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Sonar Estimation of Summer Chum and Pink Salmon in the Anvik River, Alaska, 2022

by

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

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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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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, 2022. Apportionment to species was determined using data collected from tower counts. A total of 46,436 (SE 769) summer chum and 8,597 (SE 610) pink salmon were estimated to have passed the sonar site. A beach seine sample fishery was conducted to collect age, sex, and length information. In addition, because of low salmon passage, few fish were caught, and the sample fishery was discontinued early. Both sonar systems functioned well with minimal interruptions to operation. 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 are observed during even years in the Yukon River drainage (Estensen et al. 2021), 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 proportioned 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 summer chum salmon passage. However, high water and turbidity during multiple seasons prevented complete estimates (Mauney 1977; Mauney 1979a). Bendix[1] sonar, capable of detecting migrating salmon, was tested alongside the counting towers from 1976 through 1979, and 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 pink salmon estimates in addition to summer chum salmon estimates during even years beginning in 1994 (Sandone 1995). Because of missing or incomplete data, no

[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: October 26, 2022).

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 appropriate 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 1979b, 1980; Mauney and Geiger 1977). In 1980, the site was moved 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, and has remained at this location. The land is public, managed by the Bureau of Land Management (BLM), 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 through 1981, the project performed carcass surveys both upriver and downriver 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 2008–2014. 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 temperature 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: October 26, 2022). Hereafter cited as AYKDBMS.

OBJECTIVES

The goal of this project in 2022 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.
2. Operate DIDSON such that 95% of migrating salmon were detected within three-quarters of the ensonified range on both banks.

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 (α = 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 per day, and data were collected for 30 minutes per hour starting at the top of the 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 flood plain. 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. This season the right bank sloped gradually to the thalweg approximately 35–45 m from shore, and the left bank sloped steeply to the thalweg approximately 20–25 m from shore, depending on water level (Figure 3).

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 4).

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 and plotted from bank-to-bank transects using a boat-mounted Humminbird 998C SI fathometer with GPS. Both banks have been observed to have stable bottom profiles since the project has operated at the current site.

Both banks were ensonified on June 15, and operations ran continuously 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 tilted the DIDSONs 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 (Figure 3), 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 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 to provide sufficient offshore distance for the fish to be detected in 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 per day, and 7 days per week, except for short periods when generators were serviced or adjustments were made to the sonars. Operators opened each 30-minute data file in an echogram viewer program, Echotastic, developed by ADF&G staff (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks), and marked each upstream fish track with a computer mouse. The DIDSON can be used to measure fish length, and this feature has been used for 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 not be salmon. Fish lengths were measured using Echotastic marking tools but 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 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 sampled hourly passage rates and then multiplying by the number of hours in a day 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), and period (p), and y_{dsp} is the count for the same sample.

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. A variance estimator based on the squared differences of successive observations was employed to accommodate these data characteristics (Wolter 1985). The variance for the passage estimate for stratum (s) on day (d) is estimated as:

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

where n_{ds} is the number of samples in the day (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).

MISSING DATA

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

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

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

After 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 to were sent to managers.

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 passing 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 range of visibility 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:

$$p_{disa} = \frac{c_{disa}}{\sum_a c_{disa}} \quad . \tag{4}$$

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:

$$\hat{p}_{dsa} = \frac{\sum_i p_{disa}}{n_d} \quad . \tag{5}$$

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:

$$\hat{y}_{dsa} = \hat{y}_{ds} \cdot \hat{p}_{dsa} \quad . \tag{6}$$

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:

$$Var_{(\hat{p}_{dsa})} = \frac{\sum_i \left(\bar{p}_{dsa} - \hat{p}_{disa}\right)^2}{n(n-1)} \quad , \tag{7}$$

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

$$\widehat{Var}\left(\hat{y}_{dsa}\right) = \hat{y}^2_{ds} \cdot \widehat{Var}\left(\hat{p}_{dsa}\right) + \hat{p}^2_{dsa} \cdot \widehat{Var}\left(\hat{y}_{ds}\right) - \widehat{Var}\left(\hat{y}_{ds}\right) \cdot \widehat{Var}\left(\hat{p}_{dsa}\right) \quad . \tag{8}$$

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

$$\hat{y}_{da} = \sum_{s} \hat{y}_{dsa} \quad , \tag{9}$$

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

$$\hat{y}_{a} = \sum_{d} \sum_{s} \hat{y}_{dsa} \quad . \tag{10}$$

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:

$$\widehat{Var}(\hat{y}_{a}) = \sum_{d} \sum_{s} \widehat{Var}(y_{dsa}) \quad , \tag{11}$$

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

$$\hat{y}_{a} \pm 1.645 \sqrt{\mathrm{Var}(\hat{y}_{a})} \quad . \tag{12}$$

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 2011 to 2021 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 (α = 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 in 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 were noted for sex and measured to the nearest 1 mm from the middle of the eye to 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 gain additional information about these species while pursuing the primary summer chum salmon sampling goal, 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

