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Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River Near Eagle, Alaska, 2024

by

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and

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August 2026

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	′
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	″
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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SONAR ESTIMATION OF CHINOOK AND FALL CHUM SALMON PASSAGE IN THE YUKON RIVER NEAR EAGLE, ALASKA, 2024

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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 28 through October 6, 2024. A total of 24,183 (SE 179) Chinook salmon were estimated to have passed the sonar site from June 28 through August 27. The midpoint of the Chinook salmon migration occurred on July 30, which was 5 days later than the historical mean. A total of 14,003 (SE 151) fall chum salmon were estimated to have passed the sonar site from August 28 through October 6. The fall chum salmon passage estimate was subsequently expanded to 16,204 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 27, which was 4 days later than the historical mean. Drift gillnetting was conducted to collect age, sex, and length data, as well as tissue samples for genetic analysis. 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 the 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, often providing the largest single source of food or income.

Fisheries management on the Yukon River is complex and challenging due to the number, diversity, and geographic range of fish stocks and user groups. Information for management decisions comes from several sources, each with 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 resulting information is typically not timely enough 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 help managers adjust harvest inseason and are crucial for postseason analysis to determine whether treaty obligations were met. The Canadian Department of Fisheries and Oceans (DFO) provided estimates of mainstem salmon passage across the U.S./Canada border using mark–recapture techniques from 1980 to 2008 (JTC 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 estimation methods that rely on visual observation, such as counting towers and weirs, are not feasible. Split-beam sonar technology is

[1] Robinson, J. Lewis. "Yukon River". Encyclopedia Britannica, October 29, 2024. https://www.britannica.com/place/Yukon-River (cited October 31, 2024; accessed May 15, 2026).

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. 2023). 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. 2023) and lower Yukon River near Pilot Station (Morrill et al. 2023), 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 study period, 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 led to overly restrictive echo angle thresholds, resulting in the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed. A recommendation from these studies was to identify 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 the hydroacoustic beam can be aimed at the bottom. Similarly, an uneven bottom profile permits fish to pass undetected by the sonar.

In 2003, ADF&G conducted a study to identify a more suitable location for deploying 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 narrowed 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 at Six Mile Bend on the Yukon River (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 estimate fall chum salmon passage (Dunbar and Crane 2007). There are 2 genetically distinct runs of chum salmon that enter the Yukon River: an early-summer component and a later-fall component (Ransbury et al. 2022). 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 migrating 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 2024, the project deployed split-beam and ARIS sonars to estimate the migration of Chinook and fall chum salmon across the U.S./Canada border. Test fisheries were conducted to determine the transition from Chinook to fall chum salmon migrations as well as to collect age, sex, and length (ASL) samples and tissue samples for genetic stock identification. This report will describe the methods used to collect sonar and fishery sampling data and will also provide passage estimates, species distributions, run timing, and climatic and hydrologic observations.

OBJECTIVES

The goal of this project in 2024 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 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 its variability 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 2.1°. The right bank profile is less linear, shorter, and steeper, extending approximately 100 m to the thalweg with a slope of approximately 6.3° (Figure 4). The thalweg is approximately 11 m deep, depending on the water level. The substrate at Six Mile Bend consists of large cobbles to small boulders on the right bank and small to medium-sized cobbles and silt on the left bank. Both banks have been observed to have stable bottom profiles throughout the project's history.

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 an EK60 digital echosounder with a general-purpose transceiver and a 2.5° x 10° 120 kHz transducer (Table 1). EK80 data acquisition software was controlled using a Simrad Controller program developed by ADF&G (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks), 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). Both the low frequency and high frequency modes utilize 48 beams and have a field of view of 28°.

Digital files were created by the EK80 software and the ARIS. Operators marked each upstream fish track using Echotastic (Version 3), an echogram viewer program developed by ADF&G staff.[2]

SONAR DEPLOYMENT AND OPERATION

River bottom profiles were checked before 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 perpendicular to each other to provide dual-axis rotation. Aiming was performed remotely using an HTI model 660 remote control unit, which provided horizontal and vertical positioning. Operators adjusted the aim by viewing the echogram in either

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[2] Echotastic software. 2023. Version 3.0.13. Developed by Carl Pfisterer, ADF&G Division of Commercial Fisheries (internal use only).

the EK80 program or Echotastic. The proper aim was achieved when an adequate substrate was present across most 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 aluminum-pipe frame 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, 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 150 m range from the transducer and to sample 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 from 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, completed 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 throughout 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 an adequate substrate was present across most 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 to sample 2 strata (S5: approximately 0.7–20 m and S6: approximately 20–40 m; Figure 2).

A fish lead was constructed using 2 m steel "T" stakes and 1-inch heavy-duty seine mesh. The seine mesh was anchored to the river bottom with a heavy chain woven along its length, which followed the substrate contours (Figure 6). Additional flotation for the upper edge was provided by gillnet floats sewn along the top of the seine mesh at approximately 0.5 m intervals. 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:

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

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

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

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 downtime), 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:

$$\hat{V}ar\ (\hat{y}) = \sum_d \sum_s \hat{V}ar\ (\hat{y}_{ds}). \tag{5}$$

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:

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

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, estimates of hourly, daily, and cumulative fish passage were produced and emailed to fishery managers each day. The estimates produced during the field season were further reviewed postseason and adjusted as necessary.

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

$$\hat{y}_{is} = \frac{L_s}{d^2}(x_i - d)^2, \tag{7}$$

where $\hat{y}_{is}$ is the daily passage estimate on the day (i) of expansion for bank (s), 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 the results were summed to obtain 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 to be 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 (data on file with ADF&G, Division of Commercial Fisheries, Yukon Management Group; Fairbanks).

Postseason, border passage estimates for both Chinook and fall chum salmon are calculated and published annually by the Yukon River Joint Technical Committee (JTC).[3]

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[4] 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 migration patterns. Chinook and fall chum salmon run timing were examined both inseason and postseason using information from sonar estimates, 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, the predominant

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3 JTC (Joint Technical Committee of the Yukon River Panel). Yukon River Joint Technical Committee Reports. Pacific Salmon Commission, Vancouver, BC, Canada. Available from https://www.yukonriverpanel.com/publications/yukon-river-joint-technical-committee-reports/ (accessed July 13, 2026).

4 The R Project for statistical computing. R version 4.3.2 (Eye Holes). [released October 31, 2023; cited October 30, 2024]. Available for download from http://www.r-project.org

species in 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 mesh sizes (5.25 in, 6.5 in, 7.5 in, and 8.5 in) and drifted on a rotating schedule during the Chinook salmon sample fishery to effectively capture all size classes present (Table 3). Nets were 25 fathoms long, approximately 8 m deep, and hung "even" at a 2:1 ratio of web to 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:

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

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:

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

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 (Figure 3): left bank inshore (LBI), left bank nearshore (LBN), and left bank offshore (LBF) for a total of 12 drifts. Nets were hung the same as for the Chinook salmon test fishery, except the LBI nets, which were approximately 3 m deep (Table 4). Drifts were targeted to last 6 minutes but were occasionally shortened as necessary to avoid snags or limit catches and 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 the net at the shore end 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. The starting mesh sizes were alternated each day (Table 3).

Captured fish were identified to species, and length was measured to the nearest 1 mm. Salmon species were measured from the middle of the eye to the fork of the tail (METF); nonsalmon species were measured from the tip of the snout to the fork of the 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 gillnet mesh sizes (*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,[5] and relative water levels were also monitored at the sonar site. Surface water temperature was measured approximately 30 cm below the surface with a HOBO U22 water temperature data logger. Data

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[5] USGS (U.S. Geological Survey). National Water Information System: Web Interface. USGS 15356000 Yukon River at Eagle, Alaska. https://waterdata.usgs.gov/monitoring-location/USGS-15356000/#startDT=2024-07-01&endDT=2024-10-06&dataTypeId=continuous-00065-0&showFieldMeasurements=true (cited November 13, 2024; accessed June 13, 2026).

loggers were attached to the sonar transducer pods on each bank and set to record hourly. Air temperature, wind velocity, and wind direction were measured daily using a thermometer and a Kestrel handheld wind meter. Other daily observations included precipitation and percent cloud cover.

RESULTS AND DISCUSSION

SONAR DEPLOYMENT

In 2024, both the right and left bank transducers were deployed in approximately the same locations as in recent years (Figure 3). Occasionally, water level fluctuations and debris necessitated moving the transducers and fish leads into deeper or shallower water; however, this did not affect sonar operation. Overall, there were no significant interruptions to project operations throughout the 2024 season. Both the left and right bank sonars operated from June 28 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 27 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 24,183 (SE 179) from June 28 through August 27 (Table 5). The first quarter point of the run was July 24, the midpoint was July 30, and the third quarter point was August 6 (Table 6). The midpoint of the Chinook salmon run, July 30, was 5 days later than the 2005–2023[6] mean passage timing (Figure 12). Chinook salmon passage peaked on July 31 with a daily estimate of 1,104 fish, and a total of 71 Chinook salmon were estimated to have passed the sonar on August 27, the last day of the Chinook salmon season (Figure 13).

Sonar sampling time missed during the Chinook salmon migration varied by strata, and totals ranged between 20.7 hours and 35.9 hours (Table 7). Time missed was typically due to generator failures, computer software errors, 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 14,003 (SE 151) fish from August 28 through October 6 (Table 5). Because the fall chum salmon migration continued after project operations ceased, the passage estimate was expanded through October 18 to a total of 16,204 fish. Based on the expanded passage estimate, the first quarter point of the run was September 17, the midpoint was September 27, and the third quarter point was October 3 (Table 8). The midpoint of the fall chum salmon run occurred 4 days later than the 2006–2023[5] mean run timing (Figure 12). Fall chum salmon passage peaked on September 29 with a daily estimate of 748 fish, and a total of 627 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 10.1 hours and 19.9 hours (Table 9).

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[6] Differences in the species transition date from year to year confound the 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.

The river bottom profile remained similar to previous seasons and was acceptable for fish detection throughout 2024. Water levels and silt did not affect fish detection, and overall, the project ran smoothly, with few interruptions to operations.

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 20 m of the transducer. During the fall chum salmon migration, on the left bank, 95% of fish were detected within 25 m of the transducer, and on the right bank, 95% of fish were detected within 15 m of the transducer. Approximately 79% (19,142) of Chinook salmon and 66% (10,706) 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. There was an increase in passage on the right bank from approximately 0900 to 2000 hours with a corresponding slight decrease in passage on the left bank during this time period (Figure 17). When both banks were combined, the increase in daytime passage 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 212 Chinook salmon and 79 fall chum salmon were captured in drift gillnets between July 1 and September 30 (Table 10). A total of 7 broad whitefish (*Coregonus nasus*), 1 burbot (*Lota lota*), 9 sheefish (*Stenodus leucichthys*), 3 arctic grayling (*Thymallus arcticus*), and 2 humpback whitefish (*Coregonus pidschian*) were also captured in the test fisheries.

A total of 1,965 fathom-hours were fished in the Chinook salmon test fishery, and 1,999 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 2007–2023 means, and the cumulative CPUE for fall chum salmon was the lowest on record (Figure 18).

The Chinook salmon sampled were made up of 139 (66%) males and 73 (34%) females. The fall chum salmon sampled were made up of 49 (62%) males and 30 (38%) females. Clipped adipose fins, an indication that fish hold coded wire tags from the hatchery in Whitehorse, Yukon Territory, were observed on 6 Chinook salmon.

A total of 212 Chinook and 79 fall chum salmon were sampled for complete ASL and genetic data. Of the scales collected, 187 (88%) Chinook and 72 (91%) fall chum salmon were ageable.[7] 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 1 (Appendix B1). The water temperature on the left bank fluctuated in July and August but generally

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[7] 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 May 15, 2026).

decreased over the latter two-thirds of the season (Figure 19). The maximum water temperature observed was 18.7°C on July 26, and the minimum was 4.0°C on October 6. The water level remained below the historical median (1995–2023) for the first two-thirds of the season, with a notable exception between August 10 and August 13, when it rose above the historical median. Water levels rose above the historical median on September 11 and remained above the median for the remainder of the season. (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, 2024.

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, 2024.

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
End range (m)	S5	20
	S6	40
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 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 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, 2024.

		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, 2024.

	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, 2024.

					95% CI	
Species	Left bank	Right bank	Total passage	SE	Lower	Upper
Chinook	19,142	5,041	24,183	179	23,832	24,534
Fall chum (excluding expansion[a])	9,052	4,951	14,003	151	13,707	14,299
Fall chum (including expansion[a,b])	10,706	5,498	16,204	151	15,908	16,500

[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, 2024.

	Daily				Cumulative			
Date	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
06/28[a]	7	7	14	7	7	7	14	0.001
06/29	0	6	6	3	7	13	20	0.001
06/30	8	10	18	4	15	23	38	0.002
07/01	14	10	24	5	29	33	62	0.003
07/02	8	22	30	5	37	55	92	0.004
07/03	6	20	26	6	43	75	118	0.005
07/04	10	24	34	6	53	99	152	0.006
07/05	12	36	48	7	65	135	200	0.008
07/06	18	44	62	7	83	179	262	0.011
07/07	26	21	47	7	109	200	309	0.013
07/08	42	10	52	7	151	210	361	0.015
07/09	58	24	82	10	209	234	443	0.018
07/10	69	22	91	14	278	256	534	0.022
07/11	110	46	156	13	388	302	690	0.029
07/12	146	50	196	20	534	352	886	0.037
07/13	176	58	234	17	710	410	1,120	0.046
07/14	200	79	279	21	910	489	1,399	0.058
07/15	198	110	308	18	1,108	599	1,707	0.071
07/16	226	130	356	25	1,334	729	2,063	0.085
07/17	230	152	382	18	1,564	881	2,445	0.101
07/18	306	81	387	20	1,870	962	2,832	0.117
07/19	339	133	472	23	2,209	1,095	3,304	0.137
07/20	330	162	492	32	2,539	1,257	3,796	0.157
07/21	406	222	628	30	2,945	1,479	4,424	0.183
07/22	470	220	690	30	3,415	1,699	5,114	0.211
07/23	587	228	815	34	4,002	1,927	5,929	0.245
07/24	601	200	801	30	4,603	2,127	6,730	0.278
07/25	725	95	820	36	5,328	2,222	7,550	0.312
07/26	841	182	1,023	35	6,169	2,404	8,573	0.355
07/27	869	216	1,085	41	7,038	2,620	9,658	0.399
07/28	894	184	1,078	38	7,932	2,804	10,736	0.444
07/29	855	120	975	36	8,787	2,924	11,711	0.484
07/30	**831**	**86**	**917**	**43**	**9,618**	**3,010**	**12,628**	**0.522**
07/31	985	119	1,104	44	10,603	3,129	13,732	0.568
08/01	969	118	1,087	46	11,572	3,247	14,819	0.613
08/02	833	90	923	33	12,405	3,337	15,742	0.651
08/03	735	84	819	30	13,140	3,421	16,561	0.685
08/04	714	44	758	30	13,854	3,465	17,319	0.716

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Table 6.–Page 2 of 2.

