Fishery Data Series No. 25-35

Sonar Estimation of Summer Chum and Pink Salmon in the Anvik River, Alaska, 2023

by

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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	$\geq$
harvest per unit effort	HPUE
less than	$<$
less than or equal to	$\leq$
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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ABSTRACT

Dual-frequency identification sonar (DIDSON) was used to estimate adult summer chum salmon *Oncorhynchus keta* and pink salmon *O. gorbuscha* passage in the Anvik River from June 15 to July 26, 2023. Apportionment to species was determined using data collected from tower counts. A total of 60,665 (SE = 778) summer chum were observed to have passed the sonar site, but no pink salmon were observed in 2023. A beach seine sample fishery was conducted to collect age, sex, and length information. A high-water event necessitated removing the sonar from the water from July 10 until July 24, and the sample fishery was discontinued after July 7. Due to the timing and extended duration, it was not possible to estimate the missing portion of the run. The range of ensonification was considered adequate for most fish that migrated upstream.

Keywords: chum salmon, *Oncorhynchus keta*, pink salmon, *Oncorhynchus gorbuscha*, dual-frequency identification sonar, DIDSON, Anvik River

INTRODUCTION

The purpose of the Anvik River sonar project is to monitor escapement of adult summer chum *Oncorhynchus keta* and pink salmon *O. gorbuscha* in the Anvik River drainage, one of the largest producers of summer chum salmon in the Yukon River drainage (Hayes et al. 2008; Larson et al. 2017; Figure 1). Additional major spawning populations of summer chum salmon within the Yukon River drainage occur in the Koyukuk and the Bonasila Rivers (Larson et al. 2017).

Pink, Chinook *O. tshawytscha*, and sockeye *O. nerka* salmon spawn in the Anvik River concurrently with summer chum salmon. A high abundance of pink salmon is observed during even years in the Yukon River drainage (Estensen et al. 2022), making apportionment of pink salmon passage on the Anvik River necessary to accurately assess summer chum salmon passage from the total sonar estimate. Because Chinook and sockeye salmon make up a small percentage of the total salmon passage, they are not apportioned in the sonar estimates. Fall chum, which are a later run of chum salmon and coho salmon *O. kisutch* have also been reported to spawn in the Anvik River drainage but do not migrate concurrently with summer chum salmon and therefore do not confound passage estimates.

Timely and accurate reporting of summer chum salmon escapement from the Anvik River sonar project helps fishery managers ensure that the Anvik River biological escapement goal (BEG) of 350,000 to 700,000 summer chum salmon is met (ADF&G 2004) while providing an opportunity for downstream subsistence and commercial harvest. Subsistence and commercial fishery openings and closures are based in part upon this assessment.

In 1971, an exploratory study was conducted to determine whether counting towers could be used to estimate salmon escapement in the Anvik River (Lebida 1972). From 1972 to 1979, counting towers were used to estimate the passage of summer chum salmon. However, high water levels and turbidity during multiple seasons prevented the collection of complete estimates (Mauney 1977; Mauney 1980). Bendix[1] sonar, capable of detecting migrating salmon, was tested alongside the counting towers from 1976 to 1979. In 1980, the project transitioned to using sonar to produce passage estimates (Buklis 1981). After this transition, counting towers continued to be used for visual counts to estimate the proportions of summer chum, pink, Chinook, and sockeye salmon. The project began producing estimates of pink salmon in addition to summer chum salmon estimates during even years, starting in 1994 (Sandone 1995). Because of missing or incomplete

[1] ADF&G (Alaska Department of Fish and Game). [Internet]. Alaska fisheries sonar: sonar technology tools. www.adfg.alaska.gov/index.cfm?adfg=sonar.sonartools (accessed November 20, 2023).

data, no pink salmon estimates were produced in 1996 and 2006 (Fair 1997; McEwen 2007). In 2017, the project began producing pink salmon estimates during both even and odd years (Lozori 2018).

Bendix sonar equipment was used to estimate salmon passage from 1980 to 2003. In 2003, a side-by-side comparison was made using Hydroacoustic Technology Incorporated (HTI) split-beam sonar equipment, and it was found that the Bendix and HTI produced similar passage estimates (Dunbar and Pfisterer 2007). In 2004, the project transitioned to using HTI sonar equipment for estimates. In 2006, a side-by-side comparison was made between HTI split-beam sonar and a dual-frequency identification sonar (DIDSON; Belcher et al. 2002). High water for most of the season prevented normal operation of the split-beam sonar, but the DIDSON passage estimate was 61% higher than the split-beam estimate (McEwen 2007). DIDSON has been used in the Yukon and Kenai Rivers (Lozori and Borden 2015; Key et al. 2016) to generate daily passage estimates, where bottom profiles are suitable for the wider beam angle and shorter range capabilities of this sonar. In 2007, the project transitioned to using DIDSON sonar.

From 1972 to 1975, the project site was located on the mainstem Anvik River 9 km above the confluence of the Yellow River[2] (Trasky 1974; Mauney 1977). From 1976 to 1979, the site was located near the confluence of Robinhood Creek (Mauney 1979, 1980; Mauney and Geiger 1977). In 1980, the site was relocated approximately 76 km upstream of the confluence of the Anvik and Yukon Rivers and 5 km below Theodore Creek at lat 62°44.21′N, long 160°40.72′W. It has remained at this location since then. The land is public, managed by the Bureau of Land Management, and leased to the Alaska Department of Fish and Game (ADF&G) until 2023. Aerial survey data indicate that summer chum salmon spawn primarily upstream of the sonar site.[3]

In 1971, the counting tower project conducted carcass surveys on the Anvik River from the confluence of the Swift River to the village of Anvik to survey all salmon species present (Lebida 1972). From 1972 to 1981, the project conducted carcass surveys at both upriver and downriver locations from the tower and sonar sites to collect age, sex, and length (ASL) data for summer chum and Chinook salmon. In 1982, the sonar project transitioned to using a beach seine to capture live summer chum and Chinook salmon to collect ASL data (Buklis 1983). Because the sonar site is far from the spawning grounds, the beach seine fishery was a more efficient method of collecting summer chum salmon ASL data than performing carcass surveys. A separate project began conducting the carcass surveys for Chinook salmon primarily upriver of the sonar site and operated through 2006 and from 2008 to 2014. In 2016, the Anvik River sonar project began collecting ASL data for sockeye salmon in addition to summer chum and Chinook salmon (Lozori 2017).

Daily hydrological and climatological measurements have been recorded for most years the project has operated. Measurements have included air temperature, wind speed and direction, cloud cover, precipitation, water temperature, and relative water depth. HOBO data loggers have been used to record water temperatures since 2007 (McEwen 2009).

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2 Lebida, R. C. Unpublished. Yukon River anadromous fish investigations, 1973. Alaska Department of Fish and Game, Juneau.

3 Arctic–Yukon–Kuskokwim Database Management System (AYKDBMS). 2006– . Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, AK. https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx (accessed December 7, 2023). Hereafter cited as AYKDBMS.

OBJECTIVES

The goal of this project in 2023 was to provide daily inseason estimates of adult summer chum and pink salmon escapement into the Anvik River to fishery managers. The primary objectives were as follows:

1. Estimate daily summer chum and pink salmon passage in the Anvik River using DIDSON to estimate fish passage and tower counts to apportion the estimates to species and determine if the summer chum salmon BEG was met.

The secondary objectives were as follows:

1. Using a beach seine, collect a minimum of 162 summer chum salmon samples during each of 4 temporal strata (corresponding to passage quartiles) throughout the season to estimate the ASL composition, such that simultaneous 95% confidence intervals of age composition in each sample were no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
2. Collect daily weather and water measurements representative of the study area.

METHODS

Summer chum and pink salmon passage were estimated using DIDSON sonar on both banks of the Anvik River. Both sonars operated continuously, 24 hours a day, and data were collected for 30 minutes per hour, starting at the top of each hour. Sonar estimates were apportioned to either summer chum or pink salmon based on the proportion of each species observed from the counting towers.

STUDY AREA

The Anvik River originates at an elevation of 400 m and flows in a southerly direction approximately 230 km to its mouth at river kilometer 512 of the Yukon River (Figure 1). In the upper reaches, the substrate consists mainly of gravel and cobble as well as exposed bedrock in some areas. The Yellow River is a major tributary of the Anvik drainage and is located approximately 100 km upstream from the mouth of the Anvik River (Figure 2). Downstream from the confluence of the Yellow River, the Anvik River changes from a moderate-gradient system to a low-gradient system, meandering through a much broader floodplain. Turbid waters from the Yellow River greatly reduce the water clarity of the Anvik River below the confluence. Numerous oxbows, old channel cutoffs, and sloughs are found throughout the lower Anvik River.

At the sonar site, the Anvik River is characterized by broad meanders, with large gravel bars on inside bends and cut banks with exposed soil, tree roots, and snags on outside bends. The river substrate at the sonar site is fine, smooth gravel, sand, and silt.

HYDROACOUSTIC EQUIPMENT

A long-range DIDSON operating at a frequency of 1.2 MHz (high-frequency option using 48 beams) was deployed on the right bank, and a standard DIDSON operating at a frequency of 1.1 MHz (low-frequency option using 48 beams) was deployed on the left bank (Table 1). The right bank had a gradual slope of approximately 2°. For this reason, a concentrator lens with a vertical beam width of approximately 2° was used to reduce surface and bottom reverberation. Laptop computers running DIDSON software controlled each DIDSON, and external hard drives were used to store data. A wireless Ethernet router transferred data from the left bank to the controlling laptop on the right bank (Figure 3).

SONAR DEPLOYMENT AND OPERATION

Prior to transducer deployment, the river bottom profile was checked to ensure the site was acceptable for ensonification. Range and depth data were collected from bank-to-bank transects using a boat-mounted Humminbird 998C SI fathometer with GPS. Both banks have consistently maintained stable bottom profiles since the project began operating at the current site (Figure 4).