Overall, there were no significant problems with sonar operation this season, and the objective of estimating summer chum and pink salmon passage in the Anvik River was met. The total summer chum salmon passage estimate at the sonar site was 46,436 (SE 769) from June 15 through July 26 (Table 2). The first quarter point occurred on July 8, the midpoint on July 11, and the third quarter point on July 18. The peak daily passage of 4,844 summer chum salmon occurred on July 9, and 967 summer chum salmon (approximately 2% of the run) passed the sonar on July 26, the last day of sonar operation. When compared to mean historical run timing (2011 to 2021), the summer chum salmon migration was 5 days late at the first quartile and 5 days late at the third quartile (Table 3). The daily passage between the first and third quartile dates ranged from 972 (July 13) to 4,844 (July 9), and an estimated total of 25,545 summer chum salmon passed the sonar site during this time (Table 2). The 2022 summer chum salmon passage estimate was the second lowest ever recorded, approximately 12% of the 2011–2021 average Anvik River passage estimate of 380,437 fish, and substantially below the BEG of 350,000–700,000 fish.

The timing of the summer chum salmon run into the Anvik River was similar to the pattern observed at the lower Yukon River sonar project near the village of Pilot Station (Figure 6). Historically, the percentage of Yukon River summer chum salmon bound for the Anvik River has fluctuated and can be broken into 2 distinct periods. During the period from 1995 to 2002, the average contribution was 46%. From 2003 to 2021, the average contribution decreased to 21%. Of the 463,806 summer chum salmon that were estimated to have passed Pilot Station this season, approximately 10% were observed at the Anvik River sonar project (AYKDBMS).

The total pink salmon passage estimate was 8,597 (SE 610) from June 15 through July 26 (Table 4). The first quarter point fell on July 18, the midpoint on July 22, and the third quarter point on July 24. Because sonar operations end before the completion of the pink salmon migration, calculations of quartile statistics were based on the proportion of the run during the time the sonar project was operational. The peak daily passage estimate of 1,199 pink salmon occurred on July 23, and 889 pink salmon passed the sonar on July 26. When compared to mean historical run timing (1994, 2000–2004, and 2008–2018, even years only), the pink salmon migration was 7 days late at the first quartile and 3 days late at the third quartile (Table 5). The daily passage between the first and third quartile dates ranged from 223 (July 24) to 1,199 (July 23), and an estimated total of 4,885 pink salmon passed the sonar site during this time. The 2022 pink salmon passage estimate was the second lowest on record, less than 2% of the mean Anvik River passage estimate of 500,480 fish (1994, 2000–2004, and 2008–2018, even years only). This is the first even year since 2004 that the total pink salmon passage estimate has not exceeded the summer chum salmon passage estimate (Figure 7).

Total sonar passage estimates 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, 3,375 minutes were missed, and on the right bank, 2,152 minutes were missed for a combination of these reasons, which resulted in a total of 654 fish and 2,185 fish being added to the estimates, respectively (Table 6).

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 18 m of the transducer on both the left and right banks (Figure 8). The objective to operate the sonar such that 95% of migrating salmon were detected within three-quarters (15 m) of the ensonified range on both banks was not met. Approximately 84% of the total summer chum and pink salmon passage (Tables 2 and 4) occurred on the right bank.

The left bank displayed a slight diurnal pattern of fish 9assagee at the Anvik River sonar site this season, with a small increase in passage from approximately 1900 through 2300 hours (Figure 9). The right bank did not display any distinct diurnal pattern. When both banks were combined, no pattern was evident.

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 18. The first summer chum salmon was observed on June 22 (Table 7). Proportionally, summer chum salmon accounted for approximately 77% (178 fish) of the total tower count on the left bank and 82% (1,094 fish) on the right bank.

Weather conditions were mostly favorable this season. There were only 3 periods on July 22 when the minimum range of visibility was not observed from the right-bank counting tower. Insufficient tower counts of fish (fewer than 5) occurred on most days from June 18 through July 7 and again from July 12 through July 22 on the left bank. On the right bank, insufficient tower counts occurred on most days from June 18 through July 4. Because of insufficient numbers of fish on these days, multiple days were combined to apportion sonar passage estimates to species.

SUMMER CHUM SALMON AGE, SEX, AND LENGTH DATA COLLECTION

In 2022, temporal strata were defined as June 15–July 7, July 8–July 10, July 11–July 17, and July 18–July 26 (Table 3). Between July 1 and July 21, a total of 356 summer chum salmon ASL samples were obtained: 43 during the first quartile, 61 during the second quartile, 189 during the third quartile, and 63 during the fourth quartile. Of these samples, 345 scales (97%) were analyzed as ageable postseason. The sample size goal of 162 summer chum salmon was only achieved in one quartile; therefore, the objective of collecting a minimum of 162 samples during each temporal stratum was not met this season (AYKDBMS).

CLIMATIC AND HYDROLOGIC OBSERVATIONS

The objective of monitoring weather and water parameters daily at the project site was met in 2022. In general, the water level decreased from the beginning of the project through July 20, then rose rapidly from July 21 through July 26 (Figure 10). Overall, between June 18 and July 26, the minimum and maximum water level differed by 92 cm. Water temperatures at the project ranged from a low of 9.0°C on July 23 to a high of 19.3°C on July 10 (Figure 11). Air temperatures ranged from a low of 10.3°C on July 25 to a high of 28.1°C on July 9 (Table 8).