Date	Daily				Cumulative			
	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
08/05	591	126	717	25	14,445	3,591	18,036	0.746
08/06	514	148	662	25	14,959	3,739	18,698	0.773
08/07	568	146	714	24	15,527	3,885	19,412	0.803
08/08	408	124	532	25	15,935	4,009	19,944	0.825
08/09	478	94	572	28	16,413	4,103	20,516	0.848
08/10	400	108	508	22	16,813	4,211	21,024	0.869
08/11	338	77	415	21	17,151	4,288	21,439	0.887
08/12	259	62	321	22	17,410	4,350	21,760	0.900
08/13	261	67	328	20	17,671	4,417	22,088	0.913
08/14	254	80	334	18	17,925	4,497	22,422	0.927
08/15	206	58	264	17	18,131	4,555	22,686	0.938
08/16	197	65	262	19	18,328	4,620	22,948	0.949
08/17	142	61	203	18	18,470	4,681	23,151	0.957
08/18	126	61	187	15	18,596	4,742	23,338	0.965
08/19	106	34	140	10	18,702	4,776	23,478	0.971
08/20	76	56	132	14	18,778	4,832	23,610	0.976
08/21	84	38	122	11	18,862	4,870	23,732	0.981
08/22	70	28	98	11	18,932	4,898	23,830	0.985
08/23	34	12	46	8	18,966	4,910	23,876	0.987
08/24	50	26	76	9	19,016	4,936	23,952	0.990
08/25	60	36	96	11	19,076	4,972	24,048	0.994
08/26	28	36	64	6	19,104	5,008	24,112	0.997
08/27[b]	38	33	71	9	19,142	5,041	24,183	1.000
Total	19,142	5,041	24,183	NA	NA	NA	NA	NA
Var	25,547	6,662	32,209	NA	NA	NA	NA	NA
SE	160	82	179	NA	NA	NA	NA	NA

Note: SE means standard error, Var means variance, and NA means not applicable. The upper portion of the outlined box identifies the second quartile of the run, the lower portion identifies the third quartile, and bold text identifies the median day of passage.

[a] The sonar was 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, 2024.

	Left bank		Right bank	
Date	Stratum 1 (0–50 m)	Stratum 2 (50–150 m)	Stratum 5 (0.7–20 m)	Stratum 6 (20–40 m)
06/28	510	504	510	558
06/29	510	480	420	390
06/30	0	0	150	72
07/01	0	0	0	0
07/02	0	0	0	216
07/03	0	0	30	138
07/04	0	0	6	0
07/05	0	0	0	48
07/06	0	0	0	138
07/07	0	0	36	12
07/08	0	0	30	54
07/09	6	0	48	180
07/10	54	30	36	0
07/11	0	0	66	0
07/12	0	0	30	30
07/13	0	0	0	0
07/14	0	12	12	0
07/15	0	0	0	24
07/16	0	0	0	0
07/17	0	0	0	0
07/18	0	0	30	0
07/19	0	0	90	30
07/20	0	0	138	0
07/21	0	0	36	6
07/22	0	0	0	0
07/23	0	0	0	0
07/24	0	0	18	30
07/25	0	0	12	0
07/26	0	0	6	0
07/27	0	0	0	0
07/28	0	0	0	0
07/29	0	0	6	0
07/30	0	0	30	18
07/31	0	0	18	186
08/01	132	150	18	0
08/02	0	0	0	0

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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 m)	Stratum 6 (20–40 m)
08/03	0	0	0	0
08/04	0	0	18	0
08/05	0	0	0	0
08/06	0	0	0	12
08/07	0	0	0	0
08/08	0	0	0	0
08/09	0	0	0	0
08/10	0	0	0	0
08/11	30	0	42	0
08/12	0	0	18	0
08/13	18	30	30	0
08/14	0	0	0	6
08/15	0	0	0	0
08/16	36	30	48	0
08/17	30	6	42	0
08/18	0	0	78	6
08/19	0	0	0	0
08/20	0	0	0	0
08/21	0	0	0	0
08/22	0	0	0	0
08/23	0	0	0	0
08/24	0	0	0	0
08/25	0	0	0	0
08/26	0	0	0	0
08/27	0	0	30	0
Total (min)	1,326	1,242	2,082	2,154
Total (h)	22.1	20.7	34.7	35.9

Table 8.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project on the Yukon River, 2024.

	Daily				Cumulative			
Date	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
08/28[a]	32	30	62	7	32	30	62	0.004
08/29	68	18	86	8	100	48	148	0.009
08/30	67	14	81	9	167	62	229	0.014
08/31	74	26	100	10	241	88	329	0.020
09/01	74	18	92	11	315	106	421	0.026
09/02	84	14	98	10	399	120	519	0.032
09/03	72	8	80	11	471	128	599	0.037
09/04	96	26	122	12	567	154	721	0.044
09/05	136	30	166	15	703	184	887	0.055
09/06	134	38	172	14	837	222	1,059	0.065
09/07	150	46	196	13	987	268	1,255	0.077
09/08	232	36	268	14	1,219	304	1,523	0.094
09/09	226	59	285	16	1,445	363	1,808	0.112
09/10	226	72	298	16	1,671	435	2,106	0.130
09/11	266	53	319	21	1,937	488	2,425	0.150
09/12	218	74	292	21	2,155	562	2,717	0.168
09/13	278	76	354	18	2,433	638	3,071	0.190
09/14	228	58	286	14	2,661	696	3,357	0.207
09/15	236	88	324	17	2,897	784	3,681	0.227
09/16	228	75	303	24	3,125	859	3,984	0.246
09/17	200	100	300	20	3,325	959	4,284	0.264
09/18	200	102	302	20	3,525	1,061	4,586	0.283
09/19	174	156	330	20	3,699	1,217	4,916	0.303
09/20	174	128	302	18	3,873	1,345	5,218	0.322
09/21	183	136	319	19	4,056	1,481	5,537	0.342
09/22	276	171	447	19	4,332	1,652	5,984	0.369
09/23	222	216	438	26	4,554	1,868	6,422	0.396
09/24	220	214	434	20	4,774	2,082	6,856	0.423
09/25	282	218	500	25	5,056	2,300	7,356	0.454
09/26	274	304	578	30	5,330	2,604	7,934	0.490
09/27	**312**	**270**	**582**	**32**	**5,642**	**2,874**	**8,516**	**0.526**
09/28	388	288	676	37	6,030	3,162	9,192	0.567
09/29	426	322	748	60	6,456	3,484	9,940	0.613
09/30	274	242	516	34	6,730	3,726	10,456	0.645
10/01	357	286	643	45	7,087	4,012	11,099	0.685
10/02	342	251	593	37	7,429	4,263	11,692	0.722
10/03	340	268	608	27	7,769	4,531	12,300	0.759

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Table 8.–Page 2 of 2.

Date	Daily				Cumulative			
	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
10/04	420	104	524	25	8,189	4,635	12,824	0.791
10/05	392	160	552	29	8,581	4,795	13,376	0.825
10/06[b]	471	156	627	33	9,052	4,951	14,003	0.864
10/07[c]	396	131	527	NA	9,448	5,082	14,530	0.897
10/08[c]	327	108	435	NA	9,775	5,190	14,965	0.924
10/09[c]	265	88	353	NA	10,040	5,278	15,318	0.945
10/10[c]	209	69	278	NA	10,249	5,347	15,596	0.962
10/11[c]	160	53	213	NA	10,409	5,400	15,809	0.976
10/12[c]	118	39	157	NA	10,527	5,439	15,966	0.985
10/13[c]	82	27	109	NA	10,609	5,466	16,075	0.992
10/14[c]	52	17	69	NA	10,661	5,483	16,144	0.996
10/15[c]	29	10	39	NA	10,690	5,493	16,183	0.999
10/16[c]	13	4	17	NA	10,703	5,497	16,200	1.000
10/17[c]	3	1	4	NA	10,706	5,498	16,204	1.000
10/18[d]	0	0	0	NA	10,706	5,498	16,204	1.000
Total	10,706	5,498	16,204	NA	NA	NA	NA	NA
Var[e]	11,321	11,590	22,911	NA	NA	NA	NA	NA
SE[e]	106	108	151	NA	NA	NA	NA	NA

Note: SE means standard error, Var means variance, and NA means not applicable. The upper portion of the outlined box identifies the second quartile of the run, the lower portion identifies the third quartile of the run, and bold text 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, 2024.

	Left bank		Right bank	
Date	Stratum 3 (0–25 m)	Stratum 4 (25–75 m)	Stratum 5 (0.7–20 m)	Stratum 6 (20–40 m)
08/28	0	0	18	6
08/29	198	180	0	0
08/30	36	42	0	0
08/31	0	0	0	0
09/01	0	0	0	0
09/02	0	0	0	0
09/03	0	0	6	0
09/04	0	0	72	30
09/05	0	0	0	0
09/06	0	0	0	0
09/07	0	0	96	0
09/08	0	0	0	18
09/09	0	0	12	30
09/10	0	0	0	0
09/11	0	0	12	0
09/12	0	0	0	12
09/13	0	0	0	0
09/14	0	0	0	0
09/15	0	0	0	0
09/16	0	0	6	0
09/17	0	0	0	0
09/18	0	0	0	6
09/19	0	0	0	0
09/20	0	0	0	0
09/21	0	0	0	0
09/22	0	0	0	12
09/23	0	0	0	0
09/24	0	0	0	0
09/25	30	18	0	0
09/26	0	0	0	0
09/27	0	0	0	0
09/28	0	0	0	30
09/29	0	0	240	204
09/30	0	0	0	0
10/01	0	6	174	36
10/02	0	0	198	0
10/03	0	0	0	0
10/04	0	0	0	36
10/05	0	0	0	18
10/06	360	360	360	360
Total (min)	624	606	1,194	798
Total (h)	10.4	10.1	19.9	13.3

Table 10.–Fish caught using gillnets at the Eagle sonar project on the Yukon River, 2024.

Species	Sampling purpose: Species composition and fall chum salmon samples	Sampling purpose: Chinook salmon samples	Total
Chinook salmon	90	122	212
Fall chum salmon	79	0	79
Broad whitefish	7	0	7
Humpback whitefish	2	0	2
Burbot	1	0	1
Sheefish	9	0	9
Arctic grayling	3	0	3
Total	191	122	313

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, 2024.

Zone[a]	Mesh size (in)	Fishing effort (fathom-hours)	Chinook salmon		Fall chum salmon	
			Catch	Proportion	Catch	Proportion
LBN	5.25	166	27	0.221	0	0.000
	6.50	171	27	0.221	0	0.000
	7.50	168	18	0.148	0	0.000
	8.50	164	26	0.213	0	0.000
Total		668	98	0.803	0	0.000
RBN	5.25	165	3	0.025	0	0.000
	6.50	165	3	0.025	0	0.000
	7.50	164	7	0.057	0	0.000
	8.50	162	4	0.033	0	0.000
Total		656	17	0.139	0	0.000
LBF	5.25	159	2	0.016	0	0.000
	6.50	164	2	0.016	0	0.000
	7.50	161	1	0.008	0	0.000
	8.50	158	2	0.016	0	0.000
Total		641	7	0.057	0	0.000
Grand total		1,965	122	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, 2024.

Zone[a]	Mesh size (in)	Fishing effort (fathom-hours)	Chinook salmon Catch	Chinook salmon Proportion	Fall chum salmon Catch	Fall chum salmon Proportion
LBI	5.25	335	11	0.122	43	0.544
	7.50	326	4	0.044	9	0.114
Total		661	15	0.167	52	0.658
LBN	5.25	343	37	0.411	18	0.228
	7.50	334	28	0.311	9	0.114
Total		677	65	0.722	27	0.342
LBF	5.25	330	5	0.056	0	0.000
	7.50	331	5	0.056	0	0.000
Total		661	10	0.111	0	0.000
Grand total		1,999	90	1.000	79	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.

