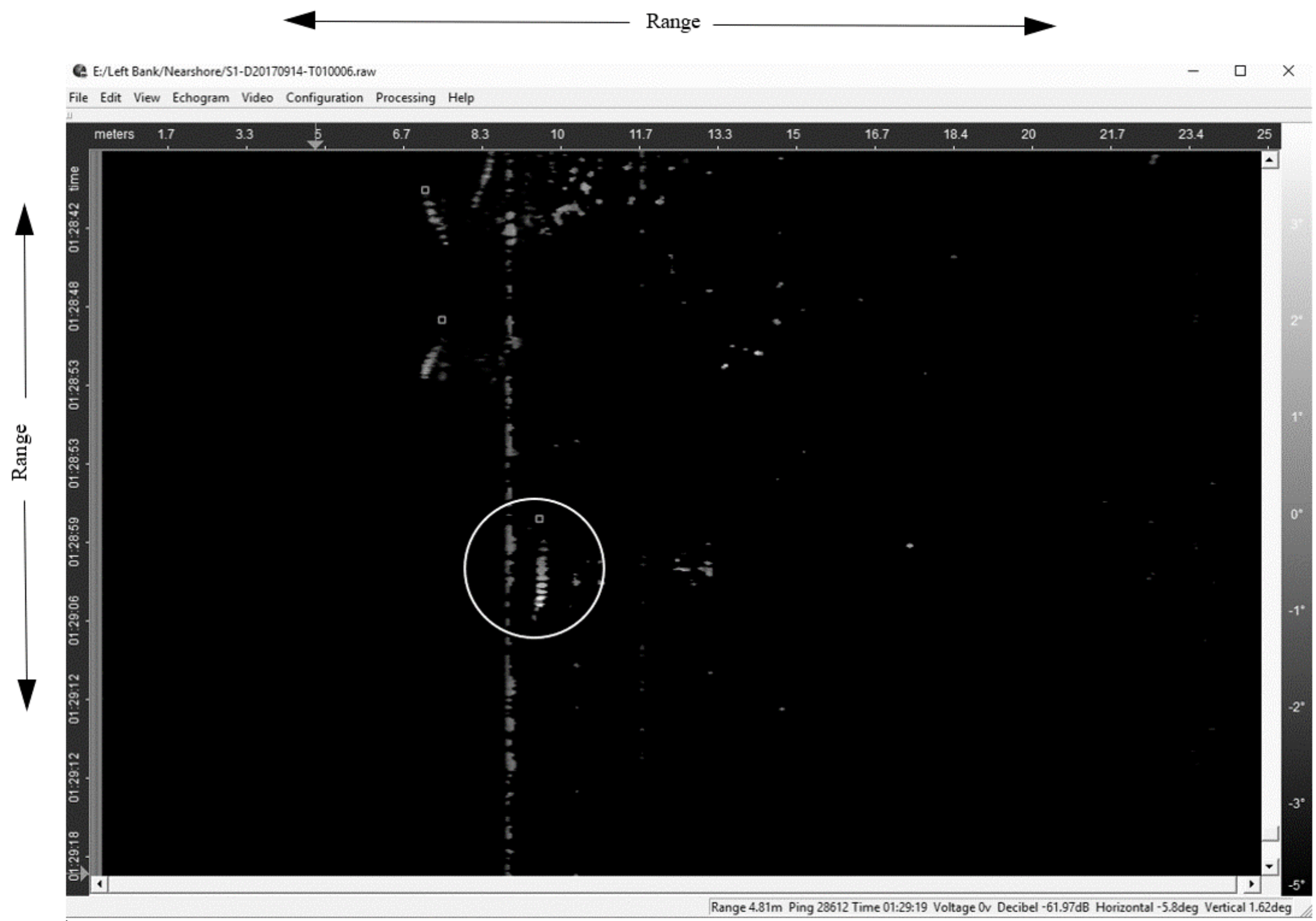



Figure 9.–Screenshot of echogram used to count and determine direction of travel from split-beam sonar data files at the Eagle sonar project on the Yukon River, 2017.

*Note*: Circle encompasses typical upstream migrating salmon.

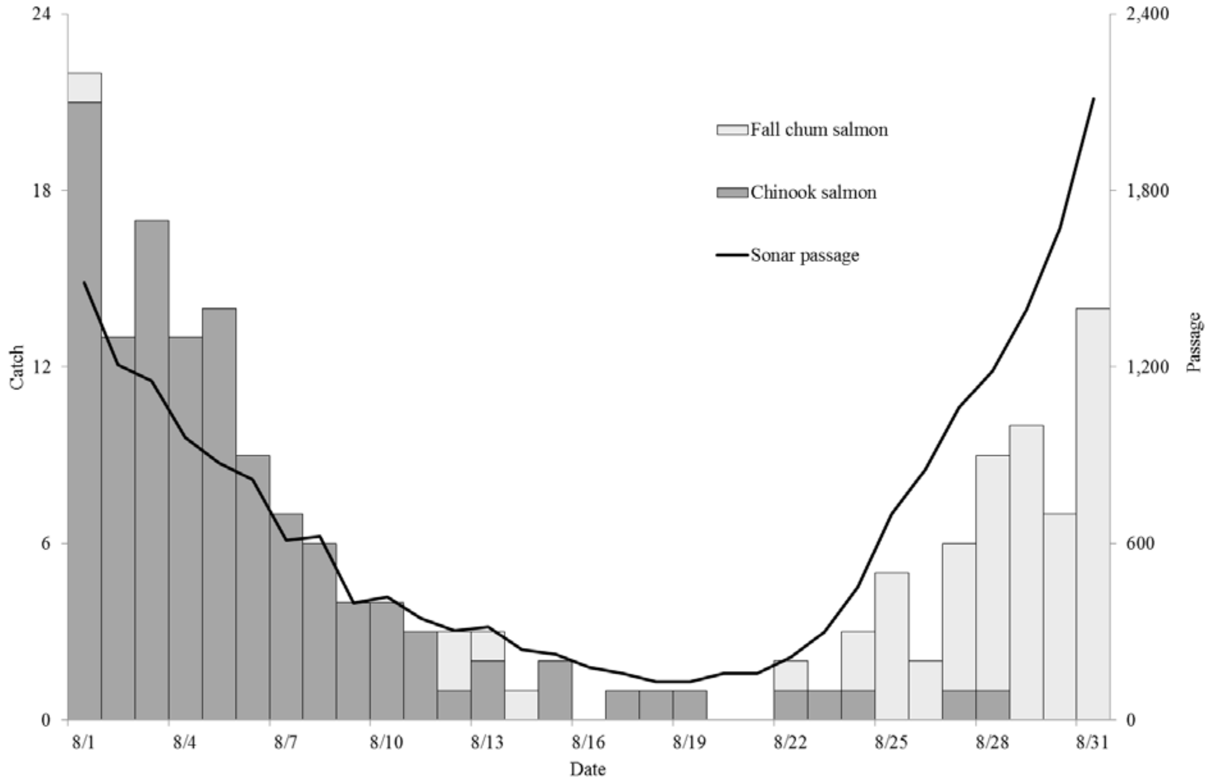



Figure 10.–Daily catch during species composition fishing and sonar passage estimates at the Eagle sonar project, on the Yukon River, 2017.