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TABLES AND FIGURES

Table 1.–Technical specifications for dual-frequency identification sonars (DIDSON) at the Anvik River sonar project, 2022.

	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, 2022.

Date	Left bank	Right bank	Daily total	Cumulative Estimate	Cumulative Proportion
6/15	10	58	68	68	0.001
6/16	84	75	159	227	0.005
6/17	42	117	159	386	0.008
6/18[a]	91	98	189	575	0.012
6/19	124	28	152	727	0.016
6/20	90	26	116	843	0.018
6/21	190	18	208	1,051	0.023
6/22	84	32	116	1,167	0.025
6/23	100	29	129	1,296	0.028
6/24	24	30	54	1,350	0.029
6/25	28	76	104	1,454	0.031
6/26	22	109	131	1,585	0.034
6/27	44	100	144	1,729	0.037
6/28	19	190	209	1,938	0.042
6/29	50	110	160	2,098	0.045
6/30	60	378	438	2,536	0.055
7/01	68	480	548	3,084	0.066
7/02	8	88	96	3,180	0.068
7/03	52	254	306	3,486	0.075
7/04	57	627	684	4,170	0.090
7/05	96	1,487	1,583	5,753	0.124
7/06	135	2,120	2,255	8,008	0.172
7/07	164	2,059	2,223	10,231	0.220
7/08[b]	821	3,008	3,829	14,060	0.303
7/09	1,332	3,512	4,844	18,904	0.407
7/10	809	3,110	3,919	22,823	0.491
7/11[c]	407	1,559	1,966	24,789	0.534
7/12	257	1,325	1,582	26,371	0.568
7/13	267	705	972	27,343	0.589
7/14	163	971	1,134	28,477	0.613
7/15	346	1,336	1,682	30,159	0.649
7/16	245	1,477	1,722	31,881	0.687
7/17	188	2,232	2,420	34,301	0.739
7/18[d]	207	1,268	1,475	35,776	0.770
7/19	95	704	799	36,575	0.788
7/20	107	884	991	37,566	0.809
7/21	228	1,186	1,414	38,980	0.839
7/22	241	1,958	2,199	41,179	0.887

-continued-

Table 2.–Page 2 of 2.

Date	Left bank	Right bank	Daily total	Cumulative Estimate	Cumulative Proportion
7/23	0	1,126	1,126	42,305	0.911
7/24	16	1,886	1,902	44,207	0.952
7/25	37	1,225	1,262	45,469	0.979
7/26	45	922	967	46,436	1.000
Total	7,453	38,983	46,436		
Variance			592,023		
SE			769		
Lower 90% CI			45,171		
Upper 90% CI			47,701		

Note: Confidence interval (CI) and standard error (SE). The large box indicates the central 50% of the summer chum salmon run.

[a] First day of tower counts.

[b] First quarter point.

[c] Midpoint.

[d] Third quarter point.

Table 3.–Annual passage estimates and passage timing for summer chum salmon runs at the Anvik River sonar project, 2011–2022.

						Days between			
Year	Sonar passage estimate	First count	First quartile	Median	Third quartile	First count & first quartile	First quartile & median	Median & third quartile	First & third quartile
2011	642,527	6/16	7/02	7/07	7/14	16	5	7	12
2012	484,090	6/18	7/09	7/14	7/18	21	5	4	9
2013	577,877	6/17	7/02	7/08	7/11	15	6	3	9
2014	399,795	6/17	7/01	7/05	7/10	14	4	5	9
2015	374,194	6/17	7/05	7/07	7/12	18	2	5	7
2016	337,819	6/16	6/28	7/05	7/13	12	7	8	15
2017	415,139	6/15	6/30	7/04	7/09	15	4	5	9
2018	305,098	6/15	7/03	7/11	7/15	18	8	4	12
2019	249,014	6/16	7/08	7/12	7/15	22	4	3	7
2020	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]	[a]
2021	18,819	6/15	7/08	7/15	7/20	23	7	5	12
2022	46,436	6/15	7/08	7/11	7/18	23	3	7	10
Mean	380,437	6/16	7/03	7/08	7/13	17	5	5	10
Median	386,995	6/16	7/02	7/07	7/13	17	5	5	9
SD	166,002	1.0	3.6	3.7	3.3	3.5	1.7	1.5	2.4

Note: Mean, median, and standard deviation (SD) calculations include data from 2011–2019 and 2021.

[a] The project did not operate in 2020 because of the COVID-19 pandemic.

Table 4.–Pink salmon daily and cumulative passage estimates at the Anvik River sonar project, 2022.