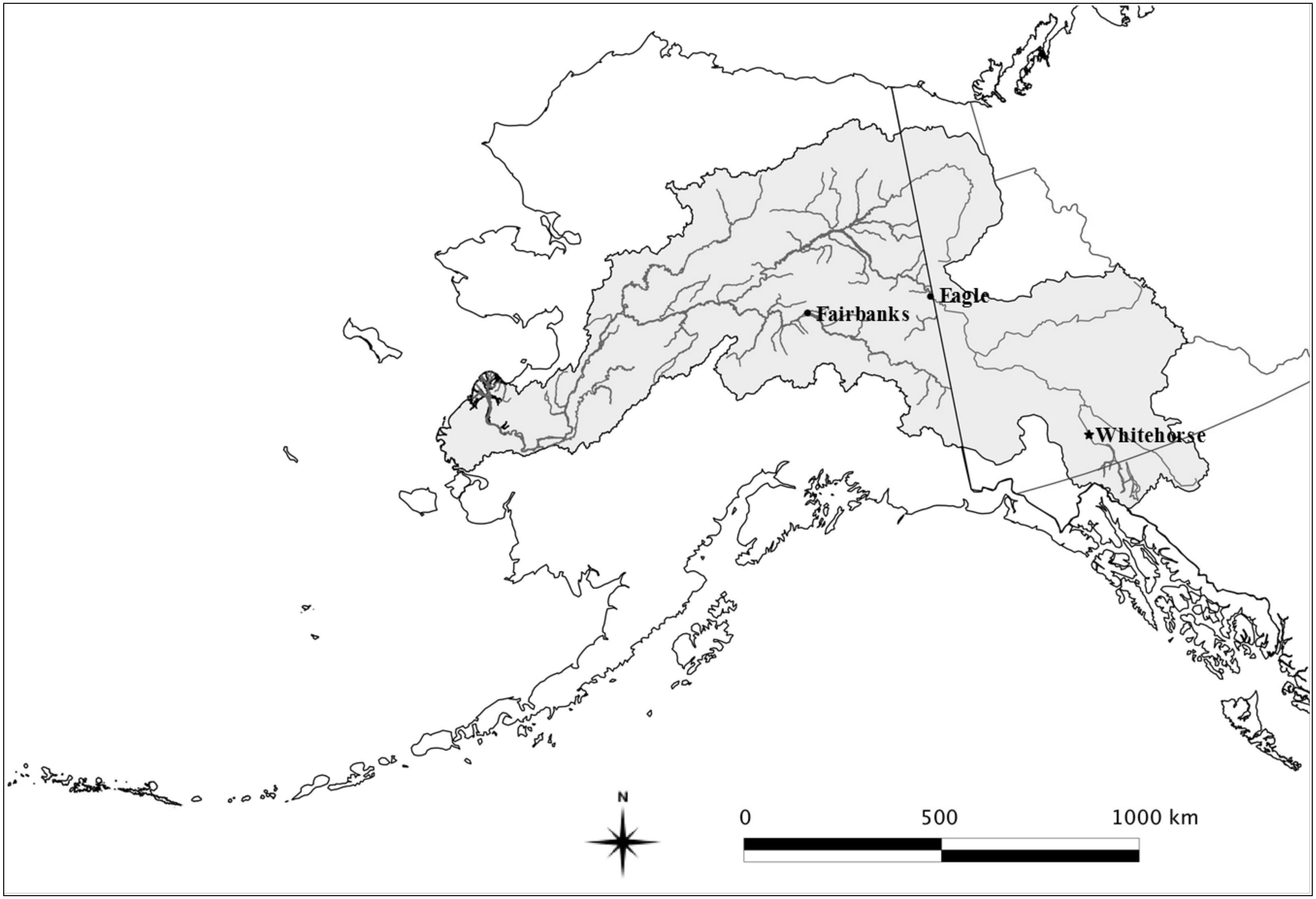


Figure 1.–Yukon River drainage.

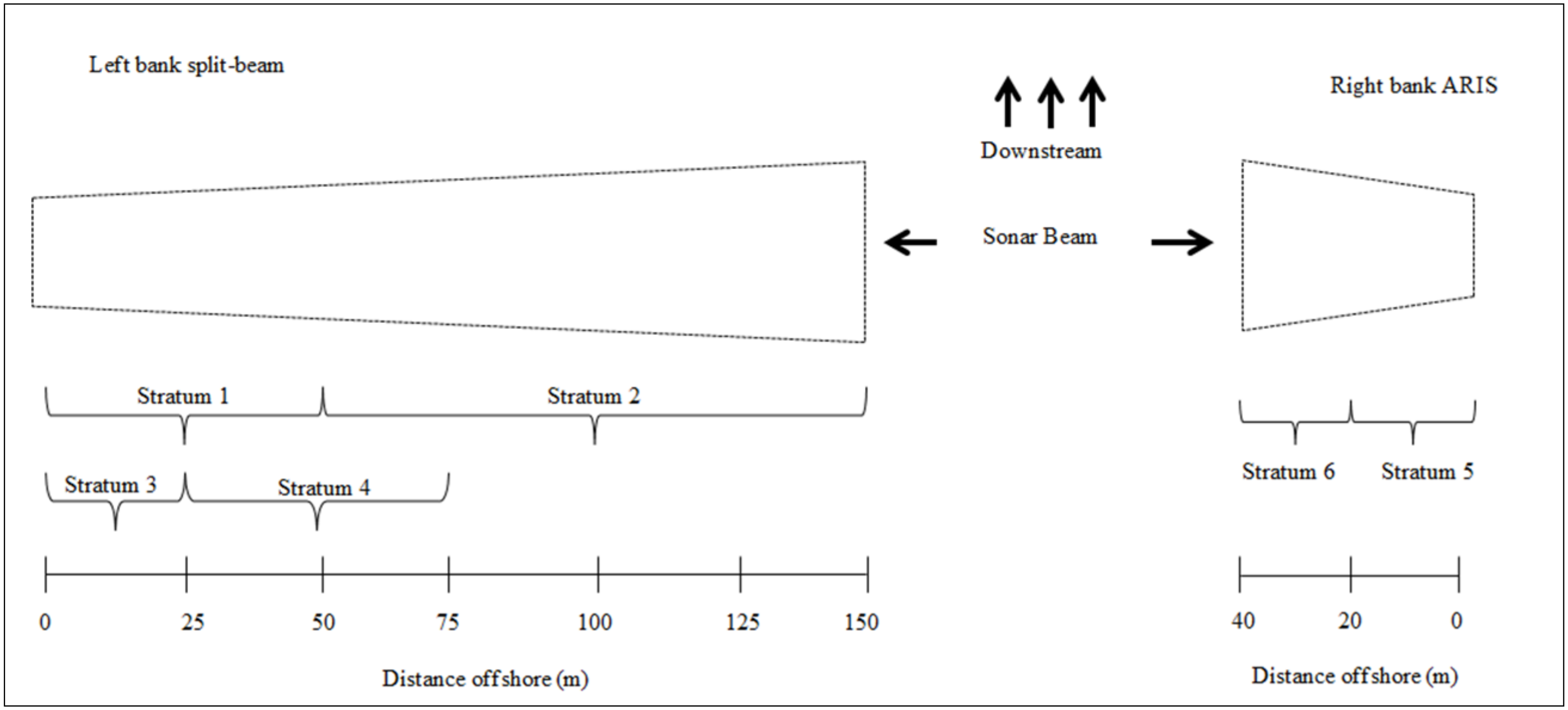


Figure 2.–Illustration of strata and approximate sonar ranges (not to scale) at the Eagle sonar project on the Yukon River, 2024.

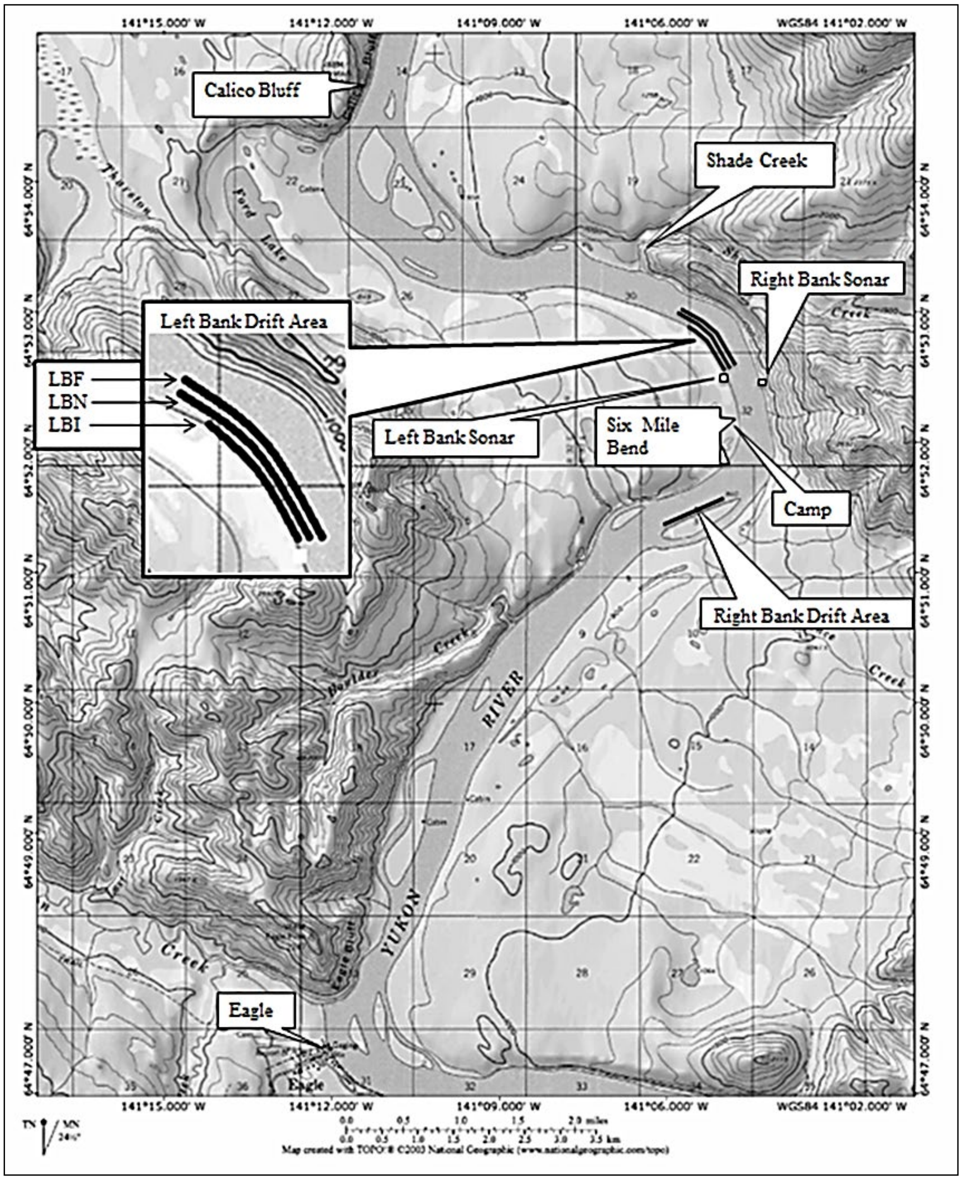


Figure 3.–Eagle sonar project site at Six Mile Bend on the Yukon River showing sonar and drift gillnet fishing locations, 2024.

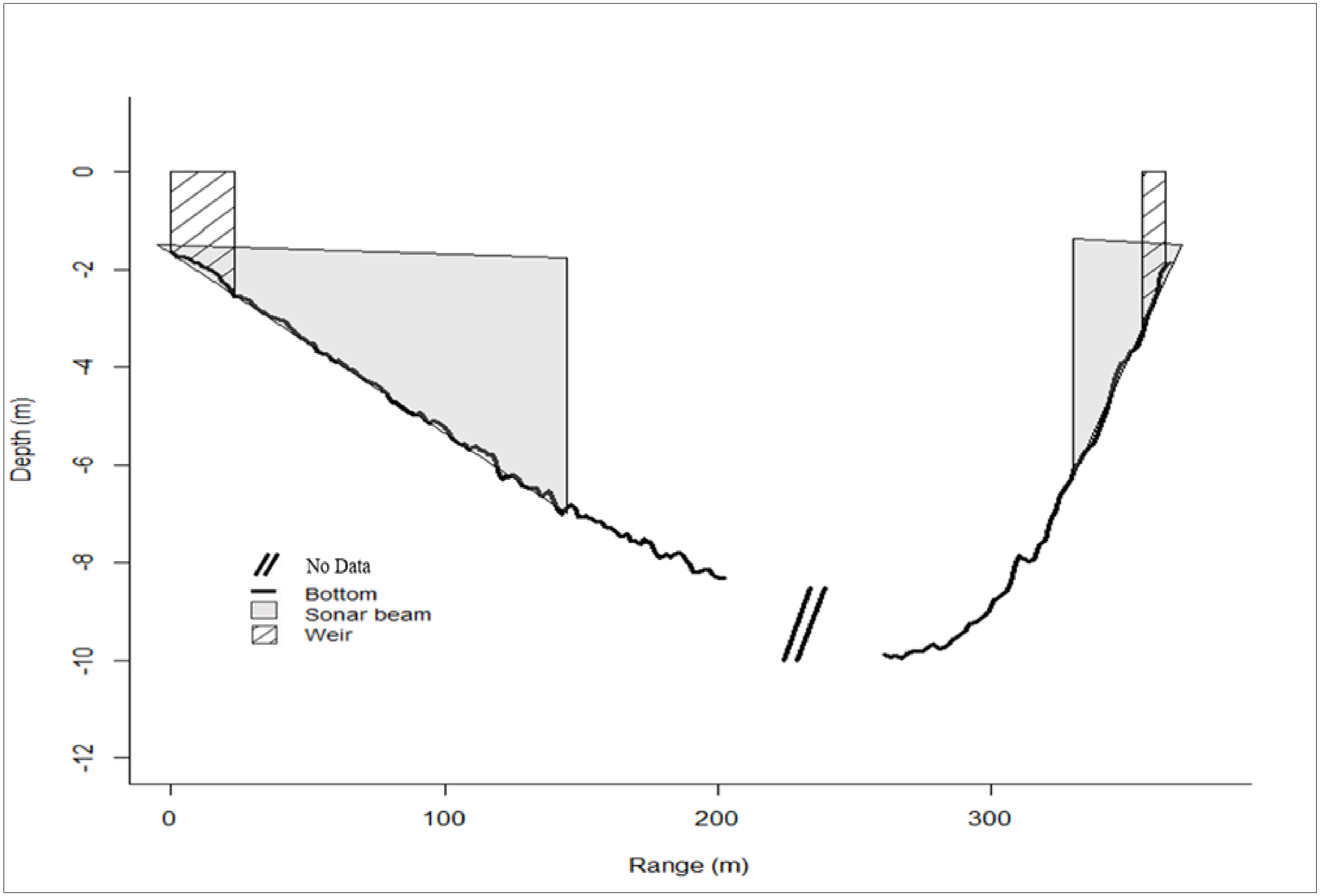


Figure 4.–Depth profile of the Yukon River in front of transducers (looking downstream) and approximate sonar coverage at the Eagle sonar project, 2024.