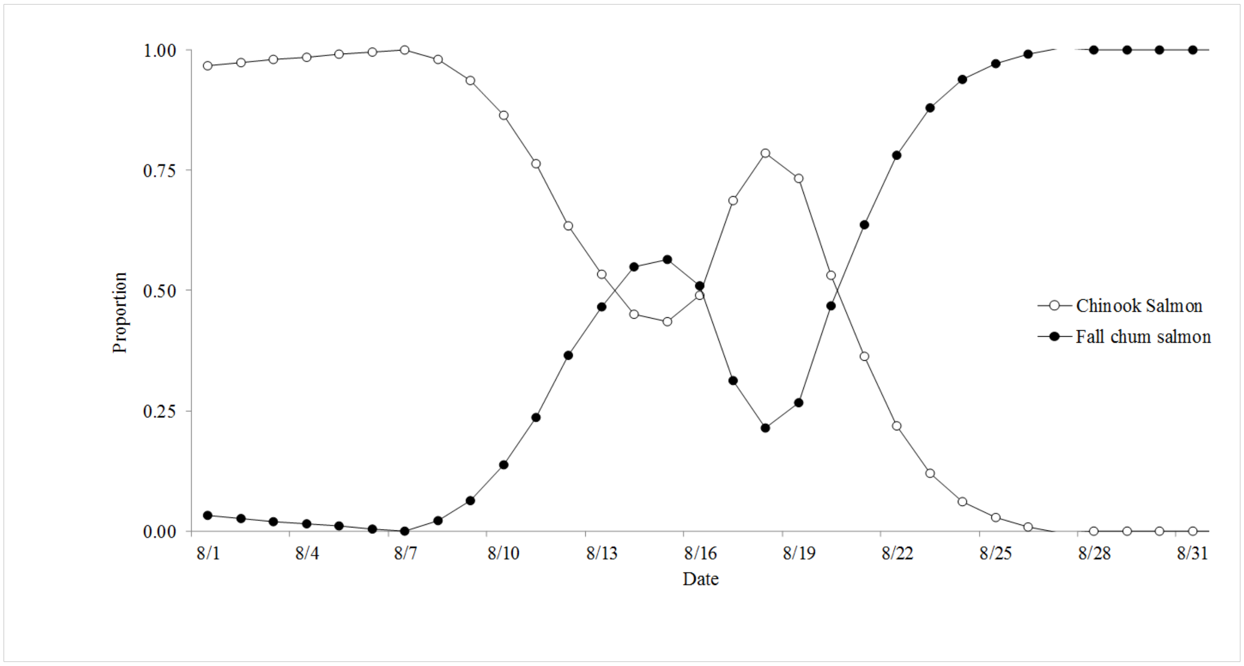



Figure 11.–Proportion of catch based on smoothed Chinook and fall chum salmon species composition catch per unit effort (CPUE) data at the Eagle sonar project, on the Yukon River, 2017.

*Note*: Species changeover date (August 21) determined at the point the curves intersect.

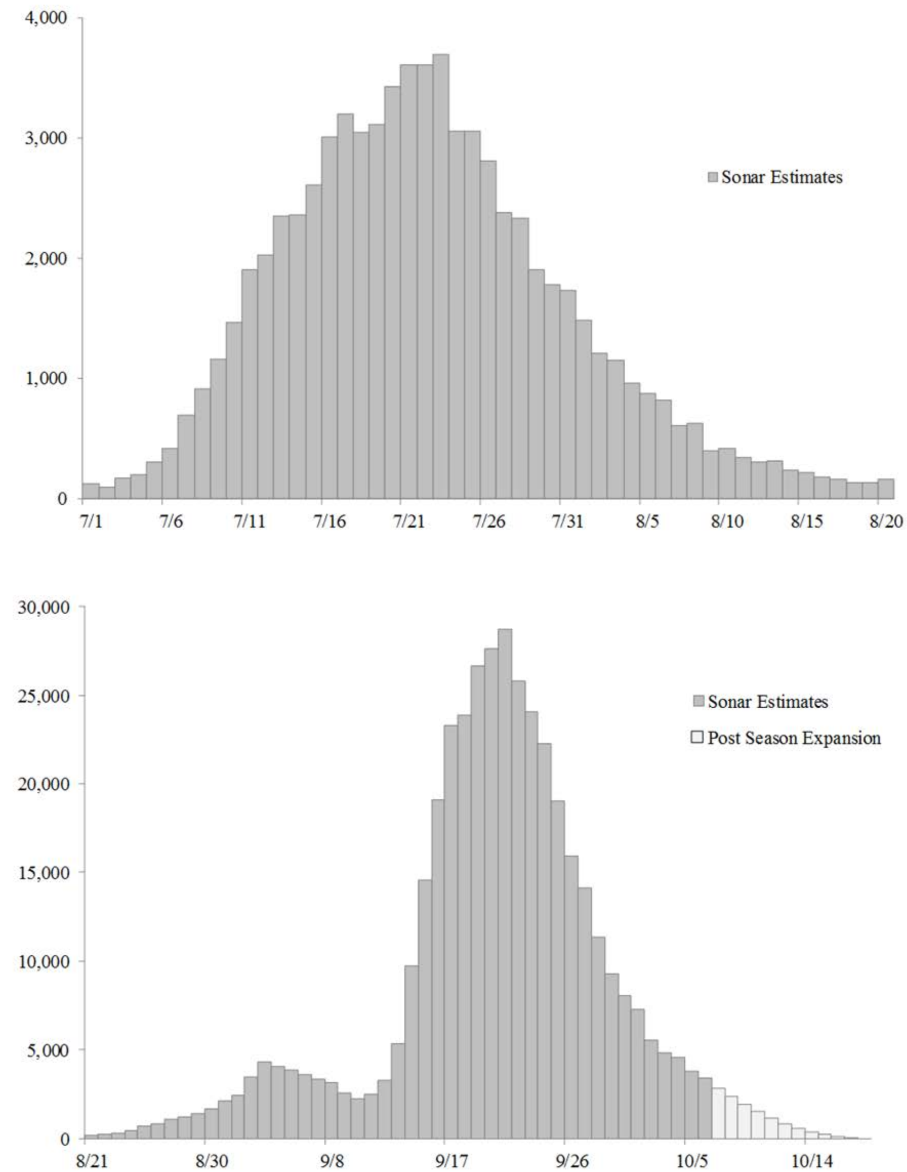
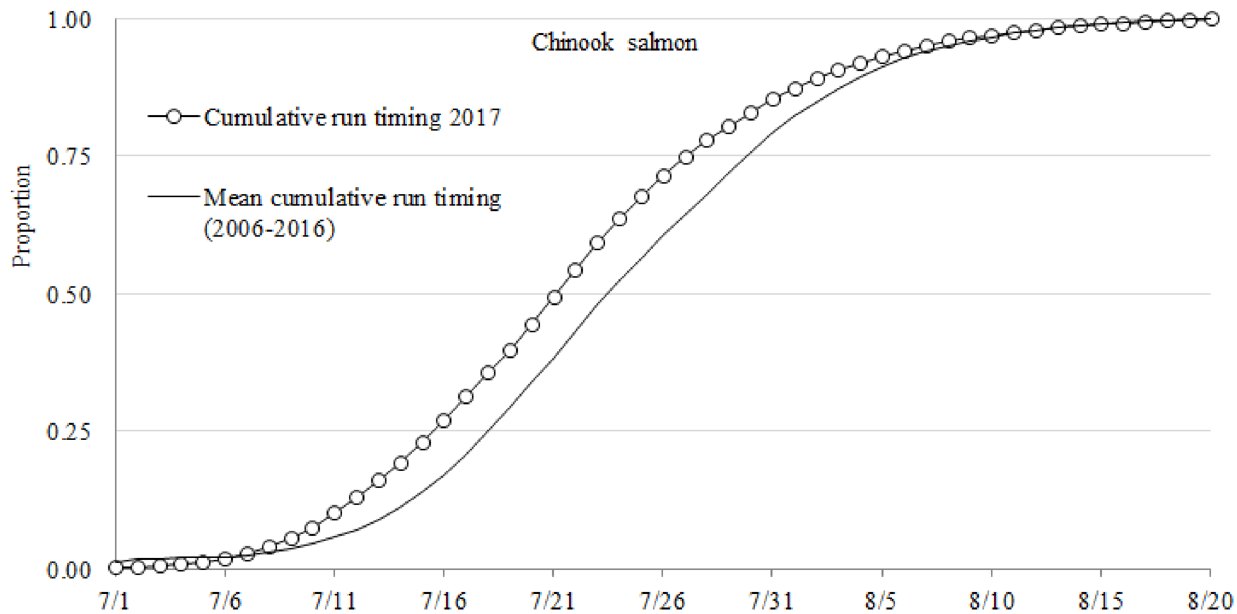



Figure 12.–Daily sonar estimates for Chinook salmon, July 1 through August 20 (top), daily sonar estimates, and postseason fall chum salmon expansion estimates for fall chum salmon, August 21 through October 18, 2017 (bottom).