				Cumulative	
Date	Left bank	Right bank	Daily total	Estimate	Proportion
6/15	0	0	0	0	0.000
6/16	0	0	0	0	0.000
6/17	0	0	0	0	0.000
6/18[a]	0	0	0	0	0.000
6/19	0	0	0	0	0.000
6/20	0	0	0	0	0.000
6/21	0	0	0	0	0.000
6/22	0	0	0	0	0.000
6/23	0	0	0	0	0.000
6/24	0	0	0	0	0.000
6/25	0	0	0	0	0.000
6/26	0	0	0	0	0.000
6/27	0	0	0	0	0.000
6/28	0	0	0	0	0.000
6/29	0	0	0	0	0.000
6/30	0	0	0	0	0.000
7/01	0	0	0	0	0.000
7/02	0	0	0	0	0.000
7/03	0	0	0	0	0.000
7/04	0	0	0	0	0.000
7/05	0	0	0	0	0.000
7/06	0	0	0	0	0.000
7/07	0	0	0	0	0.000
7/08	0	0	0	0	0.000
7/09	7	42	49	49	0.006
7/10	78	0	78	127	0.015
7/11	4	0	4	131	0.015
7/12	3	0	3	134	0.016
7/13	3	66	69	203	0.024
7/14	2	126	128	331	0.039
7/15	49	323	372	703	0.082
7/16	35	386	421	1,124	0.131
7/17	188	448	636	1,760	0.205
7/18[b]	159	497	656	2,416	0.281
7/19	73	467	540	2,956	0.344
7/20	16	672	688	3,644	0.424
7/21	35	568	603	4,247	0.494
7/22[c]	37	939	976	5,223	0.608
7/23	172	1,027	1,199	6,422	0.747
7/24[d]	90	133	223	6,645	0.773
7/25	183	880	1,063	7,708	0.897
7/26	226	663	889	8,597	1.000
Total	1,360	7,237	8,597		
Variance			372,339		
SE			610		
Lower 90% CI			7,594		
Upper 90% CI			9,600		

Note: The large box indicates the central 50% of the pink salmon run.

[a] First day of tower counts.

[b] First quarter point.

[c] Midpoint.

[d] Third quarter point.

Table 5.–Annual passage estimates and passage timing for pink salmon runs at the Anvik River sonar project, 1994–2022.

						Days between			
Year	Sonar passage estimate	First count	First quartile	Median	Third quartile	First count & first quartile	First quartile & median	Median & third quartile	First & third quartile
1994	252,999	6/27	7/18	7/20	7/22	21	2	2	4
1996	[a]	7/01	[a]	[a]	[a]	[a]	[a]	[a]	[a]
1998[b]	146,095	7/12	7/17	7/20	7/22	5	3	2	5
2000	24,859	7/07	7/13	7/16	7/21	6	3	5	8
2002	131,482	6/30	7/10	7/13	7/15	10	3	2	5
2004	4,512	7/05	7/17	7/19	7/22	12	2	3	5
2006[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]	[c]
2008	734,837	6/29	7/15	7/19	7/22	16	4	3	7
2010	505,509	6/30	7/10	7/15	7/21	10	5	6	11
2012	591,387	7/01	7/07	7/17	7/21	6	10	4	14
2014	973,254	6/26	7/04	7/16	7/21	8	12	5	17
2016	663,617	6/26	7/08	7/21	7/24	12	13	3	16
2017[d]	865	7/01	7/04	7/08	7/15	3	4	7	11
2018	1,122,346	6/25	7/16	7/19	7/23	21	3	4	7
2019	241	7/07	7/12	7/12	7/16	5	0	4	4
2020	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]	[e]
2021	0	NA	NA	NA	NA	NA	NA	NA	NA
2022	8,597	7/09	7/18	7/22	7/24	9	4	2	6
Mean	500,480	6/29	7/11	7/17	7/21	12	6	4	9
Median	548,448	6/29	7/11	7/18	7/21	11	4	4	8
SD	370,090	3.7	4.5	2.4	2.3	5.2	4.1	1.3	4.5

Note: Mean, median, and standard deviation (SD) calculations include data from the following even years: 1994, 2000–2004, and 2008–2018. NA means not available.

[a] Total pink salmon passage was not estimated in 1996.

[b] Because of high turbid water in 1998, tower counts used to apportion pink and summer chum salmon were delayed until July 12.

[c] No data available for 2006.

[d] The project began reporting pink salmon estimates starting in 2017.

[e] The project did not operate in 2020 because of the COVID-19 pandemic.

Table 6.–Sampling time missed, and the resulting number of fish added to the estimate at the Anvik River sonar project, 2022.

	Left bank		Right bank	
Date	Minutes	Fish	Minutes	Fish
6/15	580.0	8	570.1	46
6/16	480.2	56	450.2	47
6/17	127.5	7	30.5	5
6/18	180.4	23	0.5	0
6/19	0.5	0	0.5	0
6/20	0.5	0	0.5	0
6/21	0.5	0	0.5	0
6/22	0.5	0	0.5	0
6/23	60.4	8	30.5	1
6/24	0.5	0	0.5	0
6/25	0.5	0	0.5	0
6/26	72.2	2	32.6	5
6/27	0.5	0	0.5	0
6/28	30.5	1	0.5	0
6/29	30.5	2	0.5	0
6/30	0.5	0	0.5	0
7/01	0.5	0	0.5	0
7/02	150.4	2	0.5	0
7/03	58.1	4	0.5	0
7/04	240.3	19	180.4	157
7/05	150.4	20	168.7	348
7/06	90.4	17	60.4	178
7/07	0.5	0	0.5	1
7/08	0.5	1	0.5	2
7/09	30.5	57	0.5	2
7/10	0.5	1	0.5	2
7/11	30.5	17	0.5	1
7/12	0.5	0	0.5	1
7/13	15.4	6	0.5	1
7/14	30.5	7	0.5	1
7/15	330.2	181	0.5	1
7/16	0.5	0	0.5	1
7/17	0.5	0	0.5	2
7/18	0.5	0	0.5	1
7/19	0.5	0	0.5	1
7/20	196.3	34	180.4	390
7/21	90.4	33	30.5	74
7/22	0.5	0	13.0	52
7/23	0.5	0	0.5	1
7/24	0.5	0	0.5	1
7/25	0.5	0	0.5	1
7/26	390.2	147	390.2	859
Total	3,375.2	654	2,151.8	2,185

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).