Both banks were ensonified on June 15 and ran continuously through 1000 hours on July 10. After this time, sonars were removed from the river due to a high-water event. Sonars were reinstalled on July 24 at 1100 hours and remained operational through 1100 hours on July 26. Operational dates were chosen based on historical summer chum salmon run timing to cover most of the summer chum salmon migration. The DIDSONs were mounted on aluminum frames and aimed using manual crank-style rotators with threaded vertical rods, which allowed the DIDSONs to be tilted vertically up or down when the handles were turned. The DIDSONs were placed offshore in a fixed location with the beams directed perpendicular to the current flow at a depth of approximately 1 m. Because the slope of the river bottom differed substantially between banks, the DIDSON was located approximately 10 m from shore on the right bank and approximately 3 m from shore on the left bank, depending on the water level. Operators adjusted the pan and tilt by viewing the video-like acoustic image and relaying aiming instructions to a technician via handheld VHF radio. The wide axis of each beam was oriented horizontally and positioned close to the river bottom to maximize the residence time of targets in the beam. For both banks, the ensonified range was 20 m, starting at 0.83 m from the DIDSON and ending at 20.83 m (Table 1). Approximately 60–80% of the river was ensonified depending on the water level. Daily visual inspections of the sonar pods and images confirmed the proper placement and orientation of the DIDSONs and alerted operators if the pods needed to be repositioned to accommodate changing water levels.

Partial weirs were erected perpendicular to the current and extended from the shore outward 1 to 3 m beyond each DIDSON (Figure 5). Freestanding weir sections were constructed of 5.1 cm diameter steel pipes connected with adjustable fittings to form tripods. Aluminum stringers were attached horizontally to the upstream side of the tripods. Vertical lengths of aluminum conduit spaced 3.8 cm apart finished the sections. The weirs diverted migrating adult salmon offshore and in front of the DIDSONs, providing sufficient offshore distance for the fish to be detected within the sonar beam while allowing small, resident, nontarget species to pass through the weirs.

SONAR DATA PROCESSING AND PASSAGE ESTIMATION

Acoustic sampling was conducted on both banks, starting at the top of each hour for 30 minutes, 24 hours a day, 7 days a week, except for short periods when generators were serviced or adjustments were made to the sonars. Operators marked each upstream fish track using Echotastic, an echogram viewer program developed by ADF&G staff.[4] The DIDSON can be used to measure fish length, and this feature has been used in other projects to differentiate between salmon and nonsalmon species (Key et al. 2016). All fish were counted except for small fish (<400 mm), which were assumed to be nonsalmon. Fish lengths were measured using Echotastic marking tools but

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

were not recorded. At the beginning of the season, when fish passage was low, most fish were measured, which trained technicians on visually estimating length. As technicians became more proficient at estimating length, fish were measured at the technicians' discretion. The upstream direction of travel was verified using the Echotastic video feature, which displayed the raw acoustic fish images. The 30-minute counts were saved as text files and recorded on a paper count form.

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

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

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

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

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

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

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

After data checks were completed, an estimate of daily and cumulative fish passage was produced and forwarded to ADF&G managers each day. Postseason, hourly rates of fish passage, sonar file times, and tower count data were reviewed for accuracy. If errors were found, the passage estimates were recalculated, and updates were sent to managers.

MISSING DATA

Estimating daily passage by multiplying the average hourly passage rates by 24 (Equation 1) compensates for missing data (either shortened or missing periods within a day) and is reflected in the variance (Equation 2) by reducing the number of samples and the fraction of the day sampled. Normally, if one or multiple days are missed, the relationship of daily passage between banks will be assessed by linear regression using the observed passage from the previous days for each bank.

If the regression is significant ($p < 0.05$), the linear regression equation of the line will then be used to calculate missing passage for each missing day (d) using the following:

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

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

If the regression of daily passage by bank is not significant or where both banks are inoperable, daily passage is interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

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

where (d) is the number of missed days, n is the number of days used for interpolation (half before and half after the missing day[s]), and x_{is} is the passage for each day (i) for each bank (s).

Extremely high water prevented deployment of the sonar from July 11 through July 23. Typically, when a project experiences downtime, the missing data is expanded by averaging the days before and after the event (Equation 5). When a single bank is down, it is often possible to estimate the missing data using the data from the other bank. In 2023, both banks were down for an extended period, which included the peak of the run, so neither of the normal methods was effective. Alternative methods of estimating the missed passage were also explored; however, these were unable to produce defensible estimates as well (Appendix A).

SPECIES APPORTIONMENT

Tower counts were conducted 4 times per day (0730, 1300, 1700, and 2000 hours) for 15 minutes on each bank to apportion the number of summer chum and pink salmon migrating past the sonar site. A 4.5 m tower was anchored in the river just downstream of the sonar at the end of the weir on the right bank and just upstream of the sonar on the left bank (Figure 5). Technicians stood on top of the towers and, using polarized sunglasses, counted salmon by species as they passed the sonar. The number of salmon species for each bank and the visible range in meters from the transducer, as determined by visual estimation, were entered into a Microsoft Access database. Nonsalmon species, which would be excluded from the sonar estimate, were not counted, or recorded. Because of the low proportion of Chinook and sockeye salmon migrating past the sonar site, these species were not proportioned in the daily estimates.

Usable tower counting periods were defined as those with at least 5 fish and a minimum visibility range of 2.0 m for the right bank and 1.0 m for the left bank. The range of visibility was estimated visually. Species proportions for each usable tower counting period (i) were calculated by dividing the count (c) for species (a) on day (d) and stratum (s) by the count summed over all species in the same tower counting period:

$$p_{disa} = \frac{c_{disa}}{\sum_a c_{disa}}. \tag{6}$$

Because of the low diurnal pattern observed at this site, the estimated proportion for each day, stratum, and species was computed as the mean of the individual proportions on that day:

$$\hat{p}_{dsa} = \frac{\sum_i p_{disa}}{n_d}. \tag{7}$$

Tower counts from multiple days were combined to compensate for insufficient tower count data and to accurately estimate species proportions, which allowed estimation of the sampling variance. Days were combined into groups such that each contained at least 2 usable tower counting periods.

Daily sonar passage estimates were apportioned to either pink or summer chum salmon by multiplying the estimated proportion by the unadjusted sonar passage estimate:

$$\hat{y}_{dsa} = \hat{y}_{ds} \bullet \hat{p}_{dsa}. \tag{8}$$

With 2 species apportioned, the variance of the proportion was computed based on the difference of the individual observations from the mean for each day:

$$Var(\hat{p}_{dsa}) = \frac{\sum_i (\bar{p}_{dsa} - \hat{p}_{disa})^2}{n(n-1)}, \tag{9}$$

and the variance of the species passage estimate was estimated as the variance of the product of 2 independent random variables (Goodman 1960):

$$\hat{V}ar(\hat{y}_{dza}) = \hat{y}_{dz}^2 \bullet \hat{V}ar(\hat{p}_{dza}) + \hat{p}_{dza}^2 \bullet \hat{V}ar(\hat{y}_{dz}) - \hat{V}ar(\hat{y}_{dz}) \bullet \hat{V}ar(\hat{p}_{dza}). \tag{10}$$

Total daily passage by species was estimated by summing both strata:

$$\hat{y}_{da} = \sum_s \hat{y}_{dsa}, \tag{11}$$

and passage estimates were summed over both strata and all days to obtain a seasonal estimate for each species:

$$\hat{y}_a = \sum_d \sum_s \hat{y}_{dsa}. \tag{12}$$

Finally, passage estimates were assumed independent between strata and among days, so the variance of their sum was estimated by the sum of their variances:

$$\hat{V}ar(\hat{y}_a) = \sum_d \sum_s \hat{V}ar(\hat{y}_{dsa}), \tag{13}$$

and, assuming normally distributed errors, 90% confidence intervals were calculated as:

$$\hat{y}_a \pm 1.645\sqrt{\hat{V}ar(\hat{y}_a)}. \tag{14}$$

Age, Sex, and Length Sampling

Temporal strata, used to characterize the age and sex composition of the summer chum salmon escapement, were defined as dates on which 25%, 50%, 75%, and 100% of the total run passed the sonar site based on historical passage timing. Historical mean quartile dates from 2012 to 2022 were used to determine inseason ASL sampling dates. These temporal strata represent an attempt to sample the escapement in proportion to the total run.

A minimum of 150 readable scales per temporal stratum were necessary to achieve simultaneous 95% confidence intervals no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$), assuming 2 major age classes and 2 minor age classes (Bromaghin 1993). To meet this standard, the seasonal ASL sample goal was set to a minimum of 162 summer chum salmon samples per stratum (648 total for the season), which allows for a scale rejection rate of 7%.

A beach seine (31 m long, 66 meshes deep, 2.5 inch mesh) drifted beginning approximately 10 m downstream of the sonar site to capture summer chum salmon for ASL data collection. All resident freshwater fish captured were tallied by species and released. Pink salmon were counted by sex (based on external characteristics) and released. Summer chum salmon were held live in a submerged holding pen, and each was noted for sex and measured to the nearest 1 mm from the middle of the eye to the tail fork, and 1 scale was taken for age determination. Scales were collected from an area posterior to the base of the dorsal fin and above the lateral line on the left side of the fish (Clutter and Whitesel 1956). The left axillary process was clipped on each sampled summer chum salmon to prevent resampling.

ASL data were also collected from Chinook and sockeye salmon using the same methods as for summer chum salmon, except 4 scale samples were taken from each fish. This sampling was established to gather additional information about these species while pursuing the primary goal of summer chum salmon sampling, with minimal additional costs to the project.

Climatic and Hydrologic Observations

Climatic and hydrologic data were collected at approximately 1800 each day at the sonar site. River depth was monitored using a staff gauge marked in 1 cm increments. Change in water depth was presented as negative or positive increments from the initial reading of 0 cm. Air temperature and subjective notes about wind speed and direction, cloud cover, and precipitation were also recorded. Water temperature was measured using a HOBO data logger, which electronically recorded the temperature every hour, on the hour, for the duration of the project.

RESULTS AND DISCUSSION

Summer Chum and Pink Salmon Estimation

The sonar equipment functioned well this season; however, high water in July caused both left and right bank sonars to be removed from the water due to staff and equipment safety concerns. Sonars were non-operational starting July 10 until they were redeployed on July 24. Passage estimates from the observed run should be considered a minimum and not reflective of the true run size.