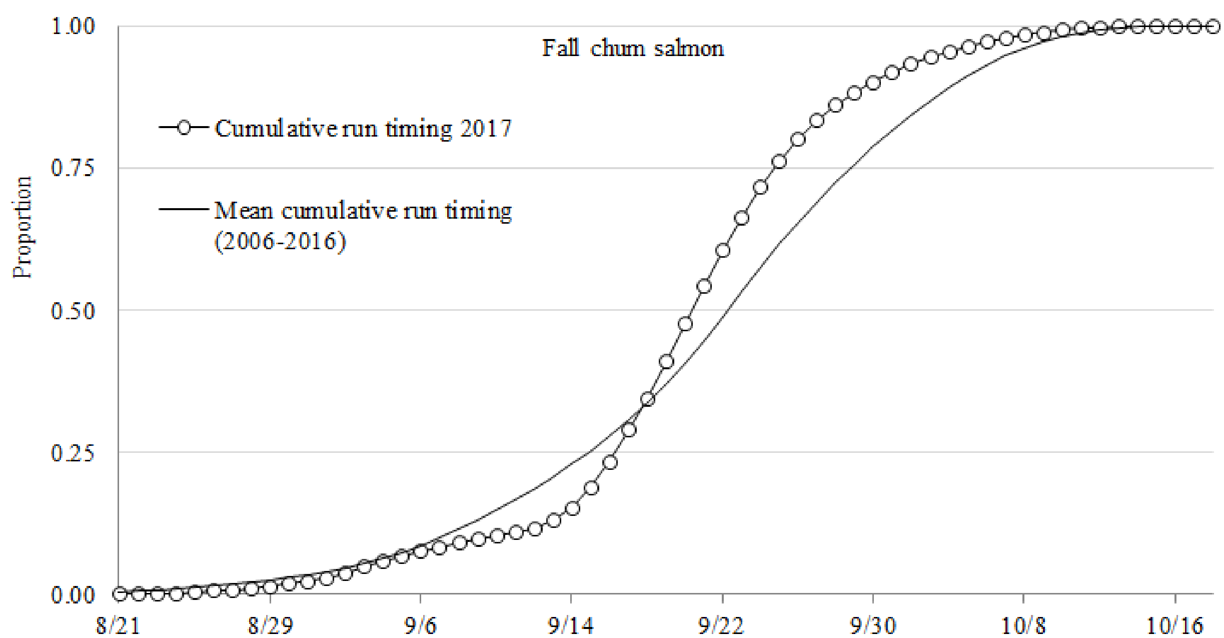




Figure 13.–2017 Chinook (top) and fall chum salmon (bottom) daily cumulative passage timing, compared to the 2005–2016 mean passage timing at the Eagle sonar project on the Yukon River.

*Note*: Fall chum salmon cumulative passage timing includes postseason expansion estimates.

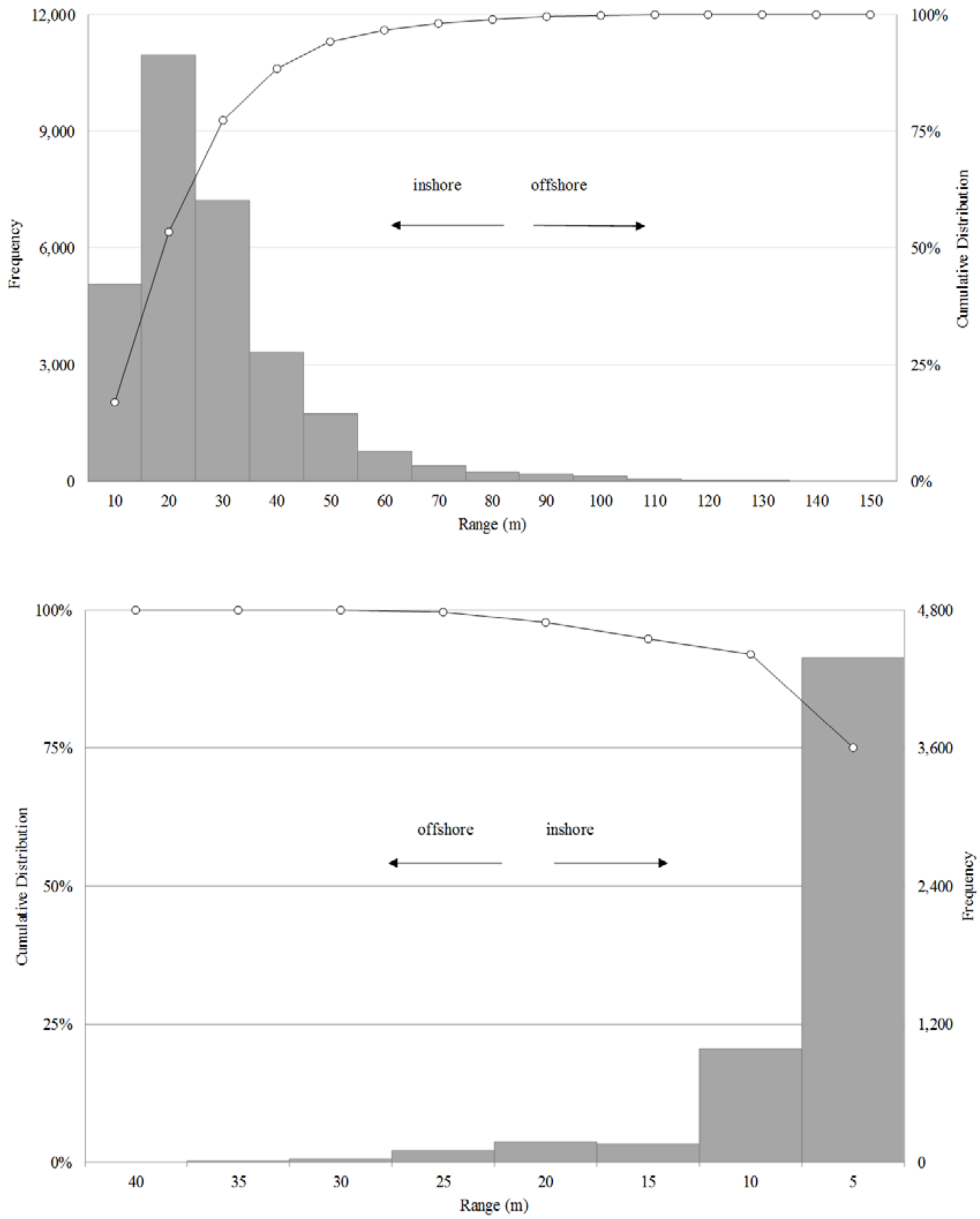



Figure 14.–Left bank (top) and right bank (bottom) horizontal distribution of upstream migrating Chinook salmon in the Yukon River at Eagle sonar project site, July 1 through August 20, 2017.