Table 7.–Salmon species and proportion of summer chum salmon observed migrating upstream during tower counts by day and bank at the Anvik River sonar project, 2022.

	Left bank					Right bank				
Date	Chum	Chinook	Pink	Sockeye	Proportion chum	Chum	Chinook	Pink	Sockeye	Proportion chum
6/18	0	0	0	0	0.000	0	0	0	0	0.000
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	1	0	0	0	1.000
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	2	0	0	0	1.000
6/28	0	0	0	0	0.000	7	0	0	0	1.000
6/29	0	0	0	0	0.000	2	0	0	0	1.000
6/30	5	0	0	0	1.000	17	0	0	0	1.000
7/01	1	0	0	0	1.000	17	0	0	0	1.000
7/02	0	0	0	0	0.000	1	0	0	0	1.000
7/03	9	0	0	0	1.000	4	0	0	1	0.800
7/04	0	0	0	0	0.000	3	0	0	0	1.000
7/05	6	0	0	0	1.000	39	0	0	0	1.000
7/06	3	0	0	0	1.000	65	0	0	0	1.000
7/07	9	0	0	0	1.000	44	0	0	1	0.978
7/08	9	0	0	0	1.000	56	0	0	0	1.000
7/09	57	0	1	1	0.966	179	7	3	4	0.927
7/10	29	0	5	0	0.853	141	4	0	2	0.959
7/11	19	0	1	3	0.826	26	2	0	0	0.929
7/12	1	0	0	0	1.000	29	0	0	0	1.000
7/13	1	0	0	0	1.000	23	1	3	0	0.852
7/14	2	0	0	0	1.000	18	0	2	0	0.900
7/15	3	0	0	0	1.000	49	1	10	4	0.766
7/16	2	0	1	0	0.667	45	1	13	2	0.738
7/17	3	0	2	0	0.600	78	0	18	4	0.780
7/18	5	0	3	0	0.625	32	1	20	4	0.561
7/19	3	0	1	0	0.750	29	1	21	0	0.569
7/20	6	0	2	0	0.750	26	0	19	0	0.578
7/21	0	0	0	0	0.000	20	0	9	0	0.690
7/22	0	0	0	0	0.000	0	0	0	0	0.000
7/23	0	0	5	0	0.000	58	0	50	0	0.537
7/24	3	0	19	0	0.136	50	0	6	0	0.893
7/25	2	1	8	0	0.182	33	0	27	0	0.550
7/26	0	0	0	0	0.000	0	0	0	0	0.000
Total	178	1	48	4	0.771	1,094	18	201	22	0.819

Table 8.–Climatic observations recorded daily at 1800 at the Anvik River sonar project site, 2022.

		Wind			
Date	Precipitation (code)[a]	Direction[b]	Velocity (kph)	Sky (code)[c]	Air temperature (°C)
6/18	A	N	1.0	O	19.1
6/19	A	NW	2.2	B	19.0
6/20	A	SW	1.2	B	21.4
6/21	A	SW	4.3	B	15.6
6/22	B	SW	1.3	O	14.6
6/23	A	SW	2.2	B	19.7
6/24	A	N	2.4	B	24.0
6/25	A	N	1.4	O	22.1
6/26	B	NW	1.8	B	18.7
6/27	B	NW	2.8	O	20.5
6/28	A	W	0.6	O	22.1
6/29	A	W	1.4	O	22.2
6/30	A	NW	1.1	C	26.8
7/01	B	NW	1.1	O	16.6
7/02	A	NW	1.6	B	27.4
7/03	A	N	0.5	O	24.0
7/04	A	W	3.6	S	16.1
7/05	A	NE	1.2	O	18.3
7/06	B	W	1.8	O	18.4
7/07	B	NE	3.1	B	17.8
7/08	A	NW	1.1	B	24.6
7/09	A	NW	1.8	S	28.1
7/10	A	NW	2.0	S	26.2
7/11	A	NW	2.1	B	24.3
7/12	B	SW	1.2	S	21.4
7/13	A	NW	1.5	B	23.8
7/14	A	W	3.2	O	17.8
7/15	B	NW	3.2	B	17.6
7/16	B	NW	1.5	B	18.9
7/17	B	NE	9.7	B	20.7
7/18	B	NW	4.3	S	15.1
7/19	B	SW	0.9	O	14.9
7/20	C	NW	1.4	O	11.3
7/21	B	NW	4.3	O	11.8
7/22	B	NW	1.0	O	14.4
7/23	B	NW	1.7	B	19.4
7/24	B	NW	2.3	O	13.5
7/25	B	SW	5.2	O	10.3
7/26	B	W	2.1	O	11.6

[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).

[c] Instantaneous cloud cover gcode: 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.