The total summer chum salmon passage estimate observed at the sonar site was 60,556 (SE = 788) from June 15 through July 26 (Table 2). There were no pink salmon estimated to have passed the site in 2023. These estimates do not include any interpolation for the days missed when sonars were inoperable due to high water; however, they include expansions for sampling time missed due to generator and sonar maintenance, short sonar file times, and days when the sonar did not operate for a full day (i.e., project startup and breakdown). On the left bank, 2,592 minutes were missed, and on the right bank, 2,461 minutes were missed for a combination of these reasons, which resulted in a total of 1,297 fish and 6,494 fish being added to the estimates, respectively (Table 3). These expansions and minutes missed mentioned previously do not include the period from July 11 through July 23, when the sonars were removed from the water.

SPATIAL AND TEMPORAL DISTRIBUTION

Consistent with historical range distributions, fish passage was predominantly shore-oriented this season. Approximately 95% of fish targets were detected within 15 m of the transducer on both the left and right banks (Figure 6), and 87.7% of the total passage occurred on the right bank (Table 2).

The left bank displayed a slight diurnal pattern of fish passage at the Anvik River sonar site this season, with an increase in passage from approximately 0000 through 0500 hours (Figure 7). The right bank displayed an increase from 2200 through 0300 hours. When both banks were combined, the increase was evident from 0000 until 0500 hours.

SPECIES APPORTIONMENT

Summer chum was the most prominent salmon species observed on both banks during tower counts. Both the left and right bank towers were installed on June 19. The first summer chum salmon was observed on June 28 (Table 4). Proportionally, summer chum salmon accounted for approximately 96% (128 fish) of the total tower count on the left bank and 99% (1,350 fish) on the right bank. There were no pink salmon observed from the counting towers this season.

Because of flooding, counting towers were removed from the water from July 10 to July 23. Outside of this period, river conditions were mostly favorable, and there were only 3 periods on July 9 when the minimum range of visibility was not observed from either bank's counting tower.

Insufficient tower counts of fish (fewer than 5) occurred most days on both banks until June 30, and until this time, all fish traces >400mm were considered summer chum salmon (Table 4). Because of insufficient numbers of fish on these days, multiple days were combined to apportion sonar passage estimates to species. Sufficient tower counts occurred on 25% of the days on the left bank and 58% of the days on the right bank.

SUMMER CHUM SALMON AGE, SEX, AND LENGTH DATA COLLECTION

Based on historical passage timing, temporal strata in 2023 were defined as June 15–July 4, July 5–July 9, July 10–July 14, and July 15–July 26. Between July 2 and July 7, a total of 157 summer chum salmon ASL samples were obtained: 108 during the first quartile and 49 during the second quartile. Of these samples, 158 scales (97%) were analyzed as ageable postseason (AYKDBMS). ASL sampling was discontinued after July 7 due to high water. The sample size goal of 162 summer chum salmon was not achieved in any quartiles; therefore, the objective of collecting a minimum of 162 samples during each temporal stratum was not met this season.

CLIMATIC AND HYDROLOGIC OBSERVATIONS

The objective of monitoring weather and water parameters daily at the project site was met in 2023. Water levels decreased from the project's beginning until July 2, after which they rose rapidly until July 11. From July 11, the water level generally decreased until July 20, when it rapidly rose again. Water levels decreased from July 22 to July 26, when the project was completed. (Figure 8). From July 10 until July 15, the water depth gauge was completely submerged, and water levels were approximated. Overall, between June 18 and July 26, the minimum and maximum water levels differed by approximately 93 cm. Water temperatures at the project ranged from a low of 7.2°C on June 15 to a high of 14.9°C on July 2 (Figure 9). Air temperatures ranged from a low of 12.2°C on July 14 to a high of 25.3°C on July 23 (Table 5).

ACKNOWLEDGMENTS

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TABLES AND FIGURES

Table 1.–Technical specifications for dual-frequency identification sonars (DIDSON) at the Anvik River sonar project, 2023.

	Bank	
Setting	Right	Left
Mode	High frequency	Low frequency
Frequency (MHz)	1.20	1.10
Number of beams	48	48
Horizontal field of view (angular degrees)	29	29
Vertical beam width (angular degrees)	2	14
Start range (m)	0.83	0.83
Window length (m)	20	20
Frame rate (per sec)	6	6
Duration (min)	30	30

Table 2.–Summer chum salmon daily and cumulative passage estimates at the Anvik River sonar project, 2023.

Date	Left bank	Right bank	Daily total	Cumulative estimate
6/15	9	24	33	33
6/16	4	33	37	70
6/17	8	14	22	92
6/18	5	38	43	135
6/19[a]	5	65	70	205
6/20	4	36	40	245
6/21	2	71	73	318
6/22	16	64	80	398
6/23	28	48	76	474
6/24	9	50	59	533
6/25	30	162	192	725
6/26	48	127	175	900
6/27	4	66	70	970
6/28	50	206	256	1,226
6/29	94	284	378	1,604
6/30	554	2,548	3,102	4,706
7/01	494	3,630	4,124	8,830
7/02	255	4,915	5,170	14,000
7/03	208	2,133	2,341	16,341
7/04	336	4,295	4,631	20,972
7/05	136	2,650	2,786	23,758
7/06	424	4,337	4,761	28,519
7/07	690	5,077	5,767	34,286
7/08	610	3,748	4,358	38,644
7/09	392	4,411	4,803	43,447
7/10	537	3,236	3,773	47,220
7/11[b]	ND	ND	ND	ND
7/12[b]	ND	ND	ND	ND
7/13[b]	ND	ND	ND	ND
7/14[b]	ND	ND	ND	ND
7/15[b]	ND	ND	ND	ND
7/16[b]	ND	ND	ND	ND
7/17[b]	ND	ND	ND	ND
7/18[b]	ND	ND	ND	ND
7/19[b]	ND	ND	ND	ND
7/20[b]	ND	ND	ND	ND
7/21[b]	ND	ND	ND	ND
7/22[b]	ND	ND	ND	ND

-continued-

Table 2.–Page 2 of 2.

Date	Left bank	Right bank	Daily total	Cumulative estimate
7/23[b]	ND	ND	ND	ND
7/24	929	4,234	5,163	52,383
7/25	1,019	3,556	4,575	56,958
7/26	536	3,062	3,598	60,556
Total	7,436	53,120	60,556	
Variance			620,622	
SE			788	
Lower 90% CI			59,260	
Upper 90% CI			61,852	

Note: Confidence interval (CI) and standard error (SE).

[a] First day of tower counts.

[b] Because of flooding, sonars had to be removed from the river. No data collected (ND).

Table 3.–Sampling time missed, and the resulting number of fish added to the estimate at the Anvik River sonar project, 2023.

	Left bank		Right bank	
Date	Minutes	Fish	Minutes	Fish
6/15	390.5	5	360.2	12
6/16	30.5	0	32.5	2
6/17	0.5	0	0.5	0
6/18	90.4	1	227.4	12
6/19	120.4	1	60.4	5
6/20	0.5	0	0.5	0
6/21	120.4	0	90.4	9
6/22	0.5	0	0.7	0
6/23	0.5	0	0.5	0
6/24	60.4	1	90.4	6
6/25	150.4	6	60.4	14
6/26	73.8	5	30.5	5
6/27	0.5	0	240.3	22
6/28	0.5	0	0.5	0
6/29	0.5	0	0.5	0
6/30	34.8	27	0.5	2
7/01	172.8	119	0.5	2
7/02	80.0	28	90.4	617
7/03	0.5	0	0.5	1
7/04	30.5	14	90.4	539
7/05	0.5	0	0.5	2
7/06	0.5	0	0.5	3
7/07	0.5	0	0.5	3
7/08	0.5	0	0.5	2
7/09	121.0	66	0.5	3
7/10	390.2	291	390.2	1,754
7/11[a]	ND	ND	ND	ND
7/12[a]	ND	ND	ND	ND
7/13[a]	ND	ND	ND	ND
7/14[a]	ND	ND	ND	ND
7/15[a]	ND	ND	ND	ND
7/16[a]	ND	ND	ND	ND
7/17[a]	ND	ND	ND	ND
7/18[a]	ND	ND	ND	ND
7/19[a]	ND	ND	ND	ND
7/20[a]	ND	ND	ND	ND
7/21[a]	ND	ND	ND	ND
7/22[a]	ND	ND	ND	ND
7/23[a]	ND	ND	ND	ND
7/24	360.2	465	330.3	1,942
7/25	0.5	1	0.5	2
7/26	360.2	266	360.2	1,532
Total	2,592.7	1,297	2,461.6	6,494

Note: Reasons for missed sampling time included generator and sonar maintenance, short sonar file times, and days when the sonar did not operate for a full day (i.e., project startup and shutdown).

[a] Sonar out of the water because of flooding, no data (ND) collected.

Table 4.–Salmon species and proportion of summer chum salmon observed migrating upstream during tower counts by day and bank at the Anvik River sonar project, 2023.

	Left bank					Right bank				
Date	Chum	Chinook	Pink	Sockeye	Proportion chum	Chum	Chinook	Pink	Sockeye	Proportion chum
6/19	0	0	0	0	0.000	0	0	0	0	0.000
6/20	0	0	0	0	0.000	0	0	0	0	0.000
6/21	0	0	0	0	0.000	0	0	0	0	0.000
6/22	0	0	0	0	0.000	0	0	0	0	0.000
6/23	0	0	0	0	0.000	0	0	0	0	0.000
6/24	0	0	0	0	0.000	0	0	0	0	0.000
6/25	0	0	0	0	0.000	0	0	0	0	0.000
6/26	0	0	0	0	0.000	0	0	0	0	0.000
6/27	0	0	0	0	0.000	0	0	0	0	0.000
6/28	0	0	0	0	0.000	5	0	0	0	1.000
6/29	0	0	0	0	0.000	2	0	0	0	1.000
6/30	33	0	0	0	1.000	128	1	0	0	0.992
7/01	1	0	0	0	0.000	72	0	0	0	1.000
7/02	0	0	0	0	0.000	158	0	0	1	0.994
7/03	2	0	0	0	1.000	57	0	0	1	0.983
7/04	2	0	0	0	0.000	186	1	0	0	0.995
7/05	2	0	0	0	1.000	67	0	0	0	1.000
7/06	6	0	0	0	1.000	148	0	0	0	1.000
7/07	20	0	0	1	0.952	132	0	0	3	0.978
7/08	3	0	0	1	0.750	82	0	0	0	1.000
7/09	1	0	0	0	1.000	66	0	0	0	1.000
7/10[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/11[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/12[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/13[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/14[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/15[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/16[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/17[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/18[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/19[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/20[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/21[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/22[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/23[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/24	17	0	0	1	0.944	86	0	0	0	1.000
7/25	28	0	0	1	0.966	138	0	0	4	0.972
7/26	13	1	0	0	0.929	23	0	0	0	1.000
Total	128	1	0	4	0.962	1,350	2	0	9	0.992

[a] Counting towers out of the water. No data collected (ND).