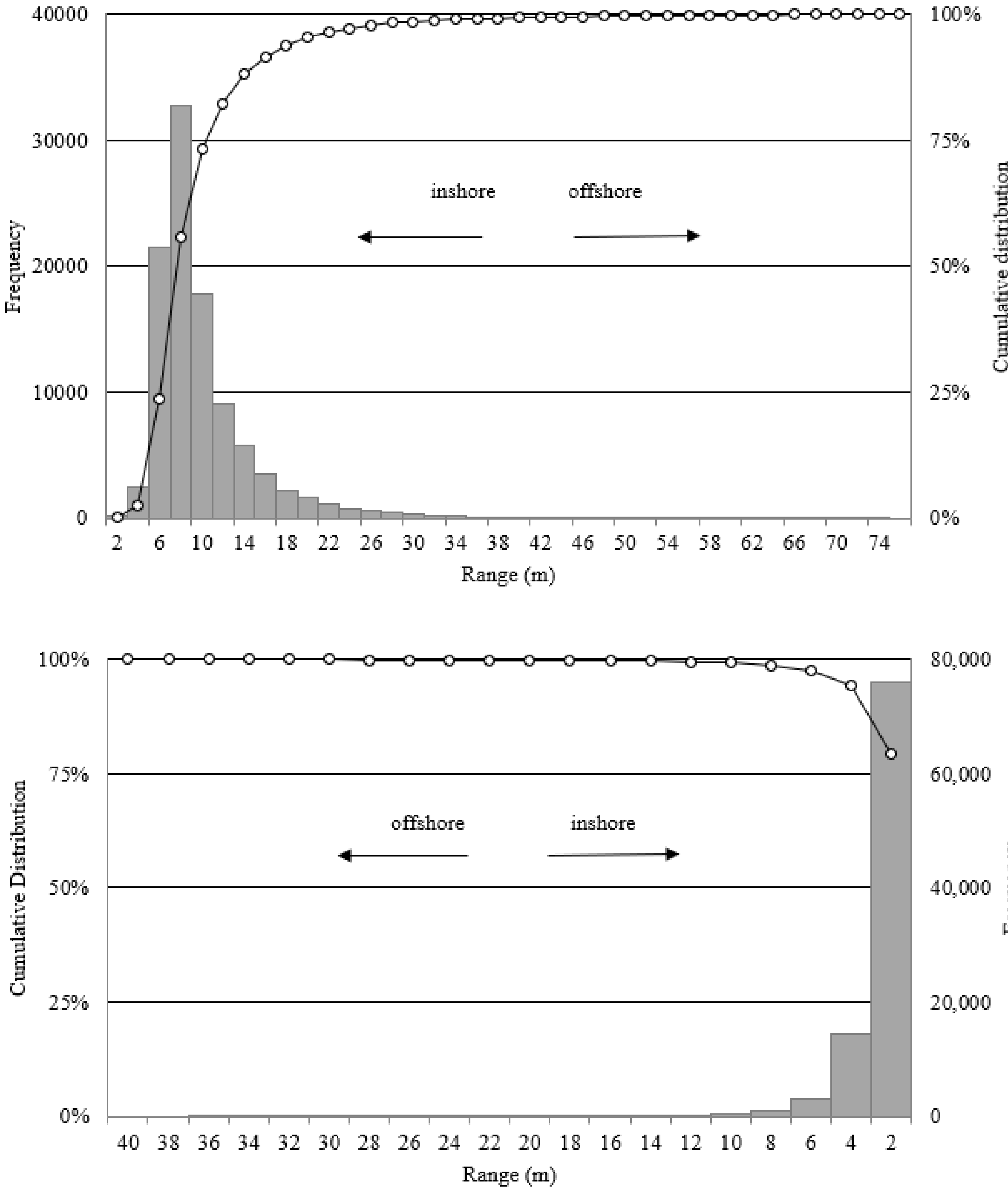



Figure 15.–Left bank (top) and right bank (bottom) horizontal distribution of upstream migrating fall chum salmon in the Yukon River at Eagle sonar project site, August 21 through October 6, 2017.

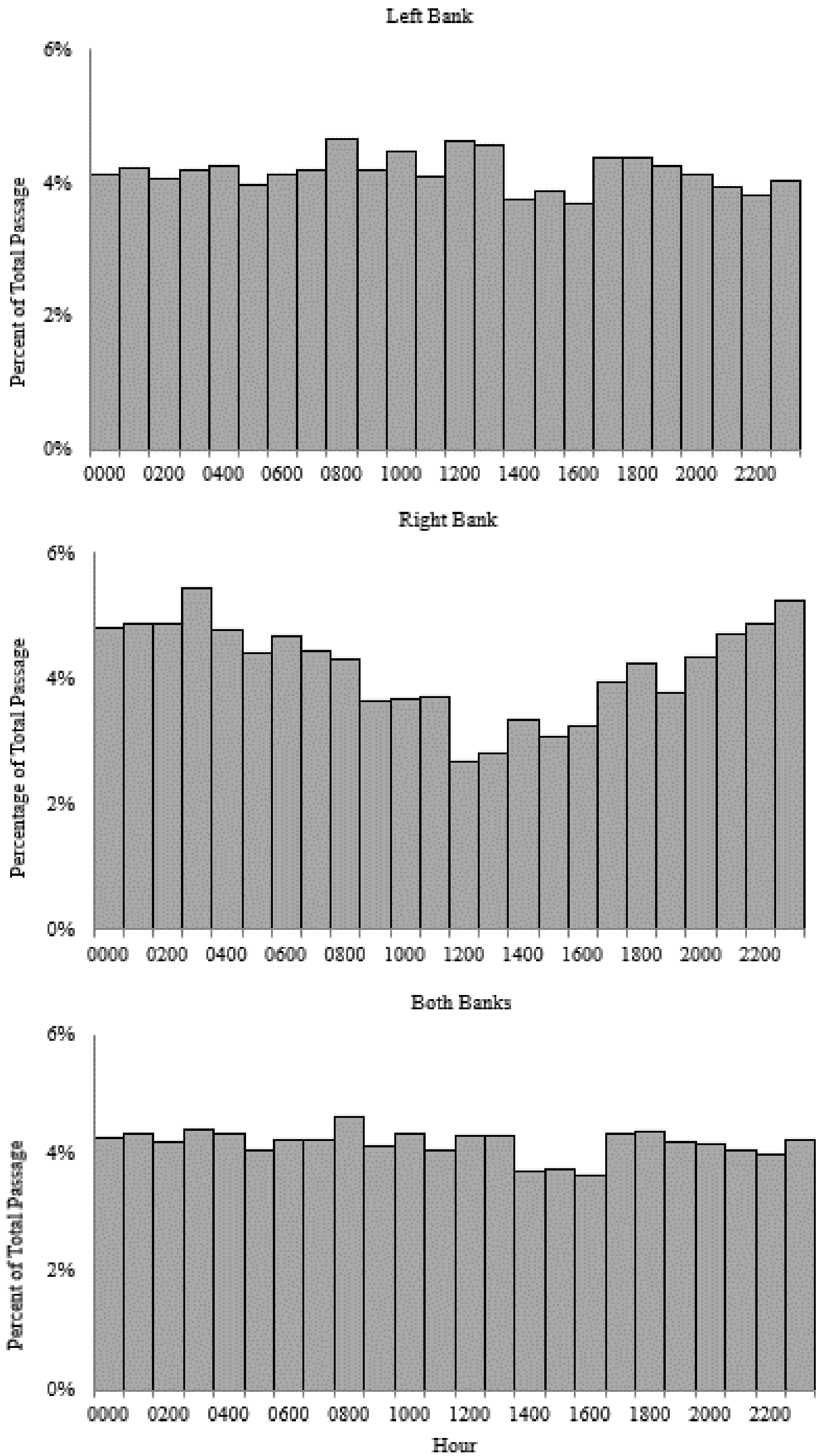



Figure 16.–Percentage of total Chinook salmon passage, by hour, observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site, July 1 through August 20, 2017.