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

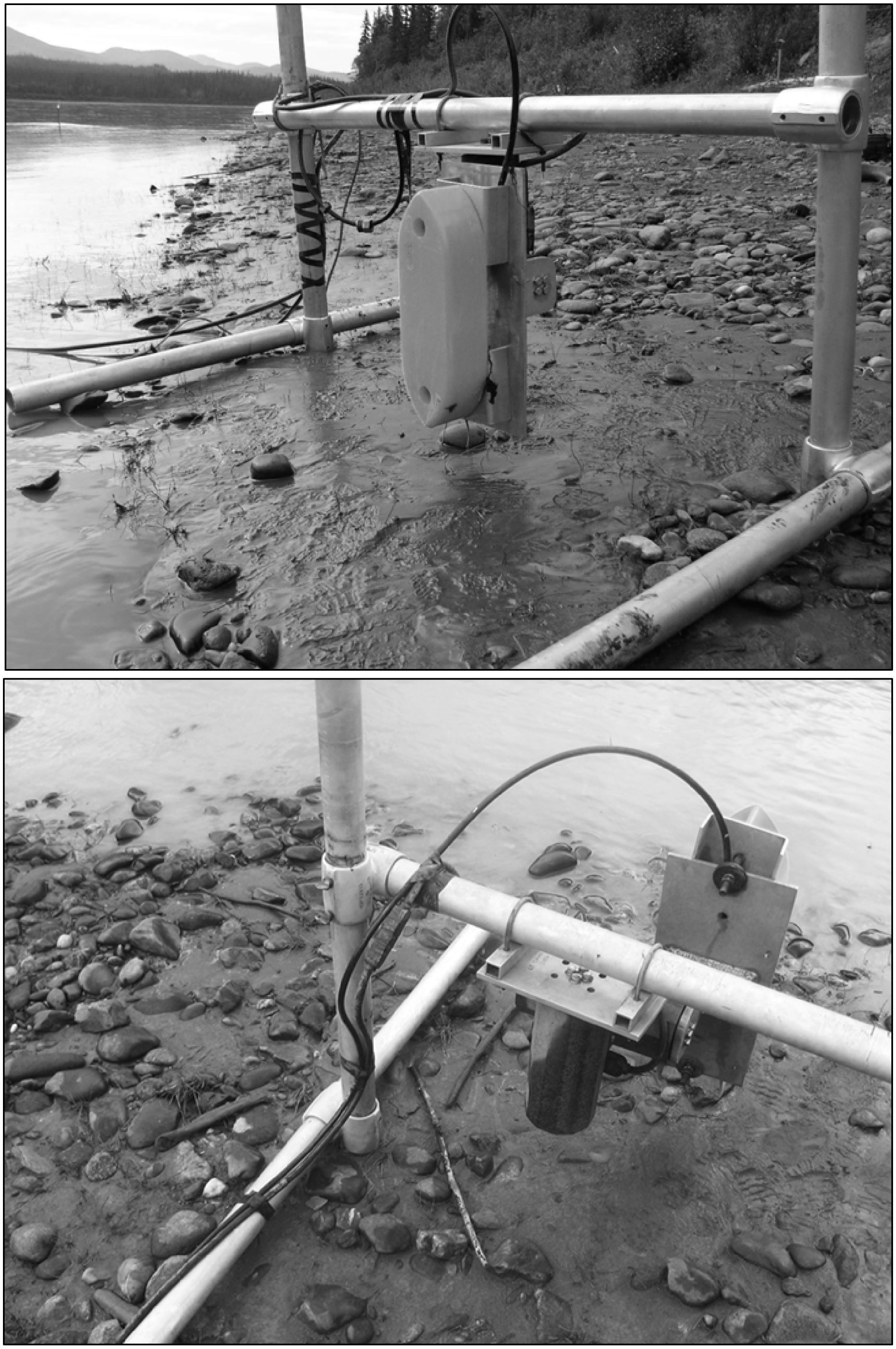


Figure 5.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single-axis automated rotators (bottom) used on the left bank at the Eagle sonar project on the Yukon River.

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.

Figure 7.–Adaptive resolution imaging sonar (ARIS) 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.

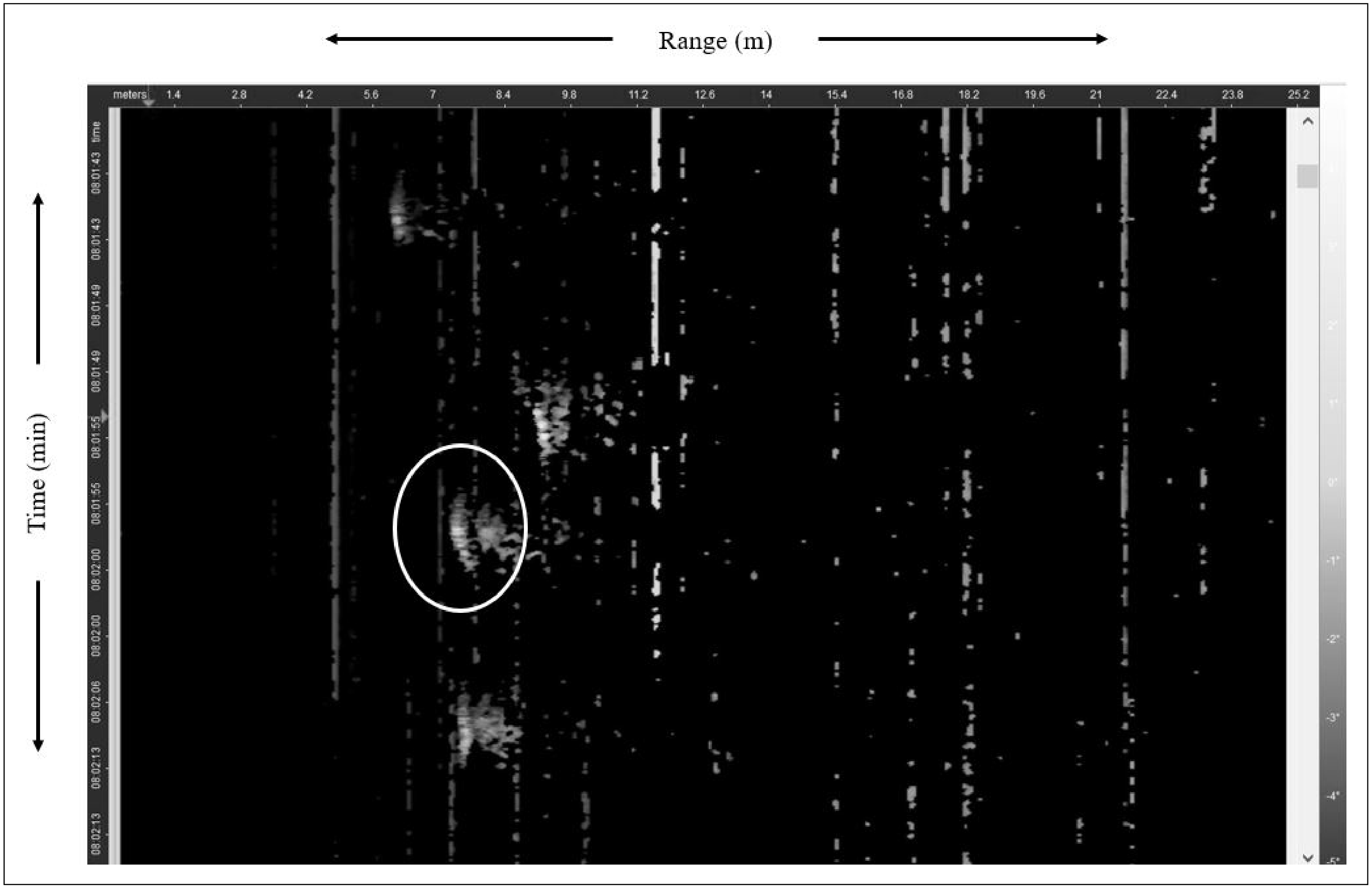


Figure 8.–Screenshot of an echogram from a split-beam sonar data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

Note: The ellipse encompasses a typical upstream migrating salmon.

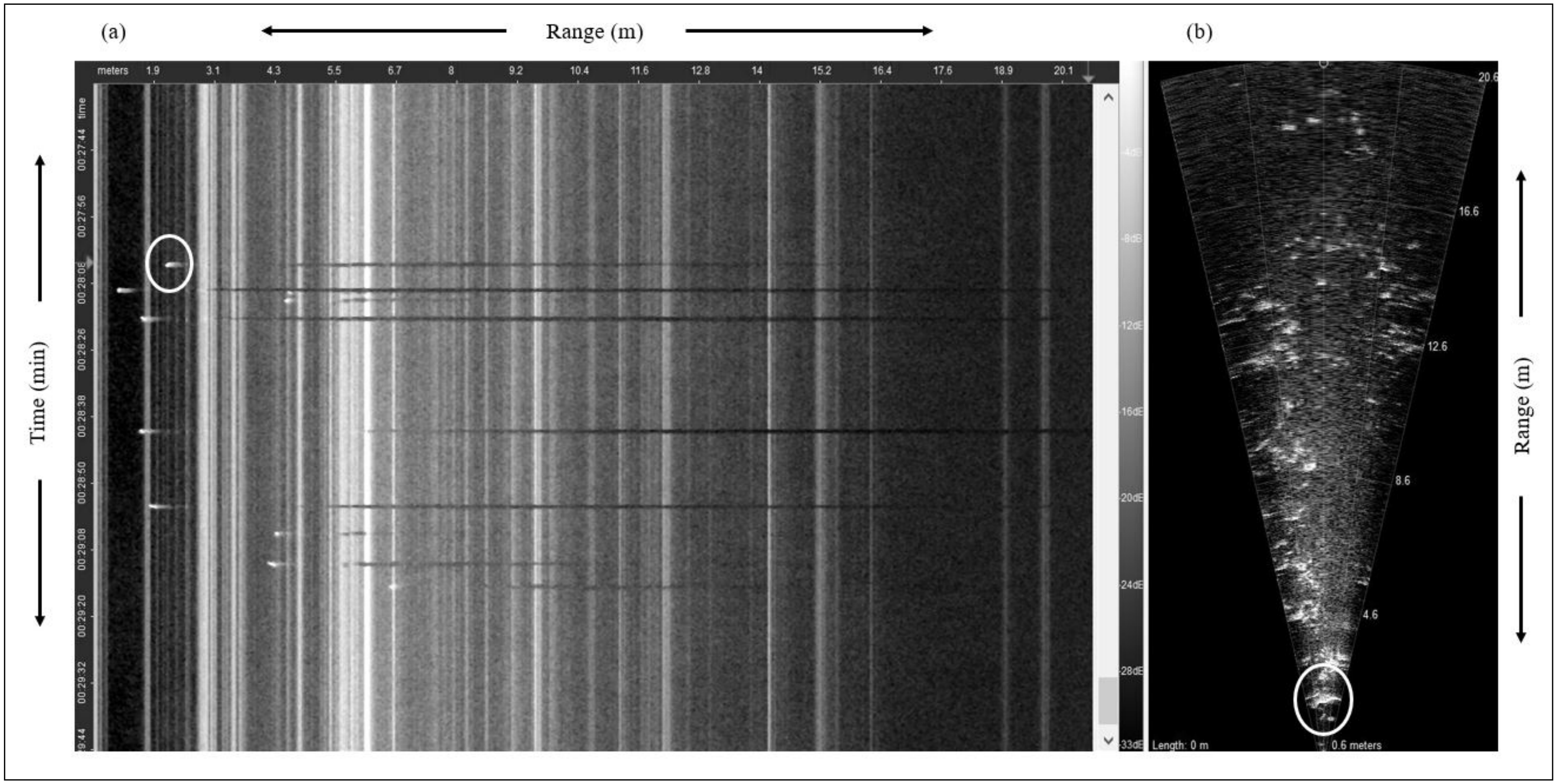


Figure 9.–Screenshots of an echogram (a) and video (b) from an ARIS data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

Note: The ellipse encompasses a typical upstream migrating salmon.