Table 5.–Climatic observations recorded at 1800 daily at the Anvik River sonar project site, 2023.

Date	Precipitation (code)[a]	Wind Direction[b]	Wind Velocity (kph)	Sky (code)[c]	Air temperature (°C)
6/16	A	ND	ND	B	ND
6/17	A	W	ND	B	ND
6/18	A	W	ND	B	ND
6/19	A	W	ND	B	ND
6/20	A	SE	ND	C	ND
6/21	A	S/SE	0.8	C	17.0
6/22	B	S	1.4	B	17.2
6/23	B	SW	5.2	B	17.9
6/24	B	NE	2.9	B	19.6
6/25	B	W	3.1	B	14.5
6/26	B	W	2.4	S	16.1
6/27	B	E	2.0	B	15.8
6/28	B	SE	2.3	S	16.6
6/29	A	NE	2.9	S	20.1
6/30	B	NE	2.7	S	18.3
7/01	A	NE	0.8	S	22.5
7/02	B	W	2.9	O	15.8
7/03	B	E	1.7	B	14.7
7/04	B	NE	2.4	B	18.1
7/05	B	NE	1.5	O	14.5
7/06	B	W	0.8	O	13.6
7/07	B	W	1.8	O	13.5
7/08	B	E	1.5	O	12.3
7/09	C	NE	1.0	O	13.6
7/10	A	ND	0.0	B	14.2
7/11	B	W	1.0	O	15.8
7/12	A	ND	ND	C	ND
7/13	B	NW	1.1	O	13.5
7/14	A	NE	1.1	O	12.2
7/15	B	NE	1.4	O	12.5
7/16	B	W	2.3	O	14.8
7/17	A	NE	0.7	B	21.1
7/18	A	NW	0.8	C	24.9
7/19	A	W	1.3	B	22.8
7/20	B	ND	1.2	O	16.9
7/21	B	W	1.4	O	16.8
7/22	B	NE	0.7	C	22.7
7/23	A	SW	0.9	S	25.3
7/24	A	SW	1.2	B	20.3
7/25	A	N	1.0	B	19.1

Note: ND indicates no data were collected.

[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 with or without precipitation.

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

[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.

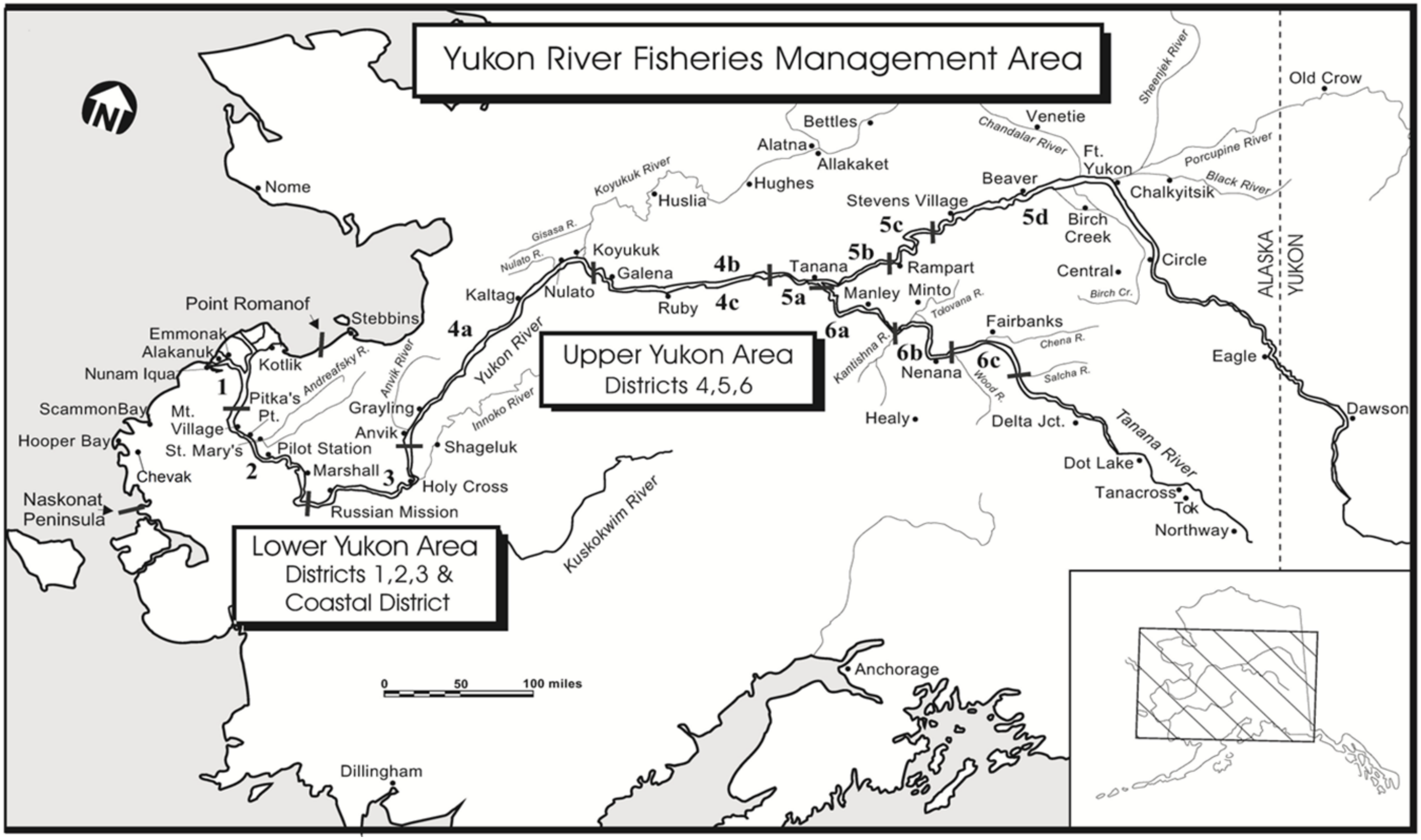

Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

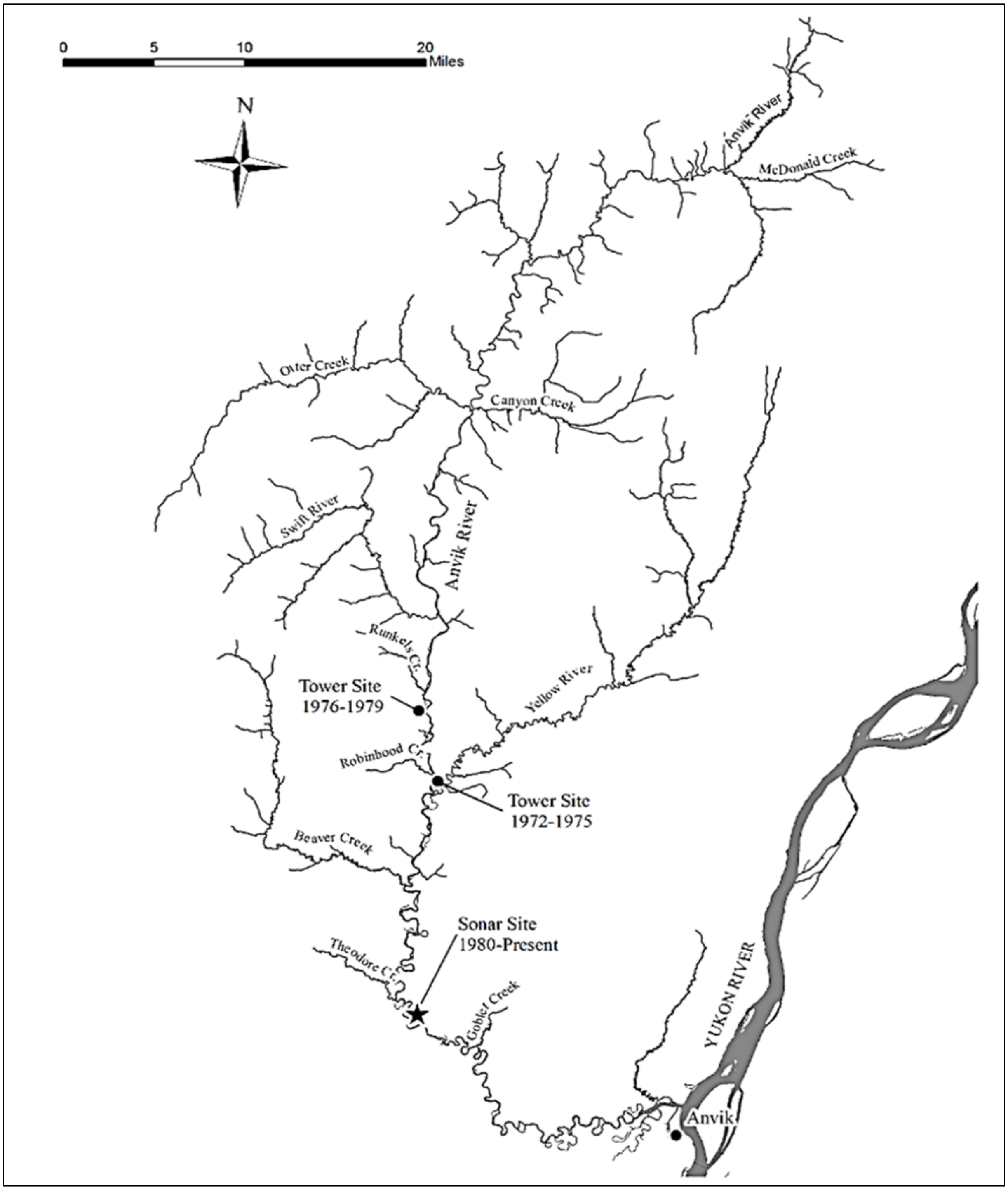

Figure 2.–Anvik River drainage with historical summer chum salmon escapement project locations.