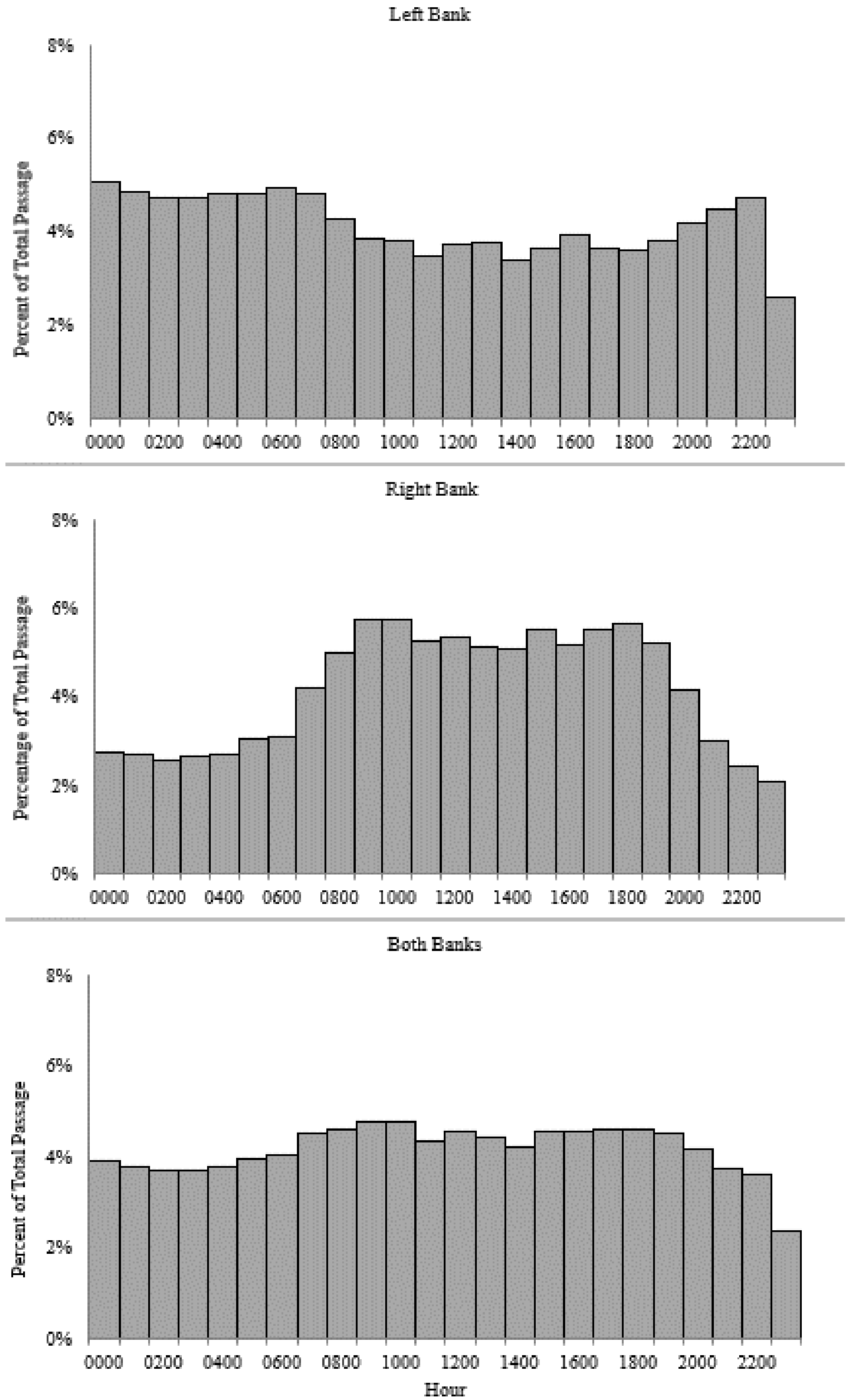
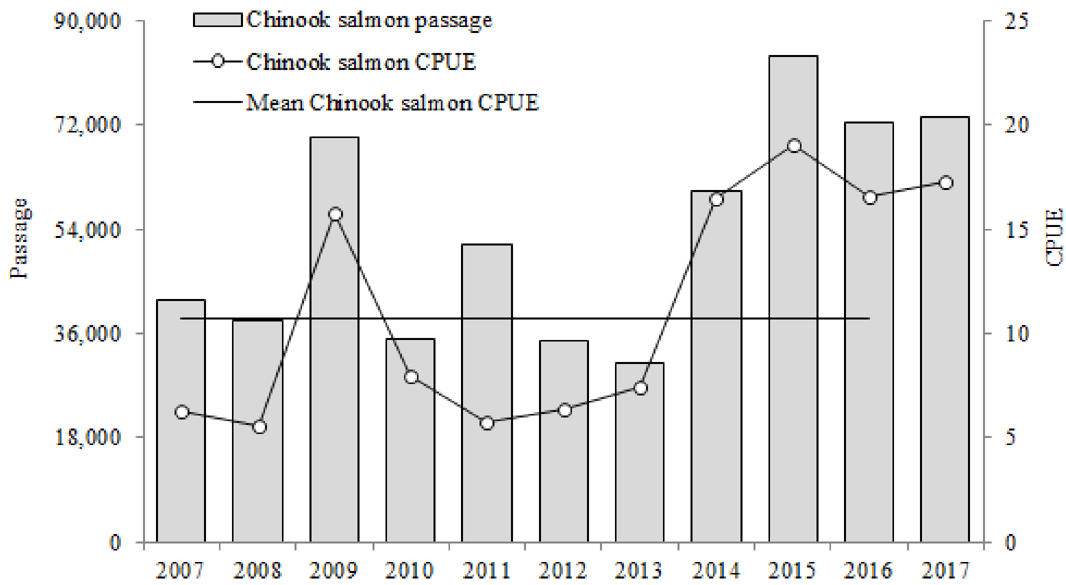



Figure 17.–Percentage of total fall chum salmon passage, by hour, observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site, August 21 through October 6, 2017.



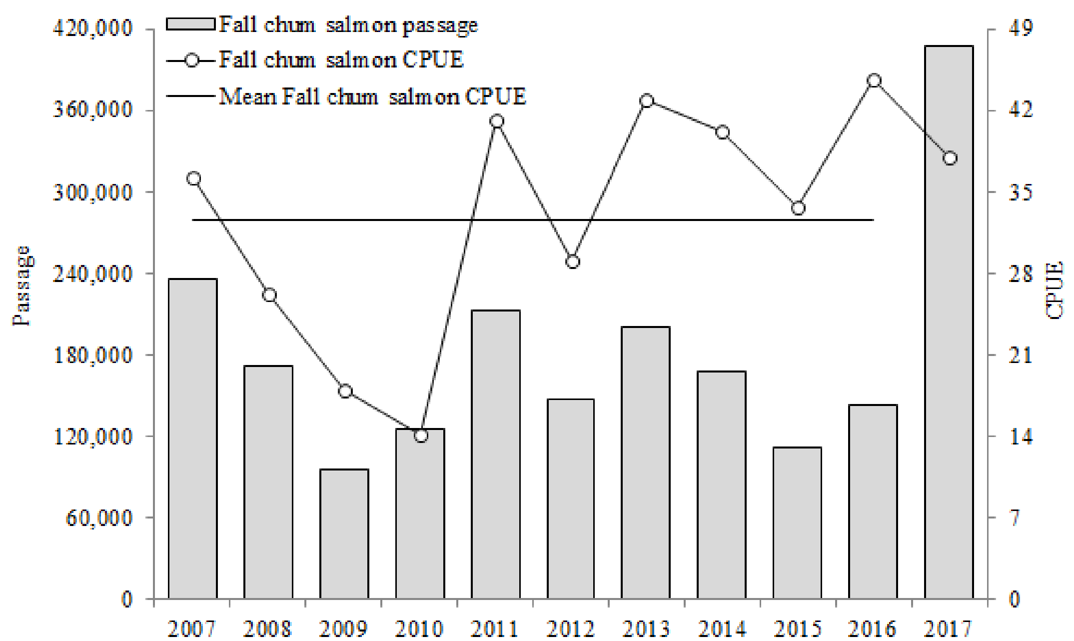




Figure 18.–Chinook (top) and fall chum salmon (bottom) passage and total cumulative catch per unit effort (CPUE) by year at the Eagle sonar project site, on the Yukon River, 2017.