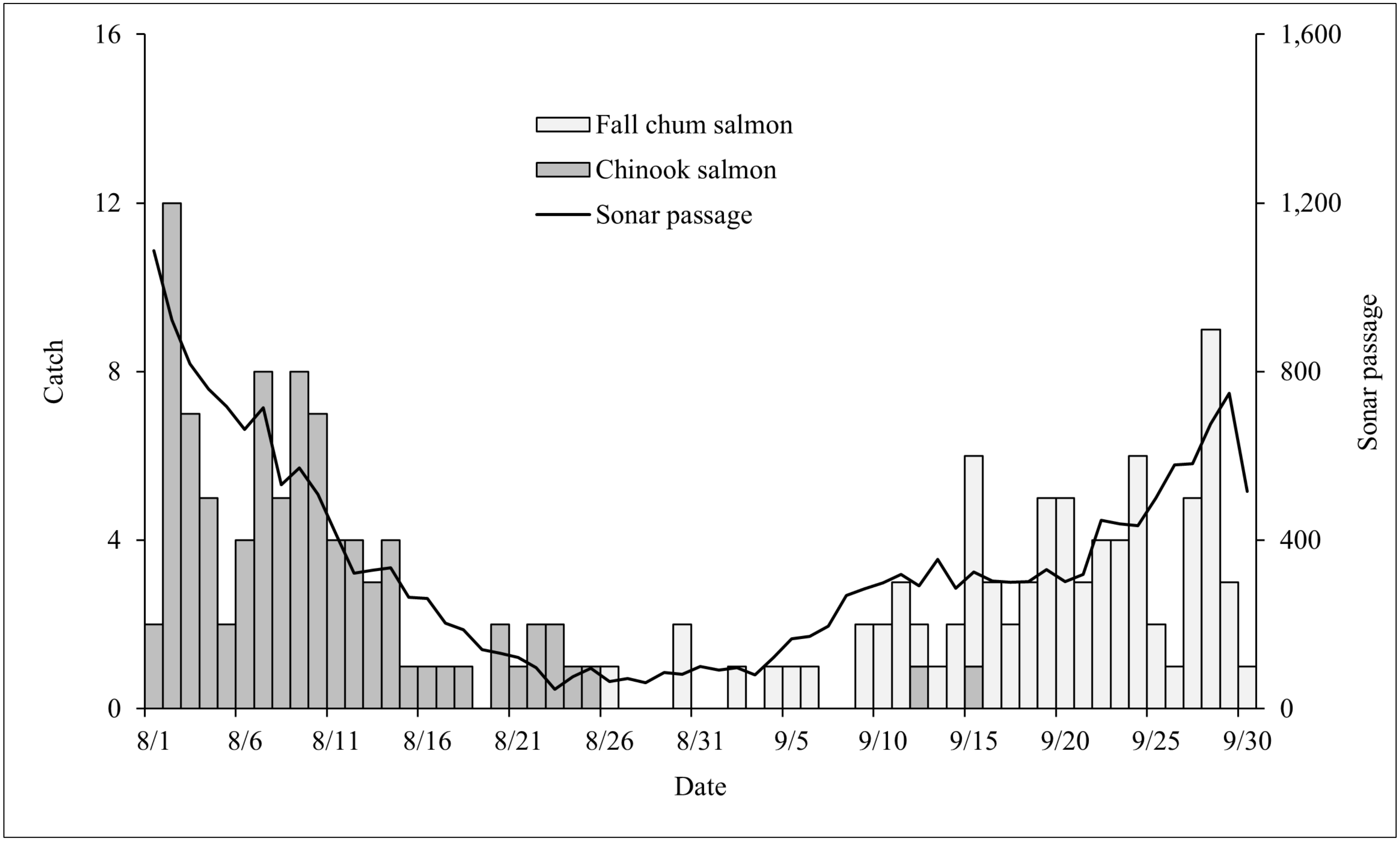


Figure 10.–Daily catch during species composition fishing and sonar passage estimates at the Eagle sonar project on the Yukon River, 2024.

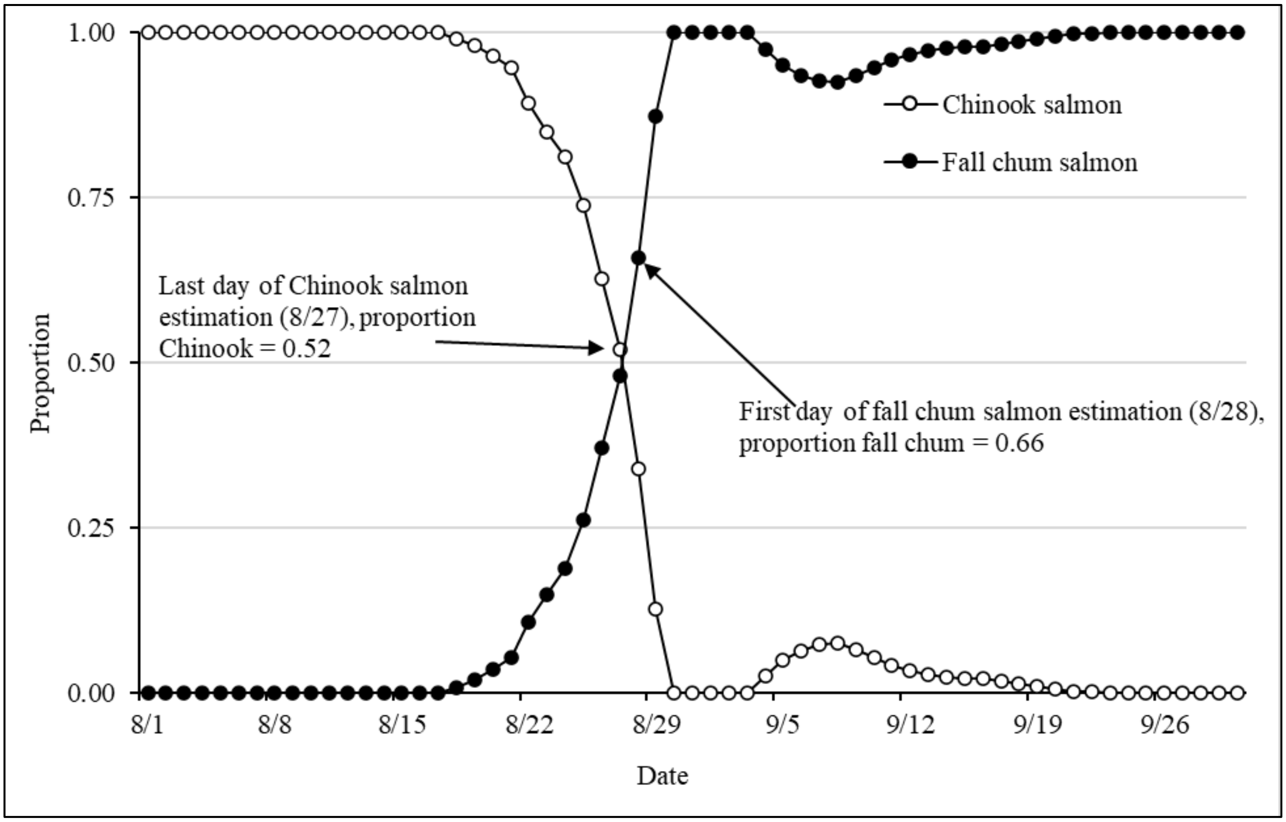


Figure 11.–Proportion of catch based on smoothed Chinook and fall chum salmon species composition CPUE data at the Eagle sonar project on the Yukon River, 2024.

Note: Species transition date (August 28) 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.

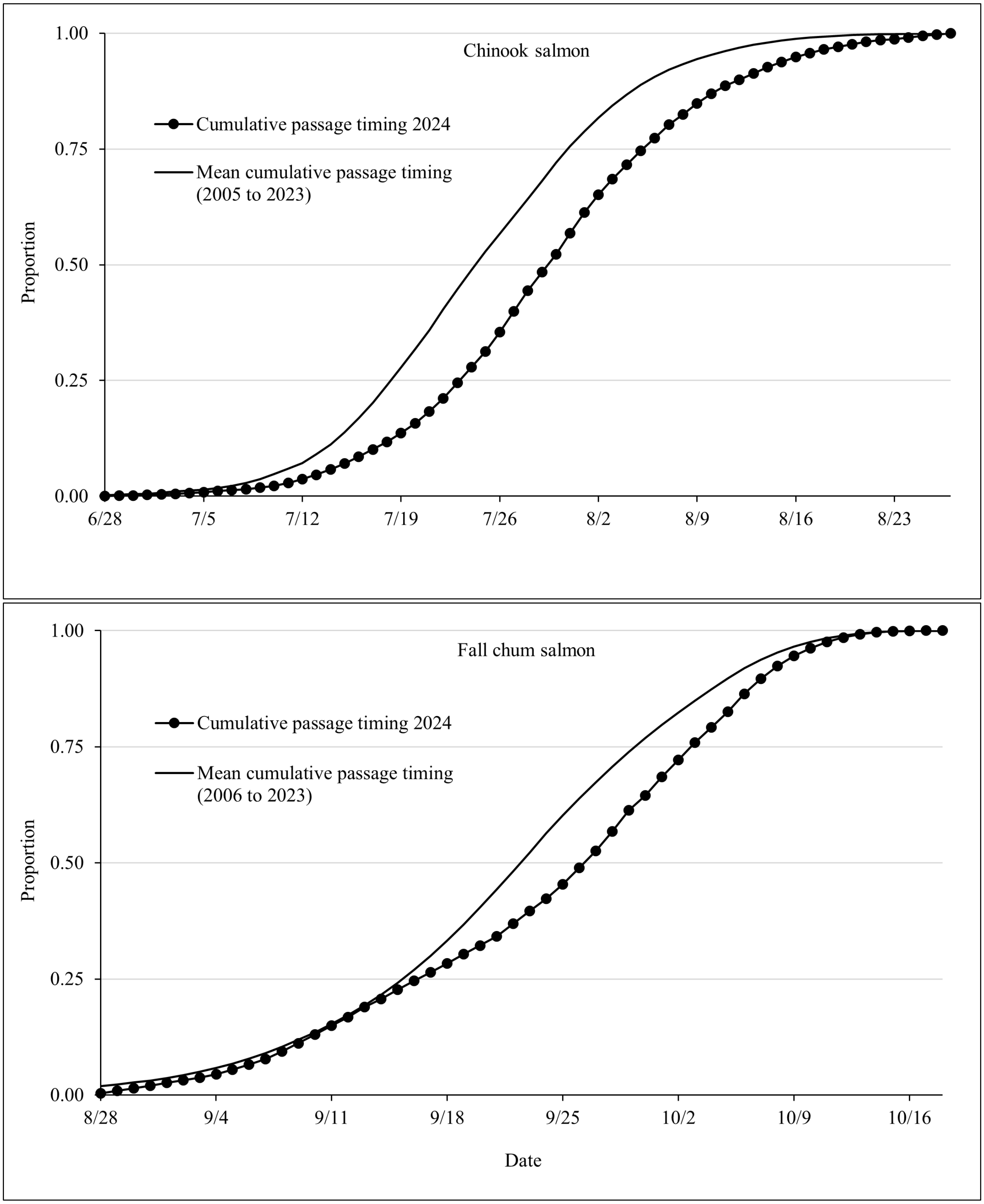


Figure 12.–2024 Chinook (top) and fall chum (bottom) salmon daily cumulative passage timing compared to the 2005–2023 (Chinook salmon) and 2006–2023 (fall chum salmon) mean passage timing at the Eagle sonar project on the Yukon River.

Note: Fall chum salmon cumulative passage timing includes postseason expansion estimates through October 18. Fall chum salmon passage was not estimated in 2005.

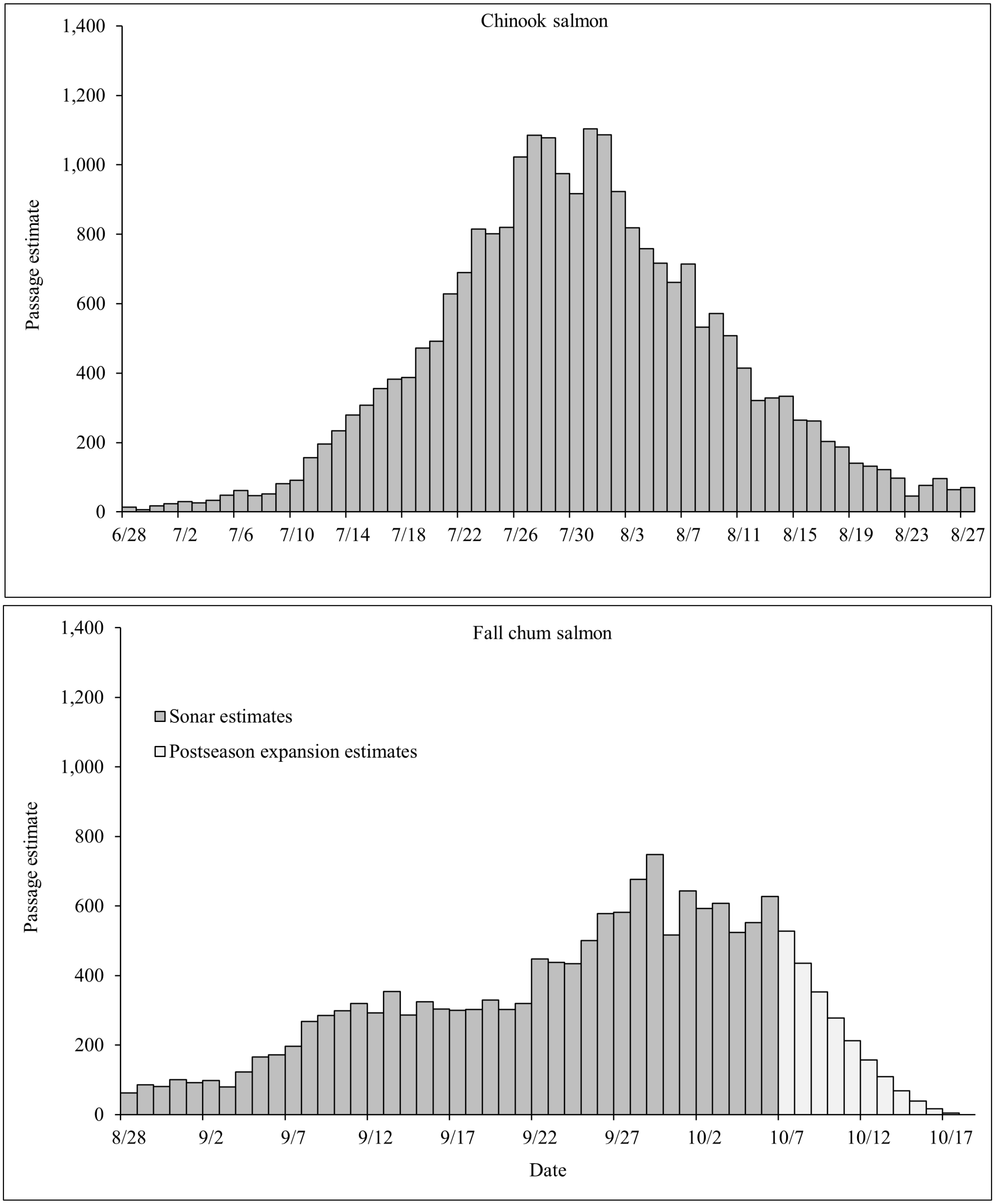
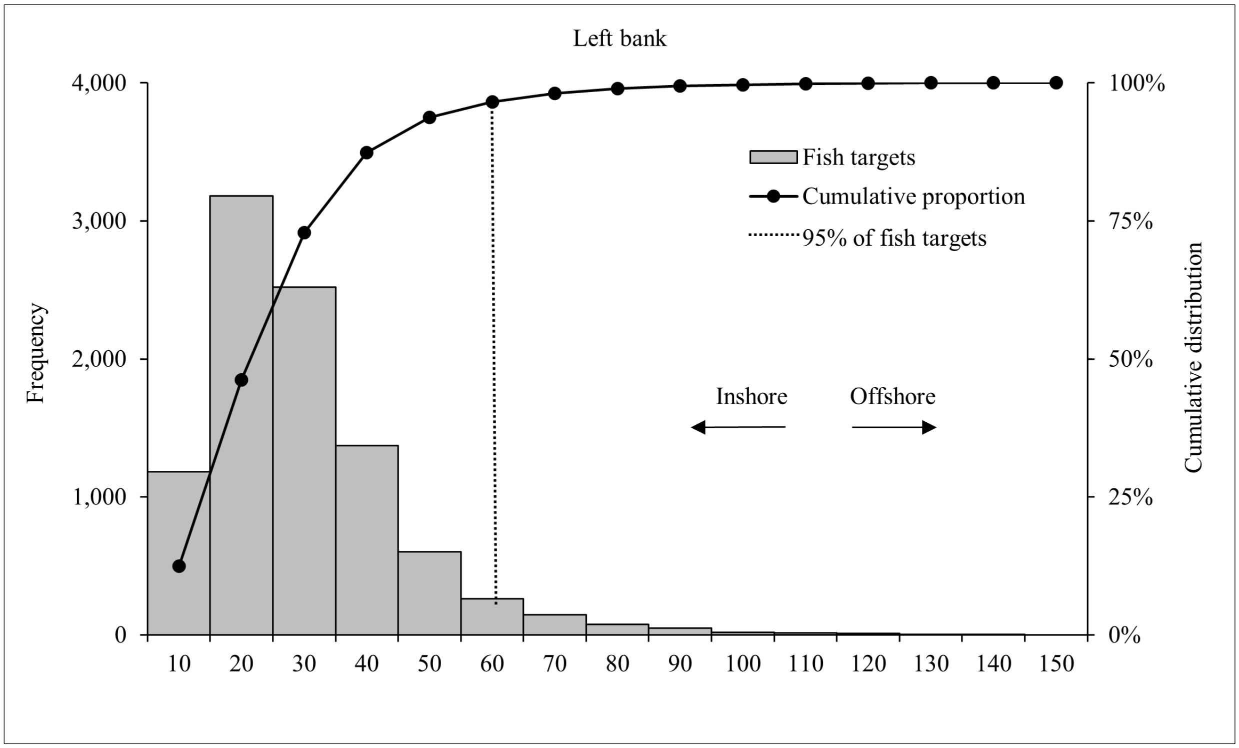