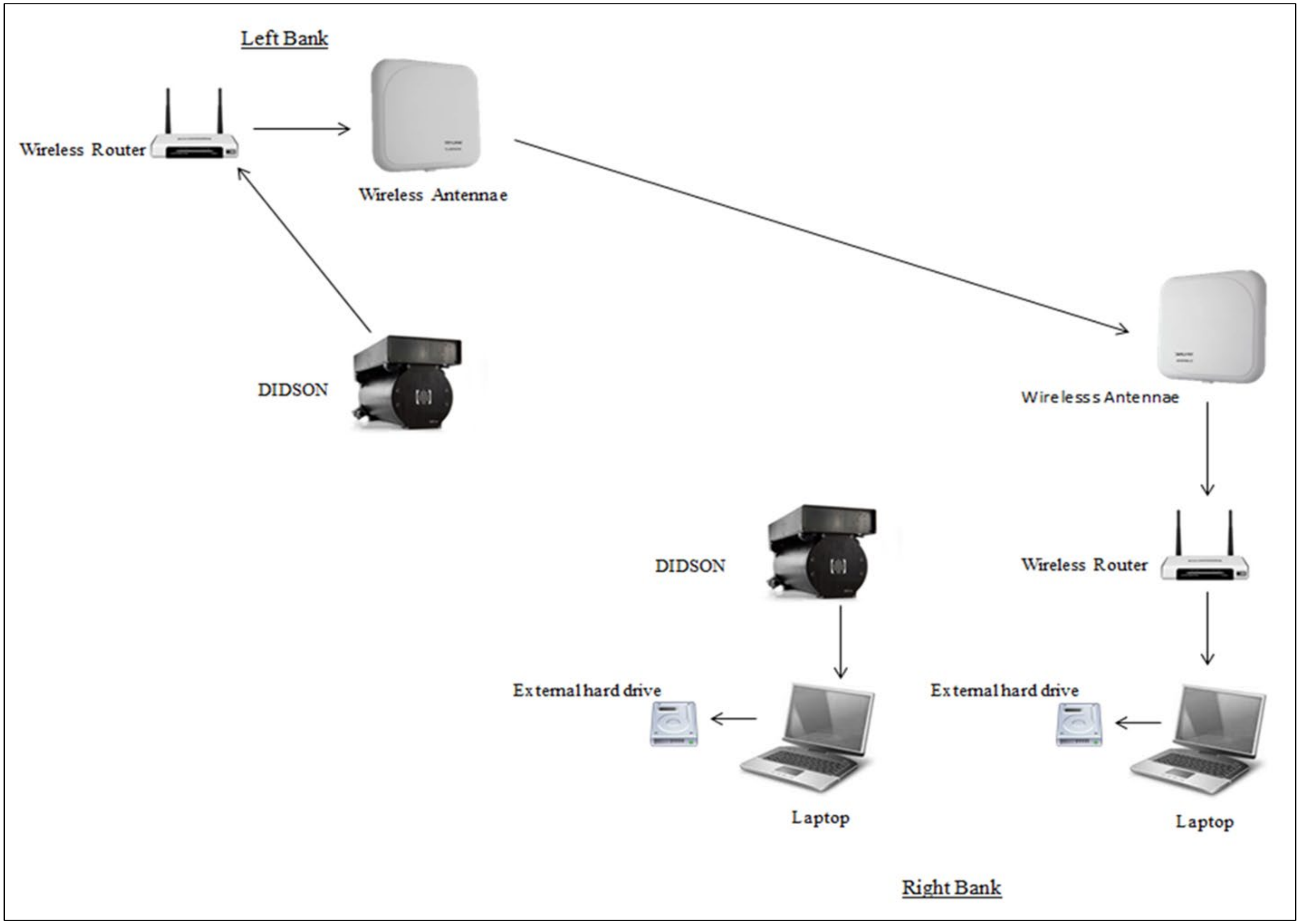

Figure 3.–DIDSON sonar equipment schematic at the Anvik River sonar project, 2023.

Note: Both the left bank and right bank laptops were housed in the right bank sonar tent.

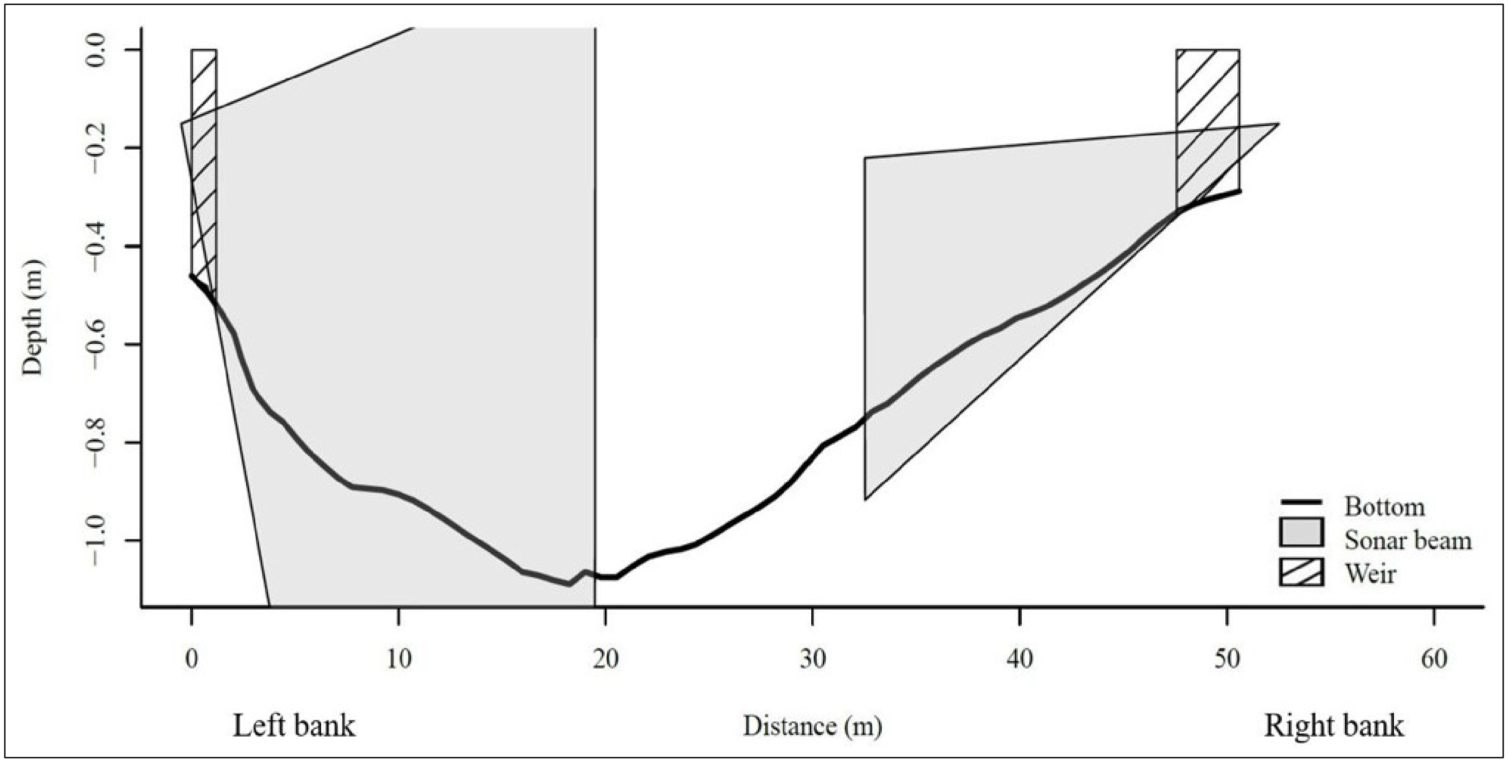

Figure 4.–Depth profile of the Anvik River and approximate sonar ranges (not to scale) at the Anvik River sonar project.