*Note*: Because test fishing sites on the right bank have changed several times throughout the years, CPUE calculations are derived from the left bank fishery only. Prior to 2013, to avoid mortalities, there were occasions that fish were released without sampling, and therefore for these years CPUE only represents fish sampled.

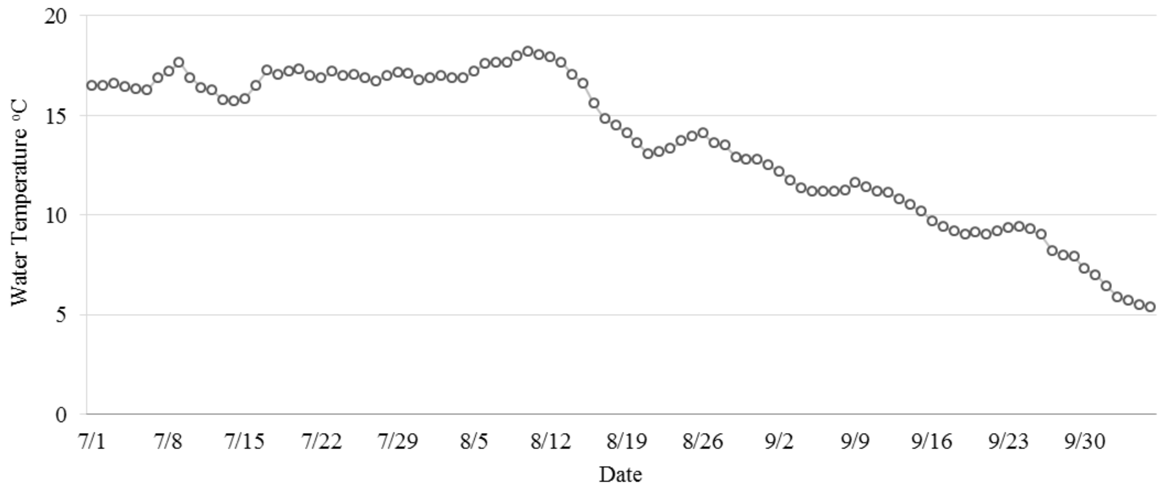



Figure 19.–Median daily water temperatures recorded on the left bank at the Eagle sonar project on the Yukon River, 2017.

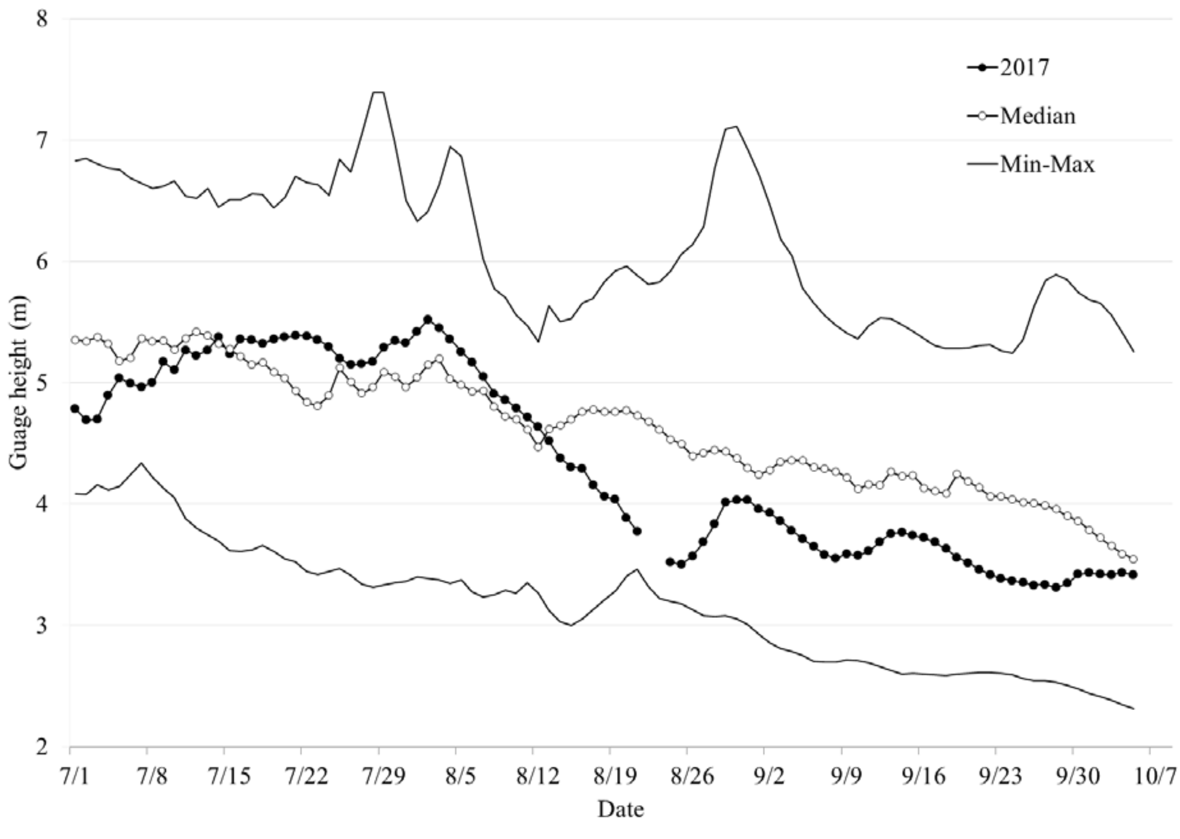



Figure 20.–Yukon River daily water level during the 2017 season at the Eagle water gage compared to minimum, maximum, and median gage height, 1995–2015.

*Source*: United States Geological Survey.

*Note*: USGS gage was out of service from August 22 to August 23, 2017.

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

Appendix A1.–Species composition test fishery catch, CPUE, and smoothed data by day and salmon species at the Eagle sonar project, on the Yukon River, 2017.