Figure 13.–Daily sonar passage estimates for Chinook salmon (top) from June 28 through August 27 and fall chum salmon (bottom) from August 28 through October 18 at the Eagle sonar project on the Yukon River, 2024.

Note: Postseason expansion estimates were calculated from October 7 through October 18.



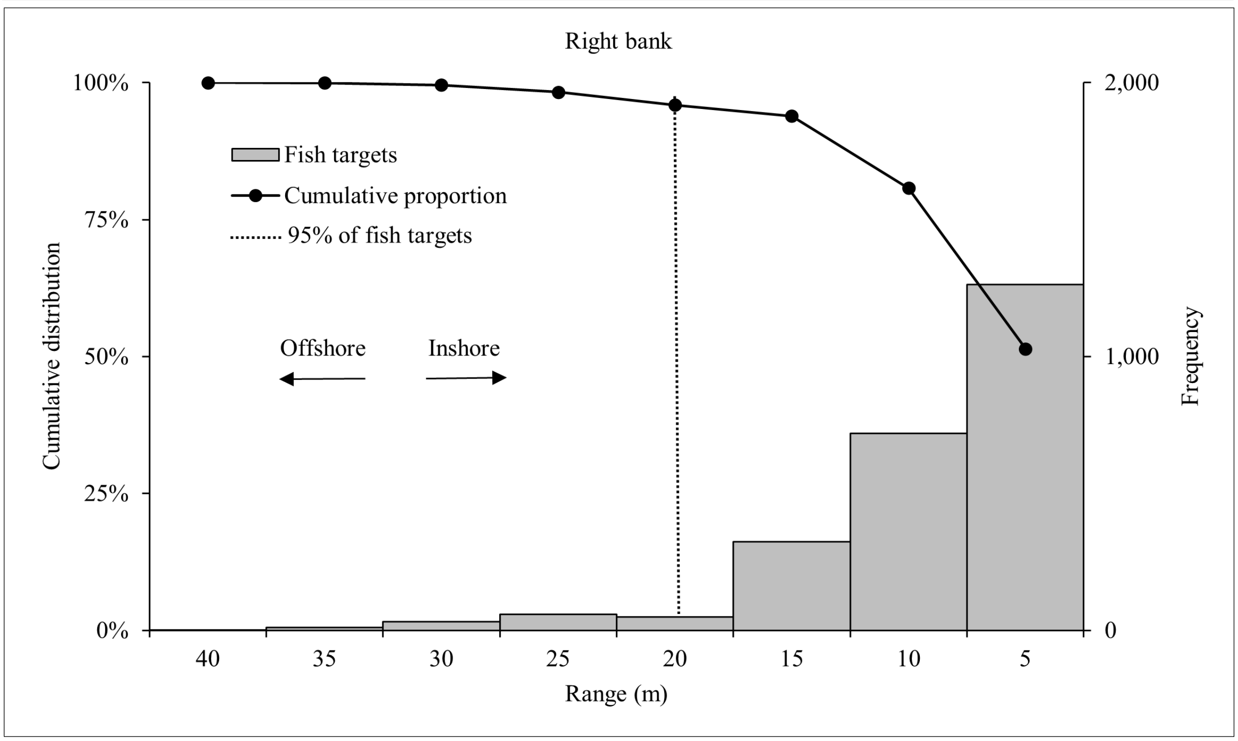


Figure 14.–Left and right bank horizontal distribution of upstream migrating Chinook salmon from June 28 through August 27 at the Eagle sonar project on the Yukon River, 2024.

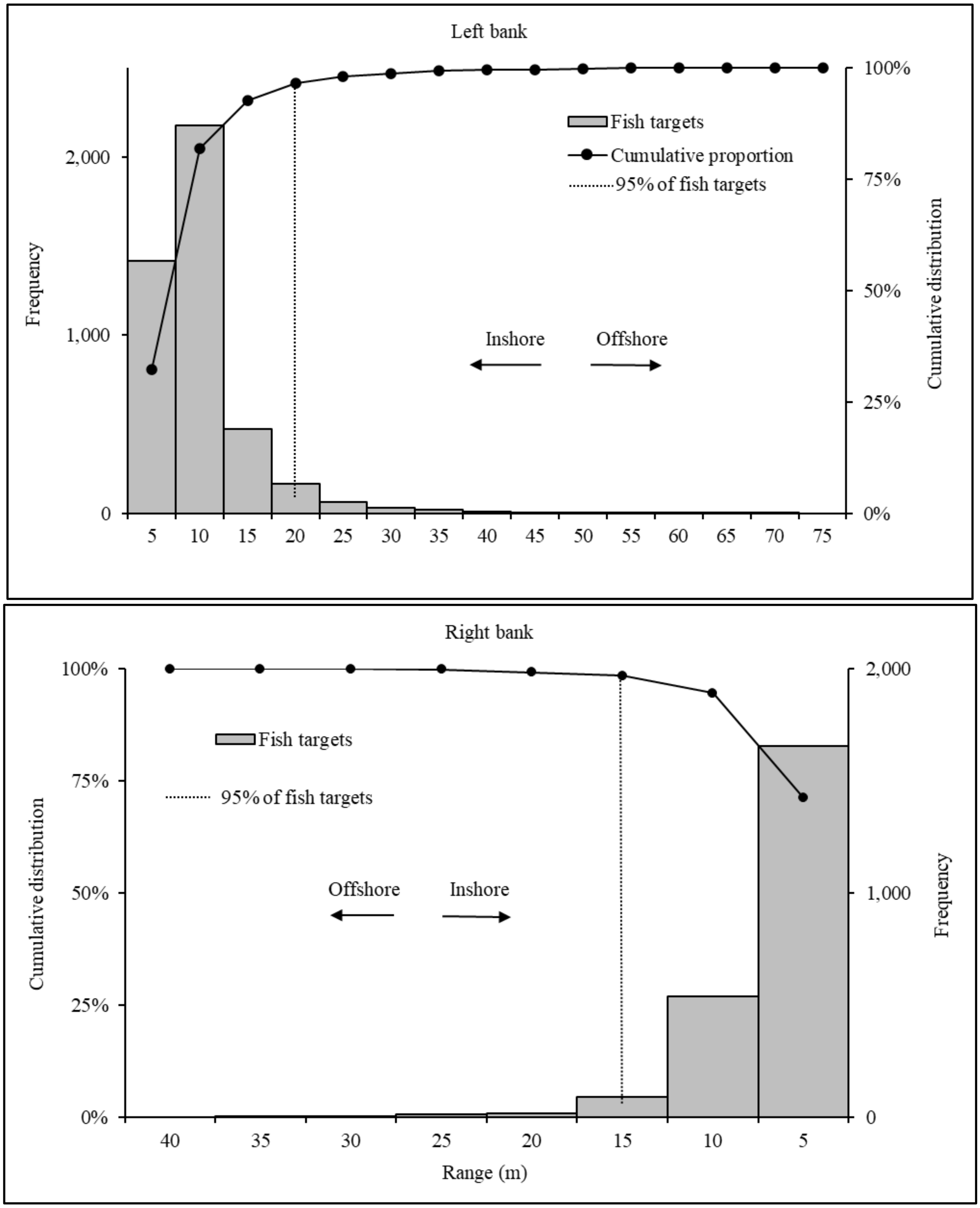


Figure 15.–Left and right bank horizontal distribution of upstream migrating fall chum salmon from August 28 through October 6 at the Eagle sonar project on the Yukon River, 2024.

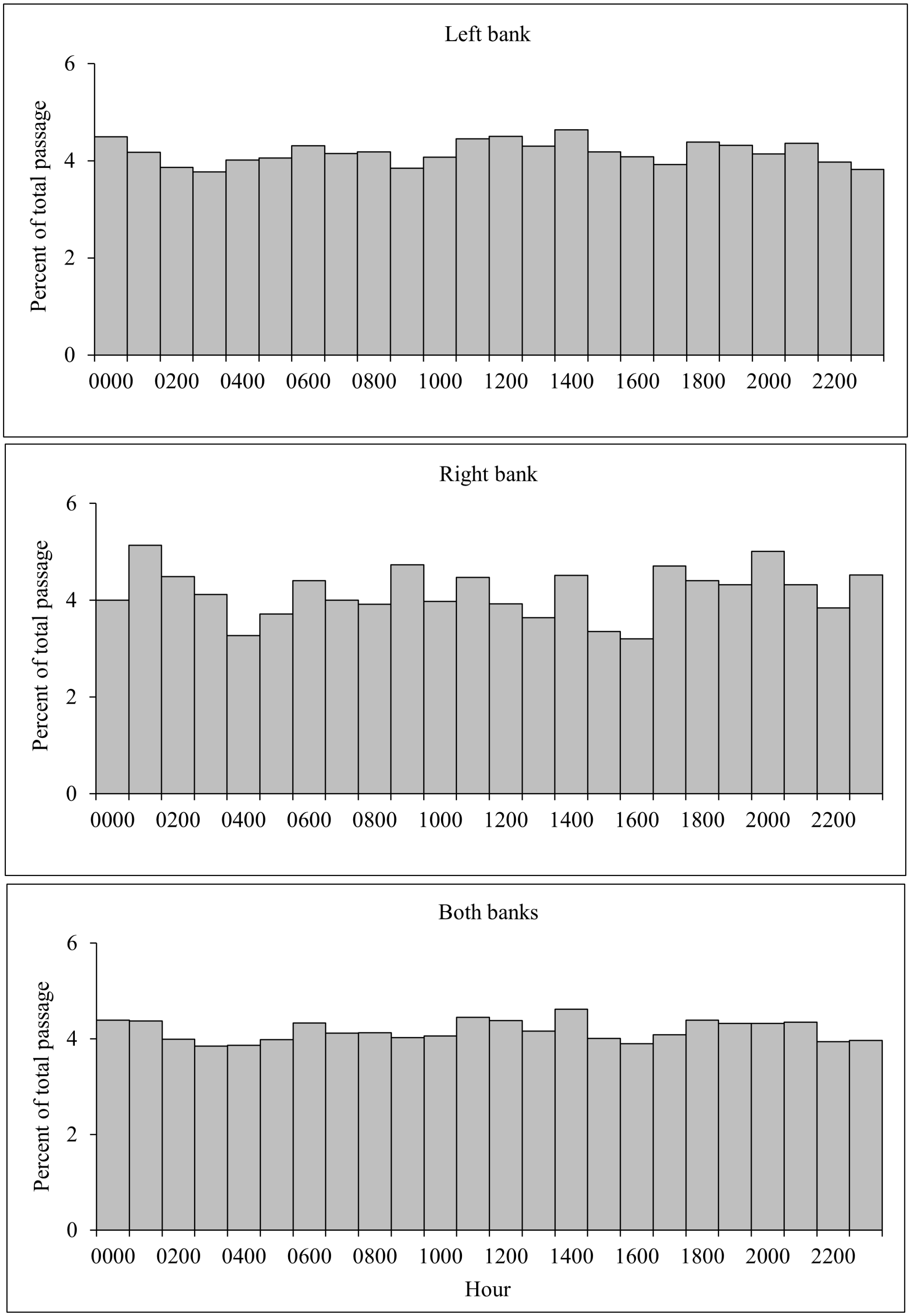


Figure 16.–Percent of total Chinook salmon passage, by hour, observed on the left bank, right bank, and both banks combined from June 28 through August 27 at the Eagle sonar project on the Yukon River, 2024.