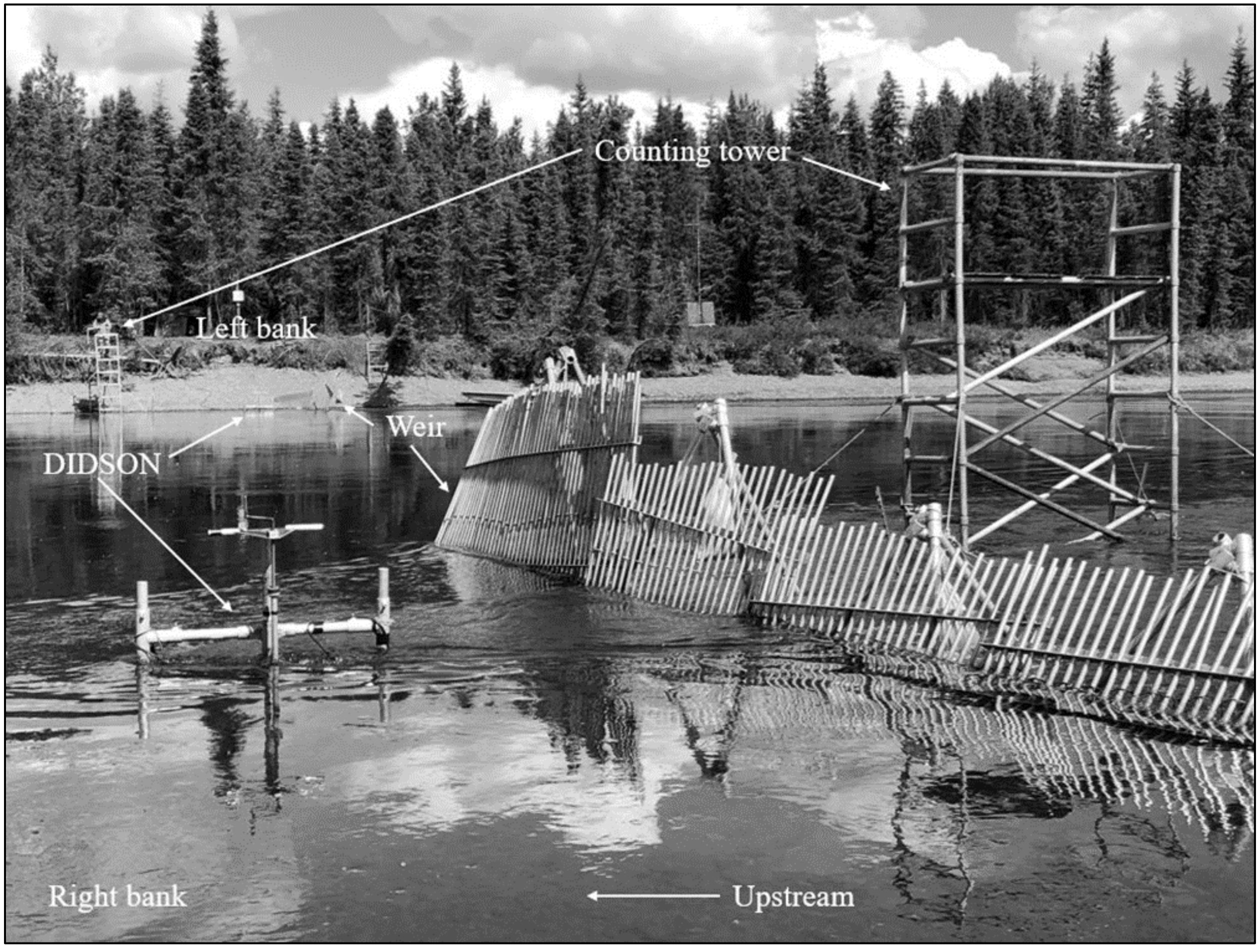

Figure 5.–Anvik River sonar project site illustrating locations of sonars, weirs, and counting towers.

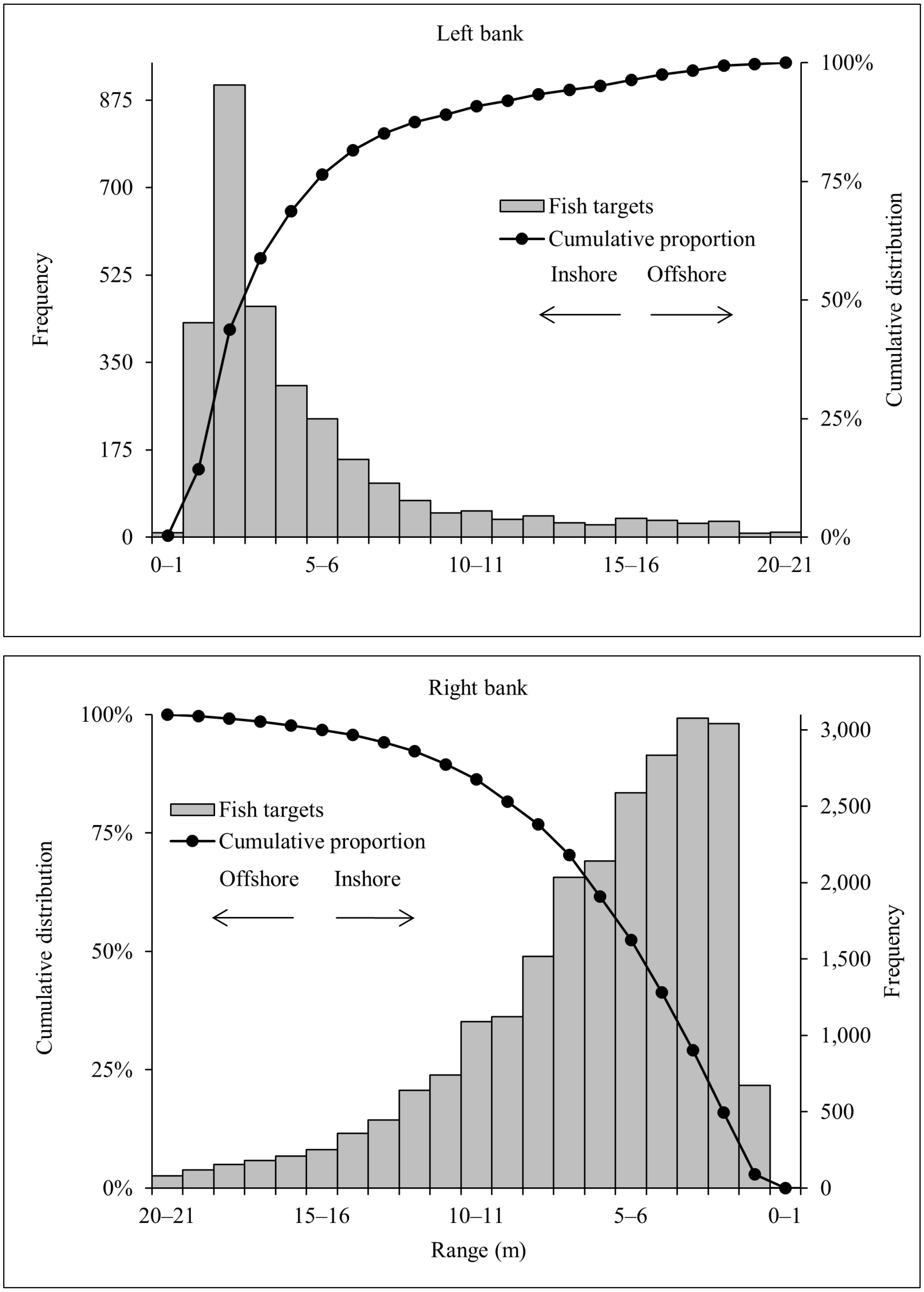

Figure 6.–Left and right bank horizontal distribution of unexpanded fish targets at the Anvik River sonar project, June 15 through July 26, 2023.

Note: For both banks, the ensonified range was 20 m, starting at 0.83 m from the DIDSON and ending at 20.83 m.

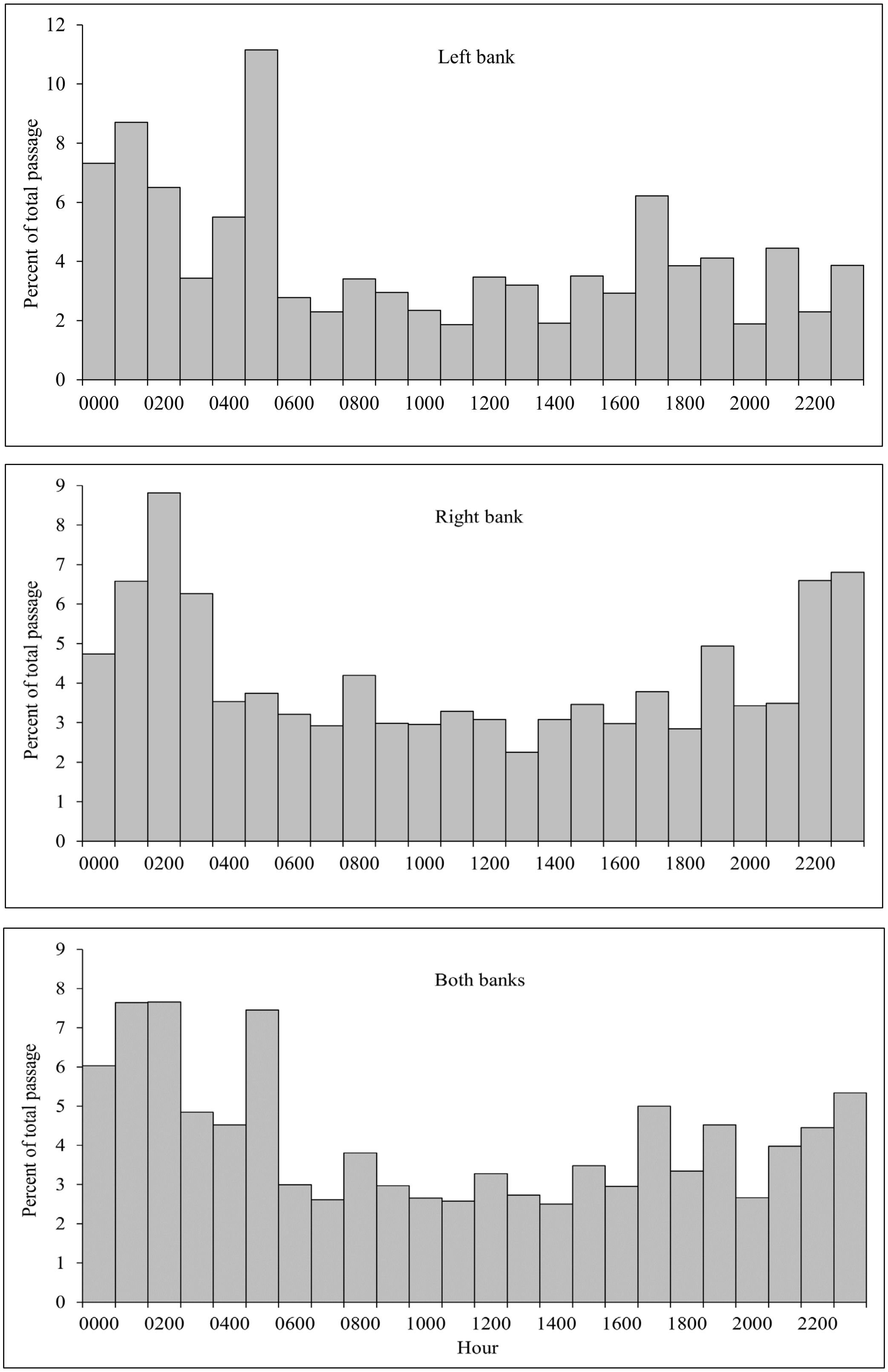

Figure 7.–Percent of total passage, by hour, observed on the left bank, right bank, and both banks combined at the Anvik River sonar project, 2023.