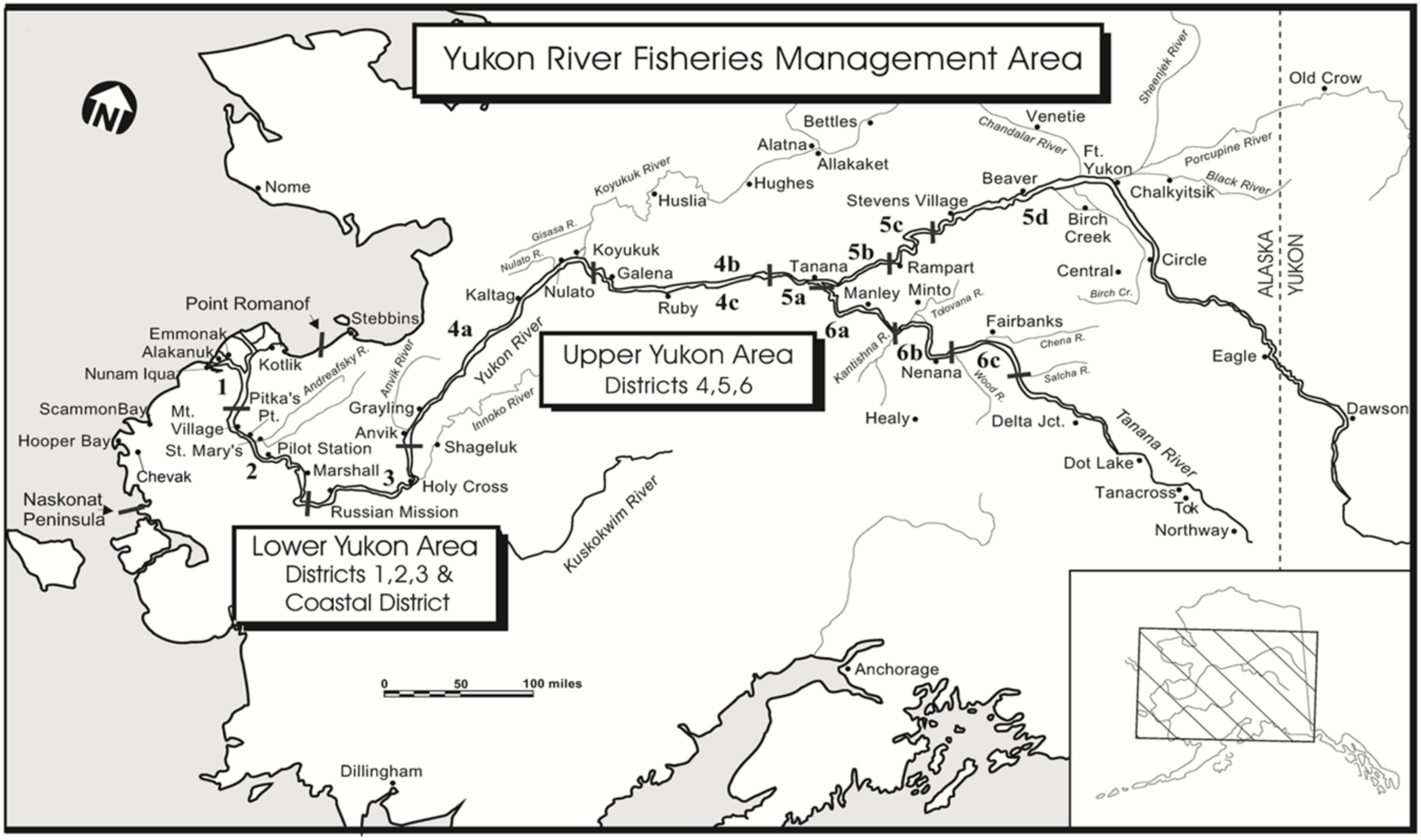


Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

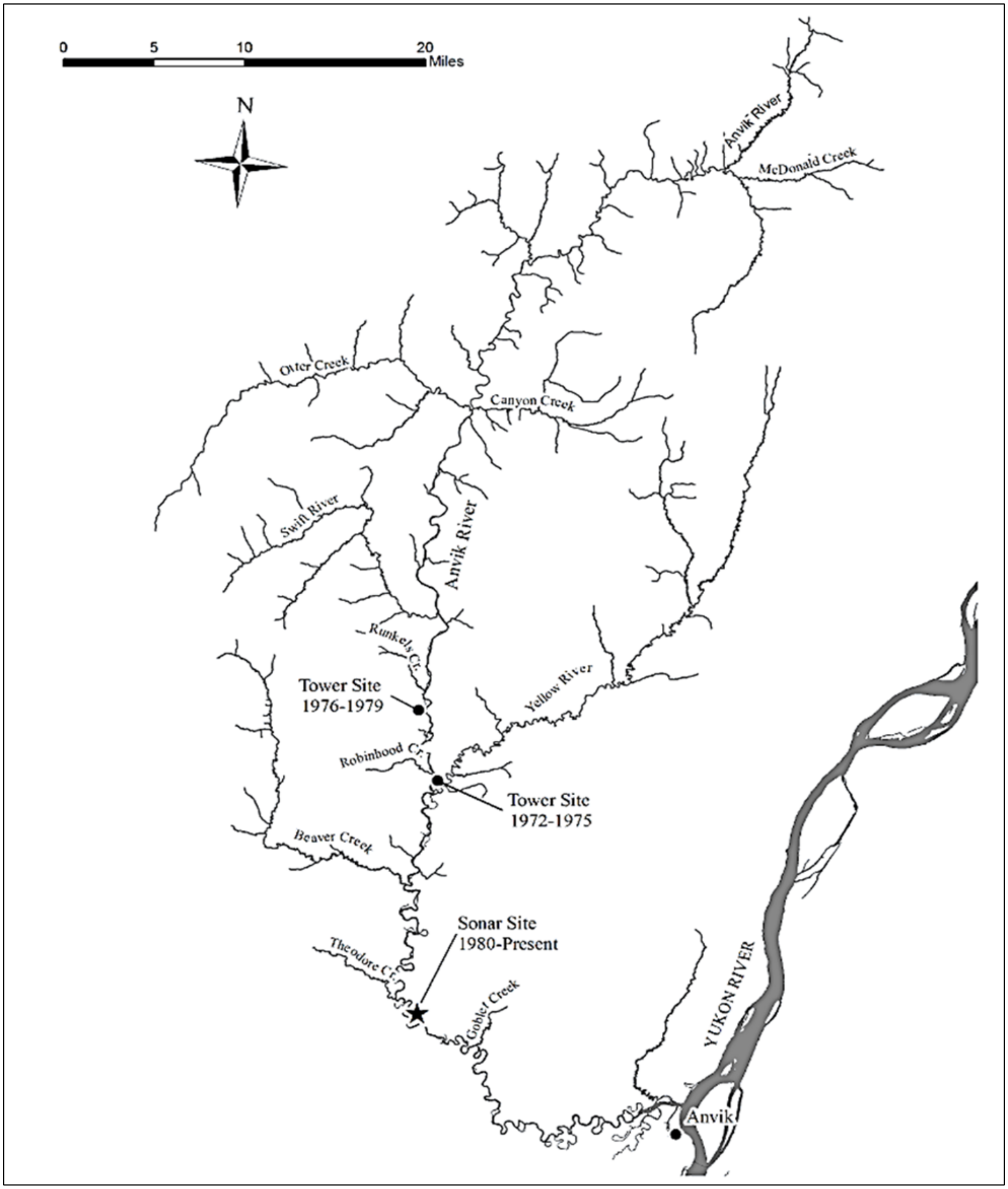


Figure 2.–Anvik River drainage with historical summer chum salmon escapement project locations.