| | 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 | 18.49 | 5 | 0.27 | 6 | 0.33 | 18.58 | 1 | 0.05 | 1 | 0.03 |
| 08/02 | 19.09 | 6 | 0.31 | 7 | 0.35 | 18.10 | 0 | 0.00 | 0 | 0.02 |
| 08/03 | 18.43 | 9 | 0.49 | 7 | 0.37 | 17.82 | 0 | 0.00 | 0 | 0.01 |
| 08/04 | 18.76 | 10 | 0.53 | 7 | 0.38 | 17.40 | 0 | 0.00 | 0 | 0.01 |
| 08/05 | 18.46 | 8 | 0.43 | 7 | 0.36 | 17.69 | 0 | 0.00 | 0 | 0.00 |
| 08/06 | 17.49 | 5 | 0.29 | 6 | 0.32 | 17.29 | 0 | 0.00 | 0 | 0.00 |
| 08/07 | 17.06 | 3 | 0.18 | 5 | 0.28 | 16.79 | 0 | 0.00 | 0 | 0.00 |
| 08/08 | 17.52 | 5 | 0.29 | 4 | 0.23 | 16.36 | 0 | 0.00 | 0 | 0.00 |
| 08/09 | 16.73 | 3 | 0.18 | 3 | 0.18 | 16.41 | 0 | 0.00 | 0 | 0.01 |
| 08/10 | 16.43 | 2 | 0.12 | 2 | 0.14 | 16.54 | 0 | 0.00 | 0 | 0.02 |
| 08/11 | 16.65 | 2 | 0.12 | 2 | 0.10 | 16.40 | 0 | 0.00 | 1 | 0.03 |
| 08/12 | 16.54 | 0 | 0.00 | 1 | 0.07 | 16.30 | 2 | 0.12 | 1 | 0.04 |
| 08/13 | 16.35 | 1 | 0.06 | 1 | 0.04 | 16.21 | 1 | 0.06 | 1 | 0.04 |
| 08/14 | 15.90 | 0 | 0.00 | 0 | 0.03 | 16.49 | 1 | 0.06 | 1 | 0.04 |
| 08/15 | 16.24 | 0 | 0.00 | 0 | 0.02 | 16.35 | 0 | 0.00 | 0 | 0.03 |
| 08/16 | 16.74 | 0 | 0.00 | 0 | 0.02 | 15.69 | 0 | 0.00 | 0 | 0.02 |
| 08/17 | 16.43 | 0 | 0.00 | 0 | 0.02 | 16.36 | 0 | 0.00 | 0 | 0.01 |
| 08/18 | 16.16 | 1 | 0.06 | 0 | 0.02 | 16.35 | 0 | 0.00 | 0 | 0.00 |
| 08/19 | 16.25 | 1 | 0.06 | 0 | 0.02 | 16.47 | 0 | 0.00 | 0 | 0.00 |
| 08/20 | 16.29 | 0 | 0.00 | 0 | 0.02 | 16.13 | 0 | 0.00 | 0 | 0.01 |
| 08/21 | 16.65 | 0 | 0.00 | 0 | 0.02 | 16.24 | 0 | 0.00 | 0 | 0.03 |
| 08/22 | 16.58 | 1 | 0.06 | 0 | 0.02 | 16.54 | 1 | 0.06 | 1 | 0.05 |
| 08/23 | 16.34 | 0 | 0.00 | 0 | 0.01 | 16.67 | 0 | 0.00 | 1 | 0.07 |
| 08/24 | 13.60 | 0 | 0.00 | 0 | 0.01 | 16.94 | 2 | 0.12 | 2 | 0.11 |
| 08/25 | 17.19 | 0 | 0.00 | 0 | 0.01 | 16.79 | 3 | 0.18 | 3 | 0.16 |
| 08/26 | 16.22 | 0 | 0.00 | 0 | 0.01 | 16.78 | 2 | 0.12 | 4 | 0.22 |
| 08/27 | 16.55 | 0 | 0.00 | 0 | 0.01 | 16.76 | 5 | 0.30 | 5 | 0.28 |
| 08/28 | 16.85 | 1 | 0.06 | 0 | 0.01 | 17.11 | 7 | 0.41 | 6 | 0.36 |
| 08/29 | 16.65 | 0 | 0.00 | 0 | 0.01 | 17.37 | 7 | 0.40 | 7 | 0.42 |
| 08/30 | 16.74 | 0 | 0.00 | 0 | 0.01 | 17.30 | 7 | 0.41 | 9 | 0.51 |
| 08/31 | 16.89 | 0 | 0.00 | 0 | 0.00 | 17.60 | 9 | 0.51 | 11 | 0.59 |

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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 |
| 09/01 | 16.71 | 0 | 0.00 | 0 | 0.00 | 17.63 | 14 | 0.79 | 13 | 0.68 |
| 09/02 | 17.14 | 0 | 0.00 | 0 | 0.00 | 17.82 | 10 | 0.56 | 14 | 0.76 |
| 09/03 | 16.82 | 0 | 0.00 | 0 | 0.00 | 18.68 | 26 | 1.39 | 16 | 0.82 |
| 09/04 | 17.19 | 0 | 0.00 | 0 | 0.00 | 18.34 | 15 | 0.82 | 16 | 0.85 |
| 09/05 | 17.17 | 0 | 0.00 | 0 | 0.00 | 18.97 | 17 | 0.90 | 16 | 0.85 |
| 09/06 | 17.68 | 0 | 0.00 | 0 | 0.00 | 17.96 | 18 | 1.00 | 15 | 0.82 |
| 09/07 | 16.93 | 0 | 0.00 | 0 | 0.00 | 17.28 | 8 | 0.46 | 14 | 0.77 |
| 09/08 | 16.70 | 0 | 0.00 | 0 | 0.00 | 17.93 | 20 | 1.12 | 13 | 0.73 |
| 09/09 | 17.22 | 0 | 0.00 | 0 | 0.00 | 17.61 | 7 | 0.40 | 13 | 0.72 |
| 09/10 | 17.07 | 0 | 0.00 | 0 | 0.00 | 17.42 | 8 | 0.46 | 14 | 0.78 |
| 09/11 | 17.24 | 0 | 0.00 | 0 | 0.00 | 18.08 | 12 | 0.66 | 16 | 0.91 |
| 09/12 | 16.52 | 0 | 0.00 | 0 | 0.00 | 18.26 | 14 | 0.77 | 19 | 1.10 |
| 09/13 | 17.97 | 0 | 0.00 | 0 | 0.00 | 19.40 | 30 | 1.55 | 23 | 1.32 |
| 09/14 | 16.97 | 0 | 0.00 | 0 | 0.00 | 17.84 | 34 | 1.91 | 25 | 1.50 |
| 09/15 | 15.84 | 0 | 0.00 | 0 | 0.00 | 15.89 | 33 | 2.08 | 25 | 1.58 |
| 09/16 | 14.65 | 0 | 0.00 | 0 | 0.00 | 14.18 | 22 | 1.55 | 25 | 1.58 |
| 09/17 | 15.29 | 0 | 0.00 | 0 | 0.00 | 14.55 | 28 | 1.92 | 24 | 1.56 |
| 09/18 | 14.41 | 0 | 0.00 | 0 | 0.00 | 13.40 | 13 | 0.97 | 23 | 1.50 |
| 09/19 | 13.48 | 0 | 0.00 | 0 | 0.00 | 13.86 | 12 | 0.87 | 22 | 1.46 |
| 09/20 | 13.89 | 0 | 0.00 | 0 | 0.00 | 15.01 | 19 | 1.27 | 22 | 1.44 |
| 09/21 | 15.18 | 0 | 0.00 | 0 | 0.00 | 14.47 | 24 | 1.66 | 22 | 1.44 |
| 09/22 | 15.21 | 0 | 0.00 | 0 | 0.00 | 15.47 | 25 | 1.62 | 22 | 1.40 |
| 09/23 | 15.77 | 0 | 0.00 | 0 | 0.00 | 15.04 | 20 | 1.33 | 21 | 1.36 |
| 09/24 | 15.12 | 0 | 0.00 | 0 | 0.00 | 15.23 | 24 | 1.58 | 21 | 1.33 |
| 09/25 | 14.66 | 0 | 0.00 | 0 | 0.00 | 16.81 | 28 | 1.67 | 22 | 1.33 |
| 09/26 | 16.13 | 0 | 0.00 | 0 | 0.00 | 15.42 | 24 | 1.56 | 22 | 1.33 |
| 09/27 | 17.26 | 0 | 0.00 | 0 | 0.00 | 16.31 | 16 | 0.98 | 23 | 1.34 |
| 09/28 | 16.91 | 0 | 0.00 | 0 | 0.00 | 16.15 | 12 | 0.74 | 23 | 1.36 |
| 09/29 | 16.68 | 0 | 0.00 | 0 | 0.00 | 18.55 | 31 | 1.67 | 23 | 1.38 |
| 09/30 | 16.87 | 0 | 0.00 | 0 | 0.00 | 17.49 | 17 | 0.97 | 24 | 1.39 |