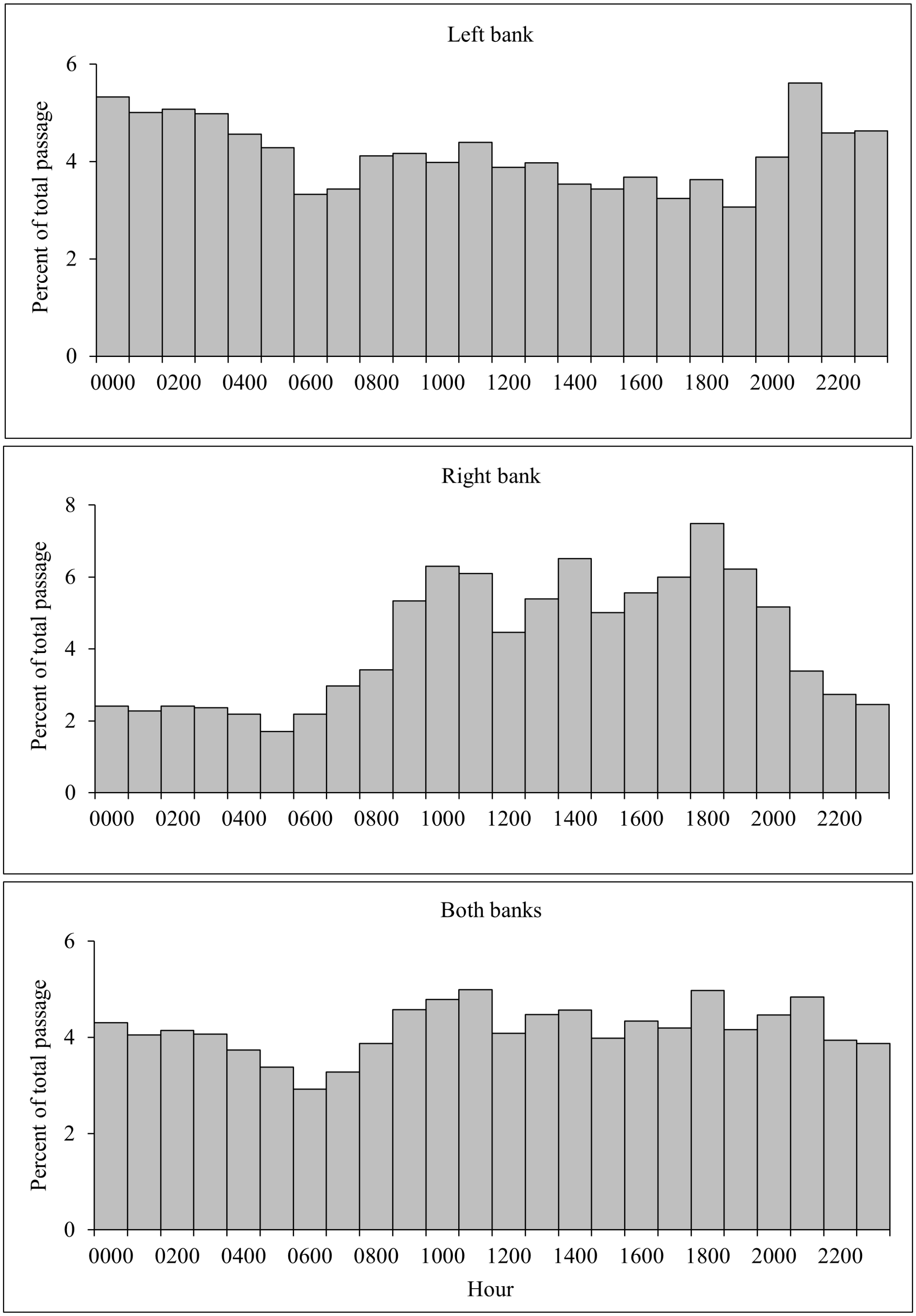


Figure 17.–Percent of total fall chum salmon passage, by hour, observed on the left bank, right bank, and both banks combined from August 28 through October 6 at the Eagle sonar project on the Yukon River, 2024.

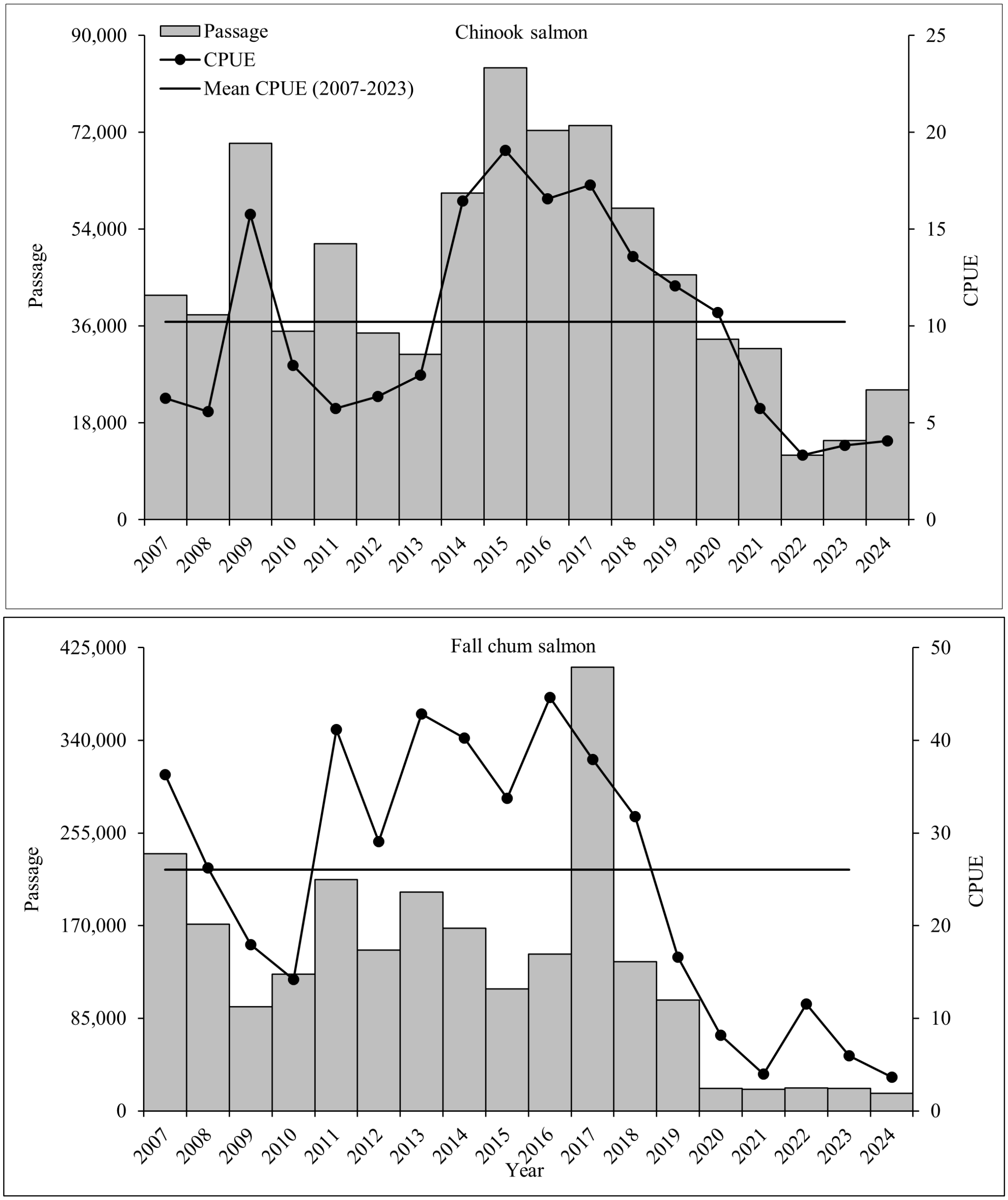


Figure 18.–Chinook and fall chum salmon passage, total cumulative catch per unit effort (CPUE) by year and mean total cumulative CPUE (2007–2023) at the Eagle sonar project on the Yukon River, 2024.

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.

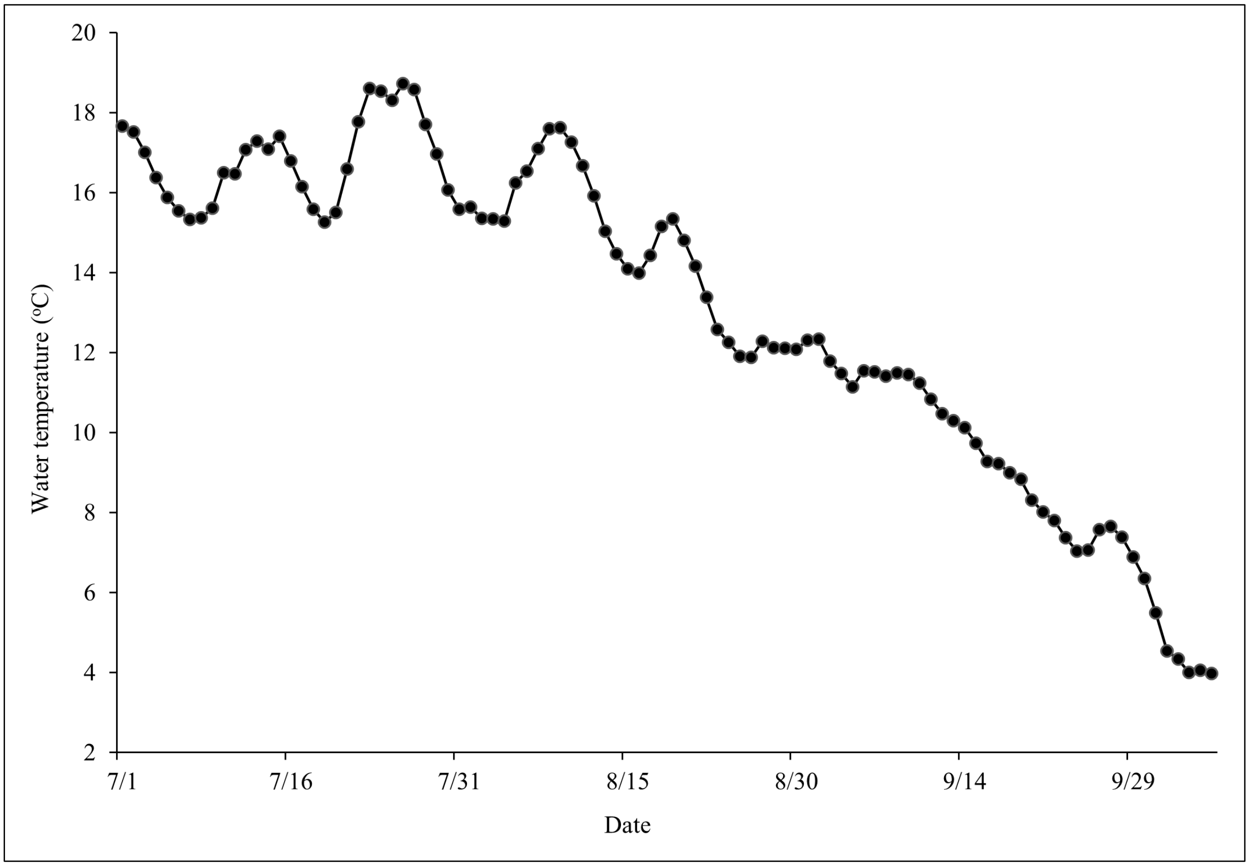


Figure 19.–Median daily water temperature recorded from July 1 through October 6 on the left bank at the Eagle sonar project on the Yukon River, 2024.

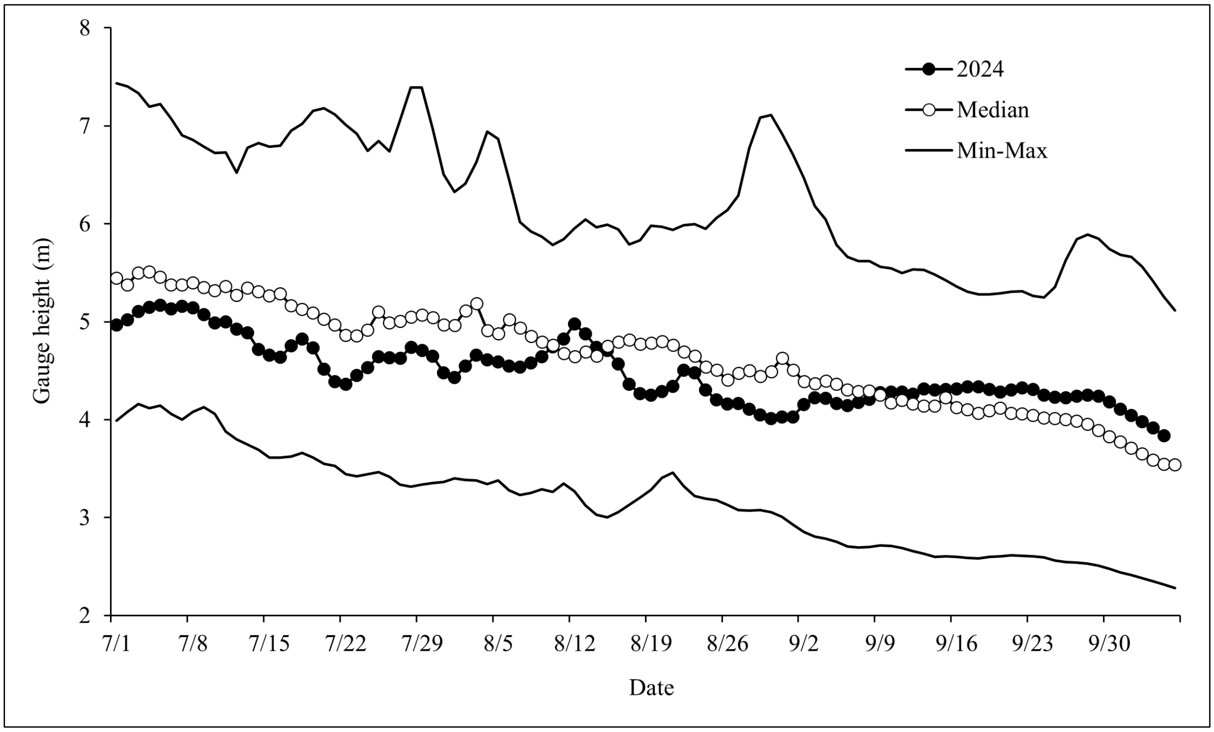


Figure 20.–Yukon River water level recorded daily at 1800 during the 2024 season at the city of Eagle, compared to minimum, maximum, and median gauge height from 1995 to 2023.