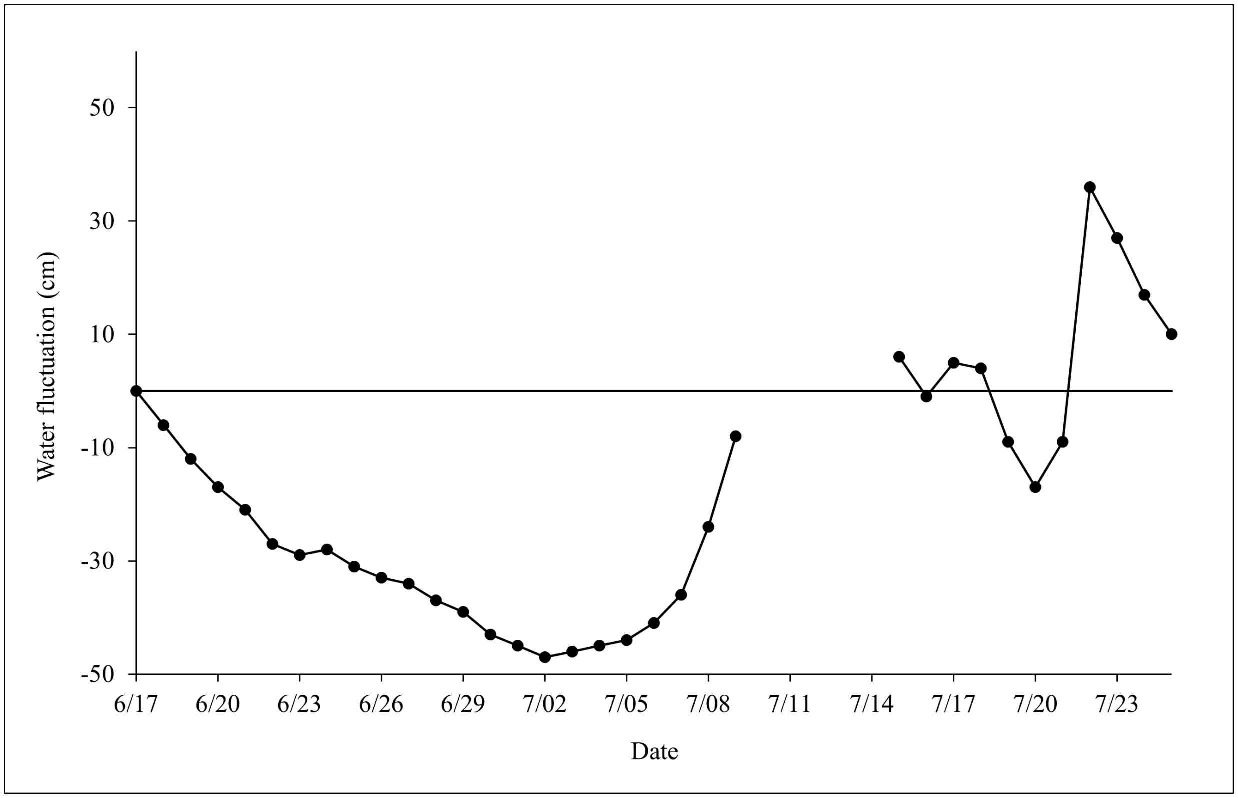

Figure 8.–Change in daily water elevation, relative to June 17, measured at the Anvik River sonar project, 2023.

Note: Depth gauge was submerged from July 10 through July 14. There were no depth readings for these days.

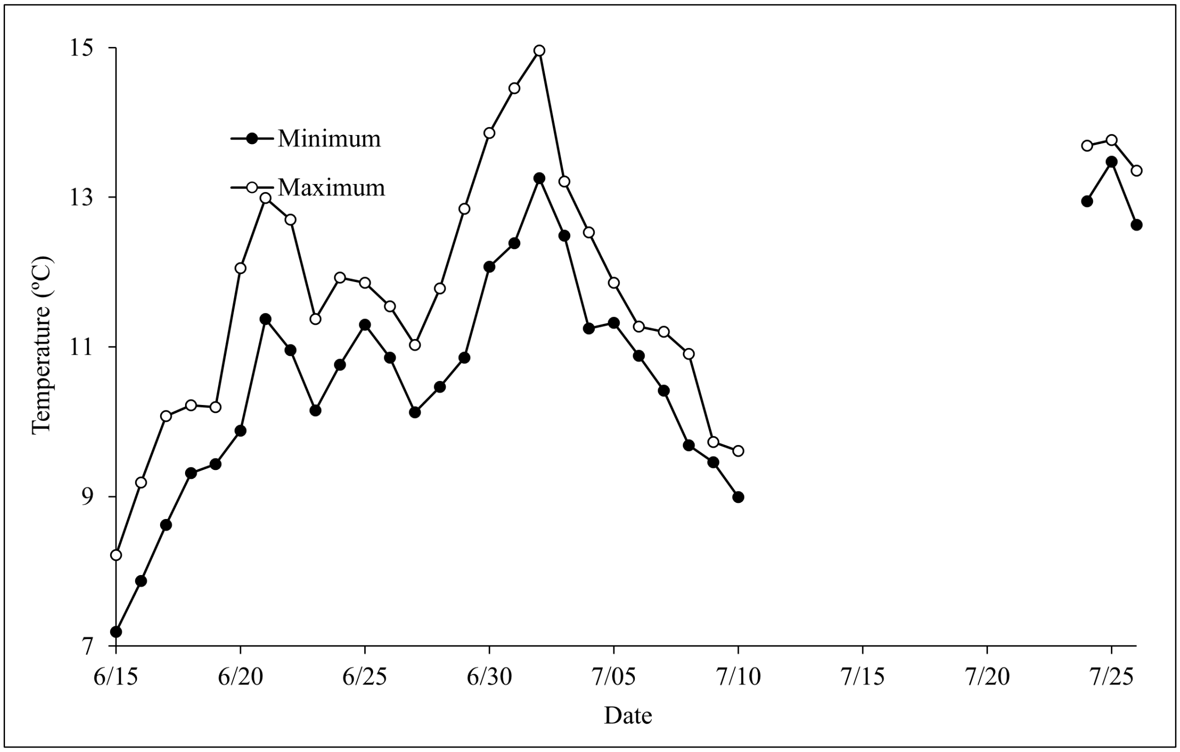

Figure 9.–Daily water temperatures on the left bank at the Anvik River sonar project, 2023.

Note: Water temperature was measured using a HOBO data logger, which electronically recorded the temperature every hour, on the hour. Loggers were out of the water from July 11 through July 23, there was no data collected during this time period.

APPENDIX A: MISSED PASSAGE ESTIMATION

Appendix A1.–Estimation of Anvik River chum salmon passage using Anvik River sonar estimates regressed against lagged Pilot Station estimates.

Pilot Station sonar project daily estimates were lagged 12 days so that the timing was consistent with the Anvik sonar project estimates (Figure 1). Standard linear regression of the Anvik River sonar estimates regressed against the lagged Pilot Station estimates resulted in a significant relationship ($p < 0.01$), with a coefficient of determination of 0.62 (Figure 2). Using this model, an estimated 36,576 summer chum could have passed the site over the missed period, giving an estimated total run size of approximately 97,000.

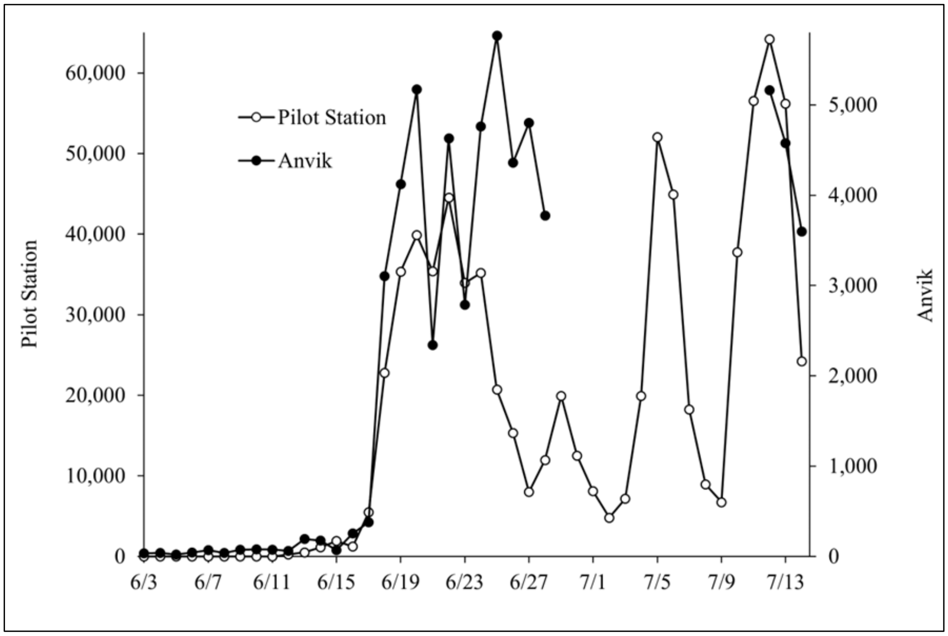

Figure 1.–Daily passage at the Anvik River sonar project and the Pilot Station sonar project (lagged 12 days).