# APPENDIX B: CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climate and hydrologic observations recorded daily at 1800 hours, at the Eagle sonar project site on the Yukon River, 2017

| | Precipitation | Wind | | Sky | Temperature (°C) | |
|---|---|---|---|---|---|---|
| Date | (code)[a] | Direction | Velocity (kph) | (code)[b] | Air | Water[c] |
| 7/01 | B | ND | 0.0 | B | 24.0 | 16.5 |
| 7/02 | B | ND | 0.0 | B | 24.0 | 16.5 |
| 7/03 | A | W/NW | 4.8 | B | 32.0 | 16.6 |
| 7/04 | A | N/W | 4.8 | S | 29.0 | 16.5 |
| 7/05 | A | ND | 0.0 | S | 29.0 | 16.3 |
| 7/06 | A | E | 3.2 | C | 35.0 | 16.3 |
| 7/07 | A | NE | 1.6 | C | 32.0 | 16.9 |
| 7/08 | A | E | 9.7 | S | 30.0 | 17.2 |
| 7/09 | B | ND | 0.0 | O | 23.0 | 17.7 |
| 7/10 | A | N | 4.8 | O | 16.0 | 16.9 |
| 7/11 | A | N | 4.8 | S | 20.0 | 16.4 |
| 7/12 | A | ND | 0.0 | O | 22.0 | 16.3 |
| 7/13 | A | N | 6.4 | S | 25.0 | 15.8 |
| 7/14 | A | ND | 0.0 | S | 27.0 | 15.7 |
| 7/15 | A | ND | 0.0 | S | 23.0 | 158 |
| 7/16 | A | N/W | 1.6 | S | 24.0 | 16.5 |
| 7/17 | B | W | 1.6 | S | 23.0 | 17.3 |
| 7/18 | A | N | 6.4 | S | 22.0 | 17.1 |
| 7/19 | A | E | 1.6 | S | 25.0 | 17.2 |
| 7/20 | A | E | 1.6 | B | 21.0 | 17.3 |
| 7/21 | A | N/W | 8.1 | S | 20.0 | 17.0 |
| 7/22 | A | E | 0.0 | S | 23.0 | 16.9 |
| 7/23 | A | W | 8.1 | B | 26.0 | 17.2 |
| 7/24 | B | ND | 0.0 | B | 20.0 | 17.0 |
| 7/25 | A | ND | 0.0 | B | 21.0 | 17.1 |
| 7/26 | A | NW | 3.2 | B | 22.0 | 16.9 |
| 7/27 | A | W | 3.2 | B | 20.0 | 16.7 |
| 7/28 | A | ND | 0.0 | S | 24.0 | 17.0 |
| 7/29 | A | ND | 0.0 | S | 25.0 | 17.2 |
| 7/30 | A | SW | 4.8 | S | 28.0 | 17.1 |
| 7/31 | B | N | 4.8 | S | 23.0 | 16.8 |
| 8/01 | B | SW | 1.6 | S | 21.0 | 16.9 |
| 8/02 | B | S | 1.6 | B | 18.0 | 17.0 |
| 8/03 | B | NW | 3.2 | B | 20.0 | 16.9 |
| 8/04 | B | N | 1.6 | B | 19.5 | 16.9 |
| 8/05 | A | NW | 6.1 | C | 25.5 | 17.2 |
| 8/06 | A | S | 3.2 | S | 30.5 | 17.6 |
| 8/07 | A | S | 3.2 | S | 25.6 | 17.7 |
| 8/08 | A | SW | 1.6 | S | 28.5 | 17.7 |
| 8/09 | A | NE | 1.6 | S | 28.0 | 18.0 |
| 8/10 | A | NE | 0.0 | S | 24.0 | 18.2 |

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Appendix B1.–Page 2 of 3.

| | Precipitation | Wind | | Sky | Temperature (°C) | |
|---|---|---|---|---|---|---|
| Date | (code)[a] | Direction | Velocity (kph) | (code)[b] | Air | Water[c] |
| 8/11 | A | S | 3.2 | S | 24.0 | 18.1 |
| 8/12 | A | N | 0.0 | S | 23.0 | 17.9 |
| 8/13 | A | N | 1.6 | S | 22.0 | 17.7 |
| 8/14 | A | S | 4.8 | O | 16.0 | 17.1 |
| 8/15 | B | NW | 1.6 | B | 17.0 | 16.6 |
| 8/16 | A | E | 0.0 | O | 22.0 | 15.6 |
| 8/17 | A | S | 0.0 | S | 17.0 | 14.8 |
| 8/18 | B | SW | 1.6 | O | 11.0 | 14.5 |
| 8/19 | B | E | 0.0 | S | 17.0 | 14.1 |
| 8/20 | A | NE | 0.0 | B | 17.0 | 13.6 |
| 8/21 | B | NW | 0.0 | O | 15.0 | 13.1 |
| 8/22 | A | S | 0.0 | O | 17.0 | 13.2 |
| 8/23 | A | W | 0.0 | S | 16.0 | 13.4 |
| 8/24 | A | NE | 4.8 | B | 21.5 | 13.7 |
| 8/25 | A | NE | 3.2 | O | 17.0 | 14.0 |
| 8/26 | A | S | 4.8 | O | 16.0 | 14.1 |
| 8/27 | B | S | 1.6 | O | 12.0 | 13.6 |
| 8/28 | A | S | 6.4 | S | 17.0 | 13.5 |
| 8/29 | A | ND | 0.0 | O | 17.0 | 12.9 |
| 8/30 | B | S | 4.8 | O | 14.0 | 12.8 |
| 8/31 | A | S | 4.8 | S | 17.0 | 12.8 |
| 9/01 | A | E | 1.6 | B | 15.0 | 12.5 |
| 9/02 | A | ND | 0.0 | C | 14.0 | 12.2 |
| 9/03 | A | N | 1.6 | C | 16.0 | 11.8 |
| 9/04 | A | N | 8.1 | O | 15.0 | 11.4 |
| 9/05 | B | ND | 0.0 | O | 14.0 | 11.2 |
| 9/06 | A | N | 3.2 | O | 18.0 | 11.2 |
| 9/07 | A | ND | 0.0 | B | 16.0 | 11.2 |
| 9/08 | A | ND | 0.0 | S | 16.0 | 11.3 |
| 9/09 | B | ND | 0.0 | O | 10.0 | 11.6 |
| 9/10 | A | ND | 0.0 | B | 11.0 | 11.4 |
| 9/11 | A | ND | 0.0 | O | 10.0 | 11.2 |
| 9/12 | A | S | 9.7 | O | 15.0 | 11.1 |
| 9/13 | A | S | 3.2 | S | 16.0 | 10.8 |
| 9/14 | A | S | 6.4 | B | 15.0 | 10.5 |
| 9/15 | A | ND | 0.0 | C | 14.0 | 10.2 |
| 9/16 | A | ND | 0.0 | S | 15.0 | 9.7 |
| 9/17 | A | ND | 0.0 | S | 17.0 | 9.4 |
| 9/18 | A | ND | 0.0 | B | 16.0 | 9.2 |
| 9/19 | A | S | 3.2 | B | 13.0 | 9.1 |
| 9/20 | B | S | 4.8 | O | 8.0 | 9.2 |

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Appendix B1.–Page 3 of 3.

| | Precipitation | Wind | | Sky | Temperature (°C) | |
|---|---|---|---|---|---|---|
| Date | (code)[a] | Direction | Velocity (kph) | (code)[b] | Air | Water |
| 9/21 | A | ND | 0.0 | O | 10.0 | 9.0 |
| 9/22 | C | ND | 0.0 | O | 8.0 | 9.2 |
| 9/23 | A | W | 1.6 | S | 12.0 | 9.4 |
| 9/24 | A | S | 3.2 | B | 10.0 | 9.4 |
| 9/25 | B | ND | 0.0 | O | 10.0 | 9.3 |
| 9/26 | B | N | 9.7 | O | 7.0 | 9.0 |
| 9/27 | A | SE | 12.9 | O | 8.0 | 8.2 |
| 9/28 | A | S | 8.1 | B | 15.0 | 8.0 |
| 9/29 | B | N | 6.4 | O | 4.0 | 7.9 |
| 9/30 | A | ND | 0.0 | O | 4.0 | 7.3 |
| 10/01 | A | S | 9.7 | C | 8.0 | 7.0 |
| 10/02 | A | S | 20.9 | O | 8.0 | 6.4 |
| 10/03 | A | ND | 0.0 | C | 10.0 | 5.9 |
| 10/04 | B | S | 6.4 | O | 9.0 | 5.7 |
| 10/05 | A | S | 3.2 | B | 10.0 | 5.5 |

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

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

[c] Water temperature collected approximately 30 cm below surface with Hobo U22 Data Logger.