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, 2024.

	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	18.04	0	0.00	2.56	0.15	17.05	0	0.00	0.00	0.00
08/02	18.10	5	0.28	2.47	0.14	17.72	0	0.00	0.00	0.00
08/03	16.94	4	0.24	2.38	0.14	16.97	0	0.00	0.00	0.00
08/04	16.96	2	0.12	2.29	0.13	17.14	0	0.00	0.00	0.00
08/05	16.54	1	0.06	2.19	0.13	16.12	0	0.00	0.00	0.00
08/06	15.66	1	0.06	2.11	0.12	16.92	0	0.00	0.00	0.00
08/07	16.04	0	0.00	2.02	0.12	17.86	0	0.00	0.00	0.00
08/08	17.37	2	0.12	1.92	0.11	16.59	0	0.00	0.00	0.00
08/09	18.10	7	0.39	1.82	0.11	16.56	0	0.00	0.00	0.00
08/10	16.81	2	0.12	1.72	0.10	17.57	0	0.00	0.00	0.00
08/11	16.80	3	0.18	1.61	0.09	16.56	0	0.00	0.00	0.00
08/12	16.46	1	0.06	1.52	0.09	17.34	0	0.00	0.00	0.00
08/13	16.26	0	0.00	1.44	0.08	17.85	0	0.00	0.00	0.00
08/14	17.61	2	0.11	1.31	0.08	17.49	0	0.00	0.00	0.00
08/15	16.77	0	0.00	1.18	0.07	16.67	0	0.00	0.00	0.00
08/16	16.02	0	0.00	1.03	0.06	16.26	0	0.00	0.00	0.00
08/17	16.53	1	0.06	0.87	0.05	15.97	0	0.00	0.00	0.00
08/18	16.86	0	0.00	0.74	0.04	16.69	0	0.00	0.01	0.00
08/19	16.33	0	0.00	0.64	0.04	16.15	0	0.00	0.01	0.00
08/20	15.73	1	0.06	0.58	0.03	15.91	0	0.00	0.02	0.00
08/21	16.31	0	0.00	0.56	0.03	15.91	0	0.00	0.03	0.00
08/22	16.14	1	0.06	0.54	0.03	15.99	0	0.00	0.06	0.00
08/23	16.06	1	0.06	0.52	0.03	15.88	0	0.00	0.09	0.01
08/24	15.81	1	0.06	0.50	0.03	16.22	0	0.00	0.12	0.01

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Appendix A1.–Page 2 of 3.

	Chinook salmon					Fall chum salmon				
Date	Large mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed	Small mesh fathom-hours	Catch	CPUE	Catch smoothed	CPUE smoothed
08/25	15.90	1	0.06	0.44	0.03	15.63	0	0.00	0.15	0.01
08/26	16.36	0	0.00	0.32	0.02	16.81	1	0.06	0.19	0.01
08/27	16.27	0	0.00	0.22	0.01	16.32	0	0.00	0.20	0.01
08/28	16.37	0	0.00	0.12	0.01	16.46	0	0.00	0.23	0.01
08/29	16.01	0	0.00	0.04	0.00	16.18	0	0.00	0.28	0.02
08/30	16.16	0	0.00	0.00	0.00	16.38	1	0.06	0.31	0.02
08/31	16.15	0	0.00	0.00	0.00	15.92	0	0.00	0.32	0.02
09/01	15.99	0	0.00	0.00	0.00	16.34	0	0.00	0.34	0.02
09/02	15.97	0	0.00	0.00	0.00	16.34	1	0.06	0.37	0.02
09/03	16.11	0	0.00	0.00	0.00	15.83	0	0.00	0.42	0.03
09/04	15.91	0	0.00	0.01	0.00	15.76	0	0.00	0.46	0.03
09/05	16.02	0	0.00	0.03	0.00	16.46	1	0.06	0.52	0.03
09/06	15.76	0	0.00	0.04	0.00	16.79	1	0.06	0.62	0.04
09/07	15.38	0	0.00	0.06	0.00	16.12	0	0.00	0.72	0.04
09/08	15.82	0	0.00	0.07	0.00	16.01	0	0.00	0.85	0.05
09/09	16.55	0	0.00	0.07	0.00	16.00	0	0.00	0.98	0.06
09/10	17.00	0	0.00	0.06	0.00	15.90	2	0.13	1.15	0.07
09/11	15.71	0	0.00	0.06	0.00	16.54	2	0.12	1.35	0.08
09/12	16.20	1	0.06	0.05	0.00	15.94	1	0.06	1.57	0.09
09/13	15.24	0	0.00	0.05	0.00	15.77	0	0.00	1.78	0.11
09/14	15.81	0	0.00	0.05	0.00	16.40	2	0.12	2.03	0.12
09/15	15.88	0	0.00	0.05	0.00	16.55	4	0.24	2.25	0.13
09/16	15.87	0	0.00	0.05	0.00	17.23	3	0.17	2.45	0.14
09/17	16.14	0	0.00	0.04	0.00	16.52	1	0.06	2.60	0.15
09/18	16.11	0	0.00	0.03	0.00	17.25	3	0.17	2.71	0.16
09/19	16.02	0	0.00	0.02	0.00	17.30	5	0.29	2.75	0.16

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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	15.97	0	0.00	0.01	0.00	16.99	4	0.24	2.88	0.17
09/21	15.76	0	0.00	0.00	0.00	16.94	3	0.18	2.95	0.18
09/22	15.90	0	0.00	0.00	0.00	17.59	3	0.17	3.02	0.18
09/23	15.57	0	0.00	0.00	0.00	16.71	2	0.12	3.06	0.18
09/24	15.93	0	0.00	0.00	0.00	16.89	5	0.30	3.11	0.19
09/25	15.29	0	0.00	0.00	0.00	15.60	2	0.13	3.06	0.18
09/26	16.30	0	0.00	0.00	0.00	15.84	0	0.00	3.00	0.18
09/27	16.29	0	0.00	0.00	0.00	15.78	1	0.06	2.92	0.18
09/28	15.33	0	0.00	0.00	0.00	16.59	9	0.54	2.85	0.17
09/29	15.41	0	0.00	0.00	0.00	16.37	3	0.18	2.77	0.17
09/30	15.86	0	0.00	0.00	0.00	16.76	1	0.06	2.69	0.16

APPENDIX B: CLIMATIC AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climatic and hydrologic observations recorded at 1800 daily at the Eagle sonar project site on the Yukon River, 2024.

Date	Precipitation (code)[a]	Wind		Sky (code)[c]	Temperature (°C)	
		Direction[b]	Velocity (kph)		Air	Water[d]
07/01	A	NA	0.0	O	ND	19.5
07/02	A	W	3.9	B	25.7	20.0
07/03	B	E	2.9	S	16.7	17.0
07/04	C	E	1.4	O	14.6	19.0
07/05	A	E	2.2	B	17.3	20.0
07/06	B	E	6.9	O	17.4	18.0
07/07	A	W	2.1	B	15.4	17.0
07/08	A	NW	5.3	B	17.2	15.0
07/09	A	NW	4.2	B	19.1	18.0
07/10	A	NW	4.3	B	23.9	19.5
07/11	A	NW	1.8	S	21.2	19.5
07/12	A	SE	9.4	S	24.1	20.0
07/13	A	SE	22.4	C	23.4	20.0
07/14	A	E	6.5	B	22.4	19.0
07/15	A	NW	2.7	C	20.9	18.0
07/16	B	SE	2.5	O	17.0	11.0
07/17	A	SE	3.5	O	14.9	11.0
07/18	A	SE	6.7	S	16.2	17.0
07/19	A	NW	7.7	C	21.6	18.0
07/20	A	SE	1.6	S	24.6	19.0
07/21	A	E	4.2	C	25.0	21.0
07/22	A	NW	6.1	S	29.9	20.0
07/23	A	NW	6.6	C	30.5	21.0
07/24	A	NW	2.1	C	29	21.5
07/25	A	SE	2.0	C	26	20.0
07/26	A	SE	9.1	B	26.4	19.5
07/27	B	SE	5.7	B	14.1	18.0
07/28	A	S	2.3	O	15.6	17.0
07/29	C	NA	0.0	S	16	17.0
07/30	A	NW	11.3	B	18.8	16.0
07/31	B	SE	2.5	0	15.0	16.0
08/01	B	SE	1.4	O	19.0	17.0
08/02	A	W	1.4	O	15.0	16.0
08/03	A	NW	1.6	B	19.0	17.0
08/04	A	SE	6.6	C	28.4	18.0
08/05	A	W	8.5	C	28.5	21.0
08/06	A	W	7.2	C	28.8	18.0

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Date	Precipitation (code)[a]	Wind		Sky (code)[c]	Temperature (°C)	
		Direction[b]	Velocity (kph)		Air	Water[d]
08/07	A	W	11.1	C	29.8	21.0
08/08	A	N	1.1	B	22.4	18.0
08/09	C	NA	0.0	O	17.4	18.5
08/10	B	W	1.1	B	16.3	17.0
08/11	O	W	3.5	C	17.8	15.0
08/12	B	NA	0.0	S	16.2	14.0
08/13	A	NW	11.7	B	17.6	15.0
08/14	A	NW	5.7	C	17.7	15.0
08/15	A	SE	13.2	C	22.4	15.0
08/16	C	SW	5.5	O	16.8	14.0
08/17	A	E	1.4	o	20.9	15.0
08/18	A	SE	9.2	O	26.9	16.0
08/19	A	NW	6.2	B	14.3	15.0
08/20	A	NW	1.2	O	13.0	14.5
08/21	B	SE	8.3	F	13.6	13.0
08/22	B	SE	2.0	B	13.5	14.0
08/23	A	SE	3.8	S	14.1	13.0
08/24	B	SW	1.4	O	12.5	12.5
08/25	B	NW	3.7	O	12.1	12.0
08/26	A	S	3.8	B	15.8	13.0
08/27	A	E	15.5	O	17.8	12.0
08/28	A	SE	5.3	S	18.0	13.0
08/29	A	NE	2.9	B	14.2	13.0
08/30	A	NW	3.8	S	16.2	13.0
08/31	A	N	5.4	B	15.6	13.0
09/01	A	NW	5.8	B	12.2	12.0
09/02	A	NE	2.7	C	13.7	14.0
09/03	A	NE	2.0	S	15.8	12.0
09/04	A	SW	20.4	B	16.5	12.0
09/05	B	S	2.8	B	19.1	13.0
09/06	A	SW	5.7	B	17.2	12.0
09/07	B	NE	1.4	O	16.3	12.0
09/08	B	NA	0.0	O	15.0	11.0
09/09	A	NW	3.0	C	16.8	12.0
09/10	A	SE	2.9	B	14.7	12.0
09/11	A	NA	0.0	C	16.0	12.0
09/12	A	NA	0.0	B	13.5	12.0
09/13	B	NW	2.9	B	13.0	10.0
09/14	B	NE	10.0	B	10.3	10.0
09/15	B	SE	2.6	B	9.6	10.0

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Date	Precipitation (code)[a]	Wind		Sky (code)[c]	Temperature (°C)	
		Direction[b]	Velocity (kph)		Air	Water[d]
09/16	C	E	5.2	O	10.3	9.0
09/17	A	NA	0.0	O	13.4	9.0
09/18	B	SE	2.5	O	11.5	9.0
09/19	A	NA	0.0	S	11.4	9.0
09/20	A	N	2.3	O	9.8	8.0
09/21	A	NA	0.0	O	15.2	8.0
09/22	A	NE	6.2	B	10.2	8.0
09/23	A	NE	3.2	O	7.7	8.0
09/24	B	NW	2.4	O	5.7	8.0
09/25	A	NW	7.6	B	7.5	8.0
09/26	A	NW	4.4	B	8.9	9.0
09/27	A	NA	0.0	S	9.4	8.0
09/28	A	NW	3.6	C	8.4	8.0
09/29	A	NW	3.4	C	5.5	8.0
09/30	A	SW	2.2	C	4.4	5.0
10/01	A	E	17.4	C	5.6	4.0
10/02	A	SE	6.0	C	9.4	4.0
10/03	A	SW	2.4	S	3.4	3.0
10/04	A	SE	4.8	B	10.1	4.0
10/05	A	SW	14.3	O	9.4	4.0
10/06[e]	A	SE	9.3	S	9.7	6.0

Note: ND means no data.

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

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

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

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

[e] Observations were taken at 12:00.