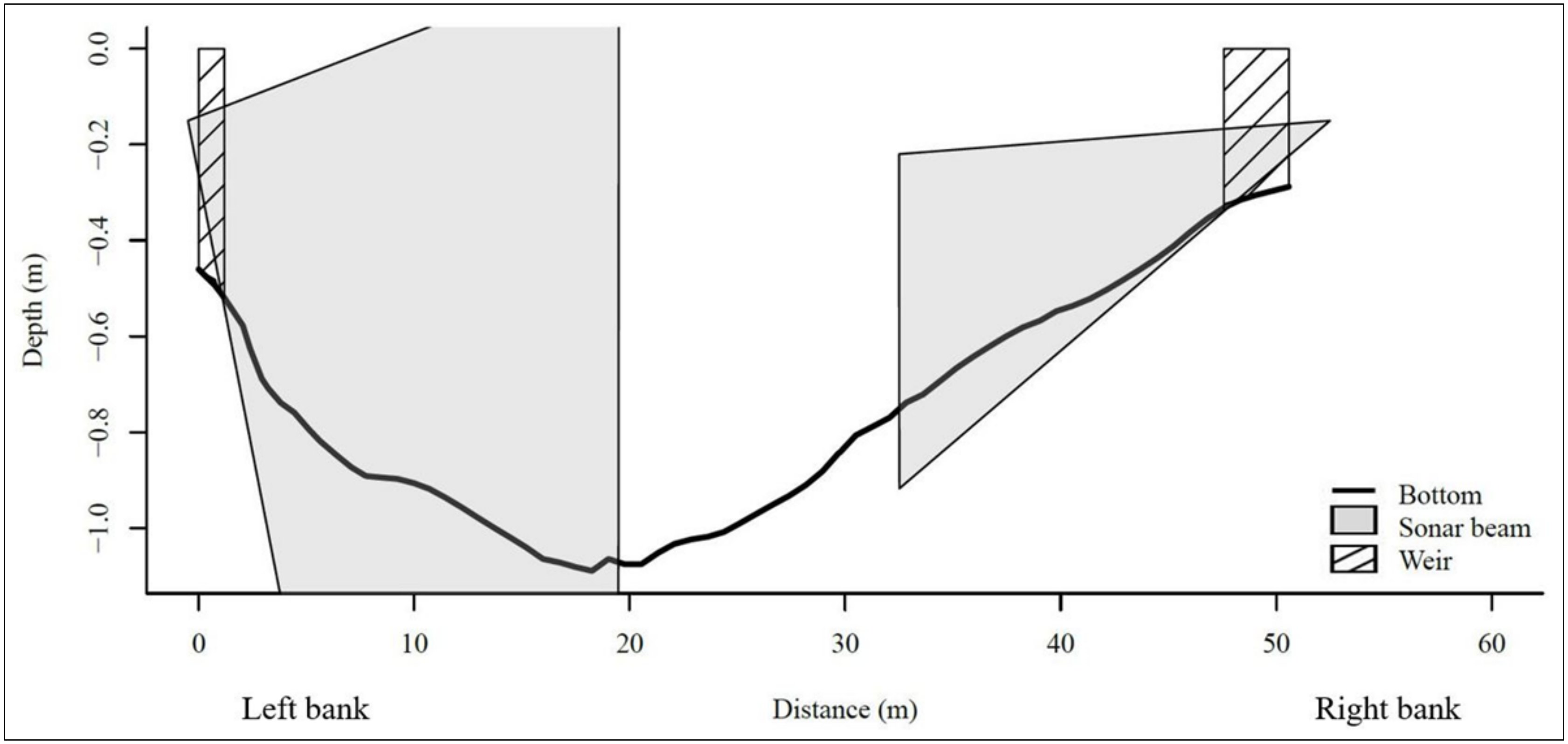


Figure 3.–Depth profile of the Anvik River and approximate sonar ranges (not to scale) at the Anvik River sonar project, June 19, 2022.