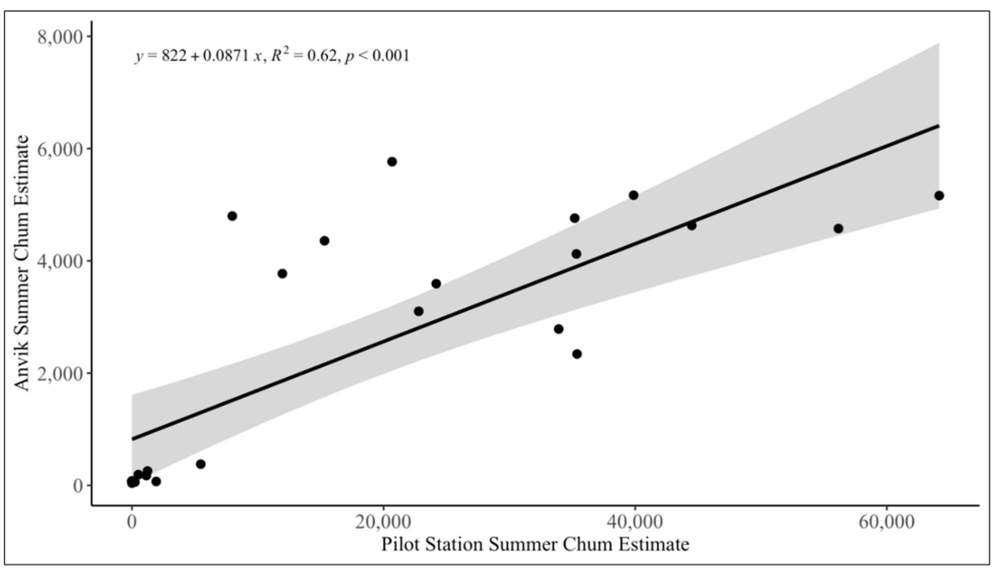

Figure 2.–Regression of Anvik River versus lagged Pilot Station summer chum estimates with 95% confidence interval), 2023.

Appendix A2.–Anvik summer chum passage estimated using the proportion observed at the Pilot Station sonar project prior to flooding.

The 2024 Pilot Station sonar chum salmon estimates were lagged 12 days (Table 1). The proportion of the cumulative lagged estimates through July 10 is 37.05% of the season total. Expanding the cumulative Anvik passage through July 10 (47,216) by this proportion gives an estimated total Anvik run size of approximately 127,000 summer chum salmon.

Table 1.–Daily Pilot Station summer chum salmon estimates lagged 12 days with cumulative passage and proportion June 23–July 30, 2023.

Date	Chum	Cumulative	Proportion
6/24	234	234	0.0003
6/25	506	740	0.0009
6/26	1,140	1,880	0.0022
6/27	1,925	3,805	0.0045
6/28	1,236	5,041	0.0060
6/29	5,469	10,510	0.0124
6/30	22,792	33,302	0.0394
7/1	35,331	68,633	0.0811
7/2	39,874	108,507	0.1283
7/3	35,381	143,888	0.1701
7/4	44,496	188,384	0.2227
7/5	33,921	222,305	0.2628
7/6	35,194	257,499	0.3044
7/7	20,676	278,175	0.3288
7/8	15,304	293,479	0.3469
7/9	7,975	301,454	0.3563
7/10	11,958	313,412	0.3705
7/11	19,893	333,305	0.3940
7/12	12,473	345,778	0.4087
7/13	8,092	353,870	0.4183
7/14	4,804	358,674	0.4240
7/15	7,135	365,809	0.4324
7/16	19,920	385,729	0.4560
7/17	52,026	437,755	0.5174
7/18	44,894	482,649	0.5705
7/19	18,229	500,878	0.5921
7/20	8,945	509,823	0.6026
7/21	6,731	516,554	0.6106
7/22	37,746	554,300	0.6552
7/23	56,516	610,816	0.7220
7/24	64,169	674,985	0.7979
7/25	56,158	731,143	0.8642
7/26	24,182	755,325	0.8928
7/27	19,410	774,735	0.9158
7/28	17,474	792,209	0.9364
7/29	25,380	817,589	0.9664
7/30	28,399	845,988	1.0000

Appendix A3.–Estimate of Anvik River summer chum passage based on the recent 5-year average of the total proportions observed at the Anvik and Pilot Station sonar projects.

The proportion of the Pilot Station summer chum salmon passage that was observed at the Anvik River sonar project was averaged across the most recent 5-years (Figure 1). Multiplying the 2023 Pilot Station sonar project summer chum salmon estimate (845,988) by the average proportion (0.1446) gives an estimated Anvik River summer chum run size of approximately 122,000.

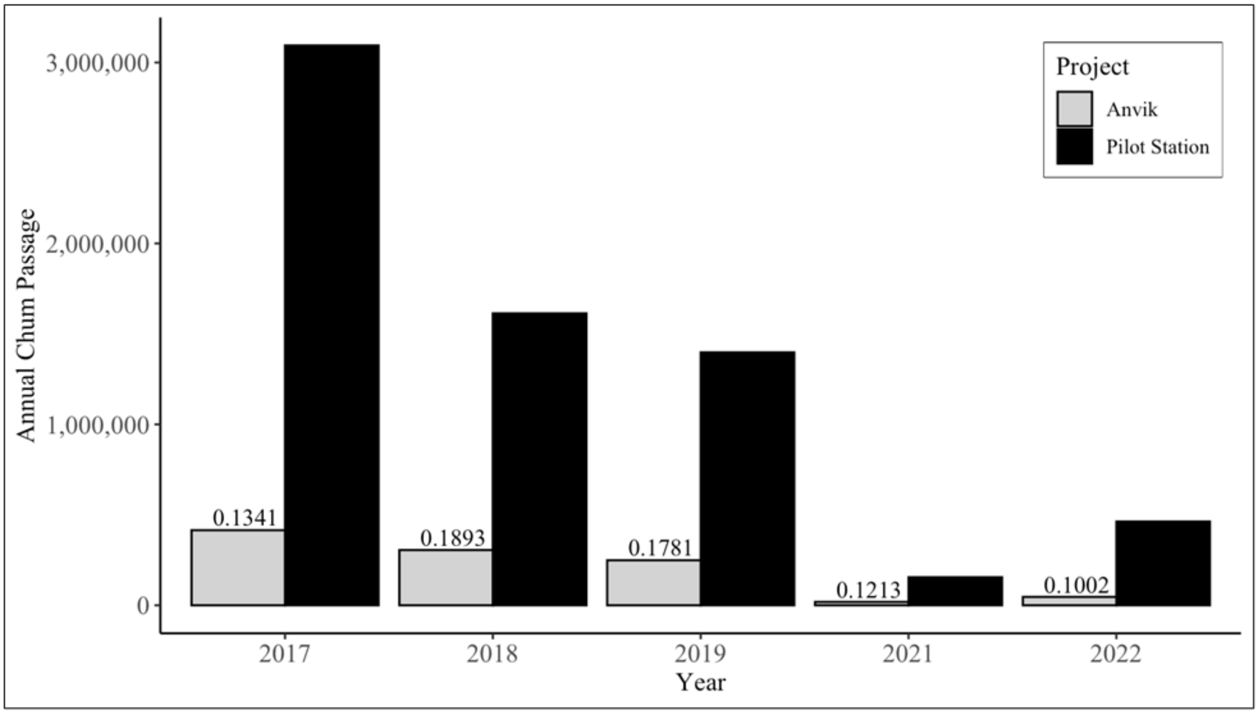

Figure 1.–Anvik River and Pilot Station summer chum estimates for the years 2017–2022 with yearly proportion.

A Bayesian estimator,[1] which assumes a log normal distribution of the run, estimated that approximately 61,000 fish passed over the missing days (Figure 1). The estimated total summer chum salmon run to the Anvik River with this method is 122,000.

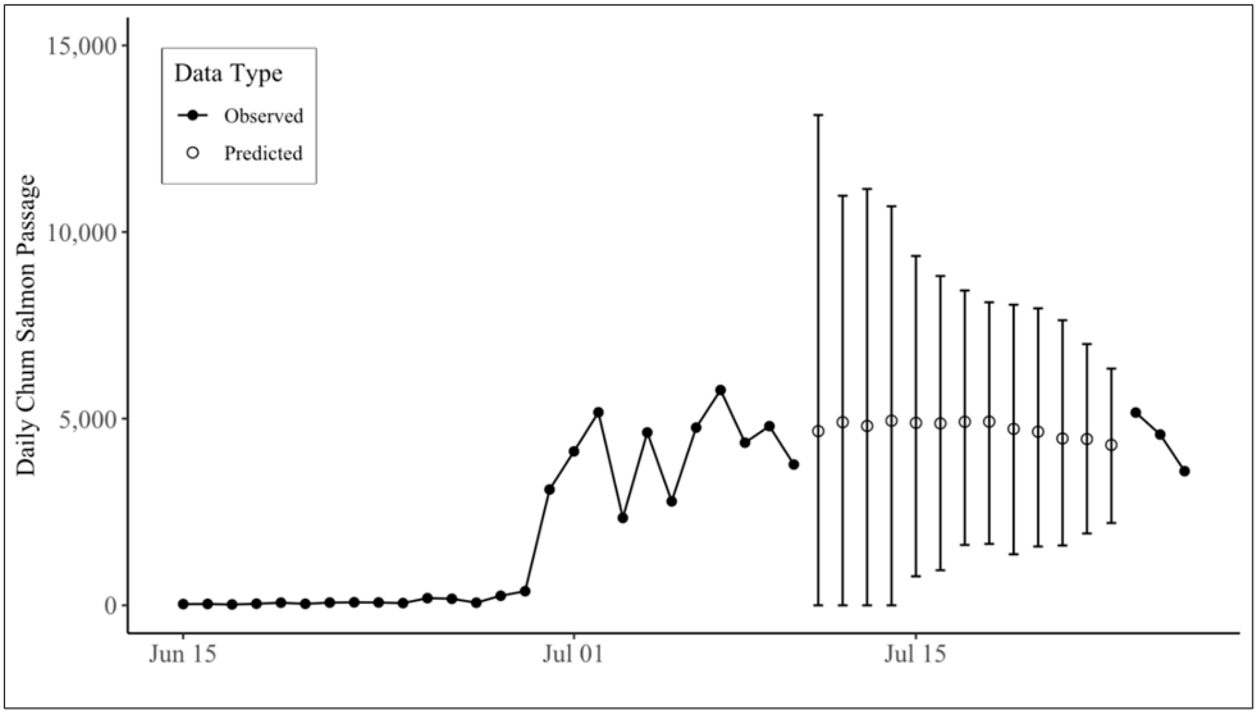

Figure 1.–Daily Anvik River chum salmon passage with Bayesian estimates for missed days with 90% credible intervals, 2023.

1 Hamazaki, T. 2025. Missing passage estimation analyses (source: https://shiny.rstudio.com/). Available from https://hamachan.shinyapps.io/Missed_Run/ (originally cited November 2, 2023; accessed July 11, 2025).