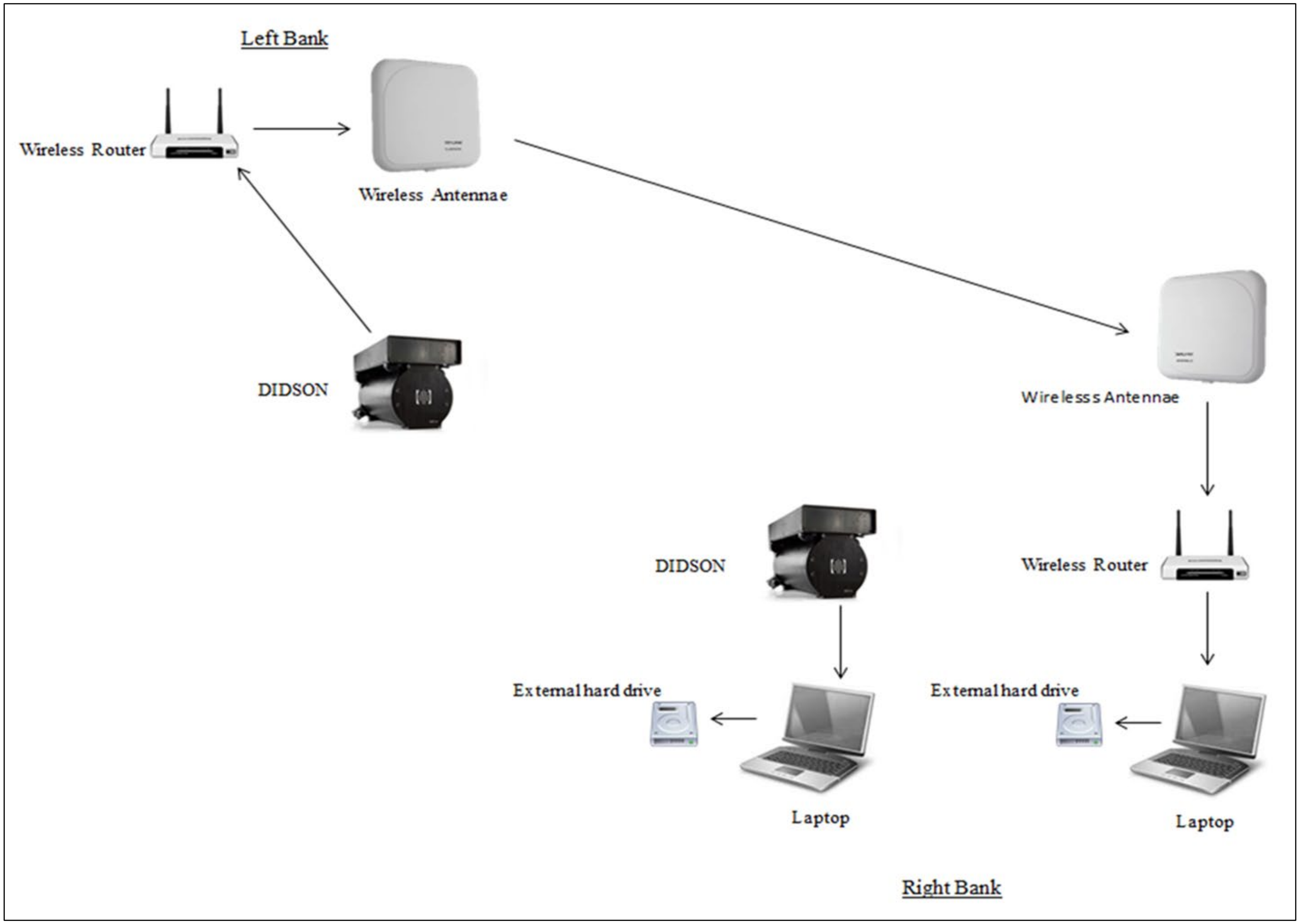


Figure 4.–DIDSON sonar equipment schematic at the Anvik River sonar project, 2022.

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

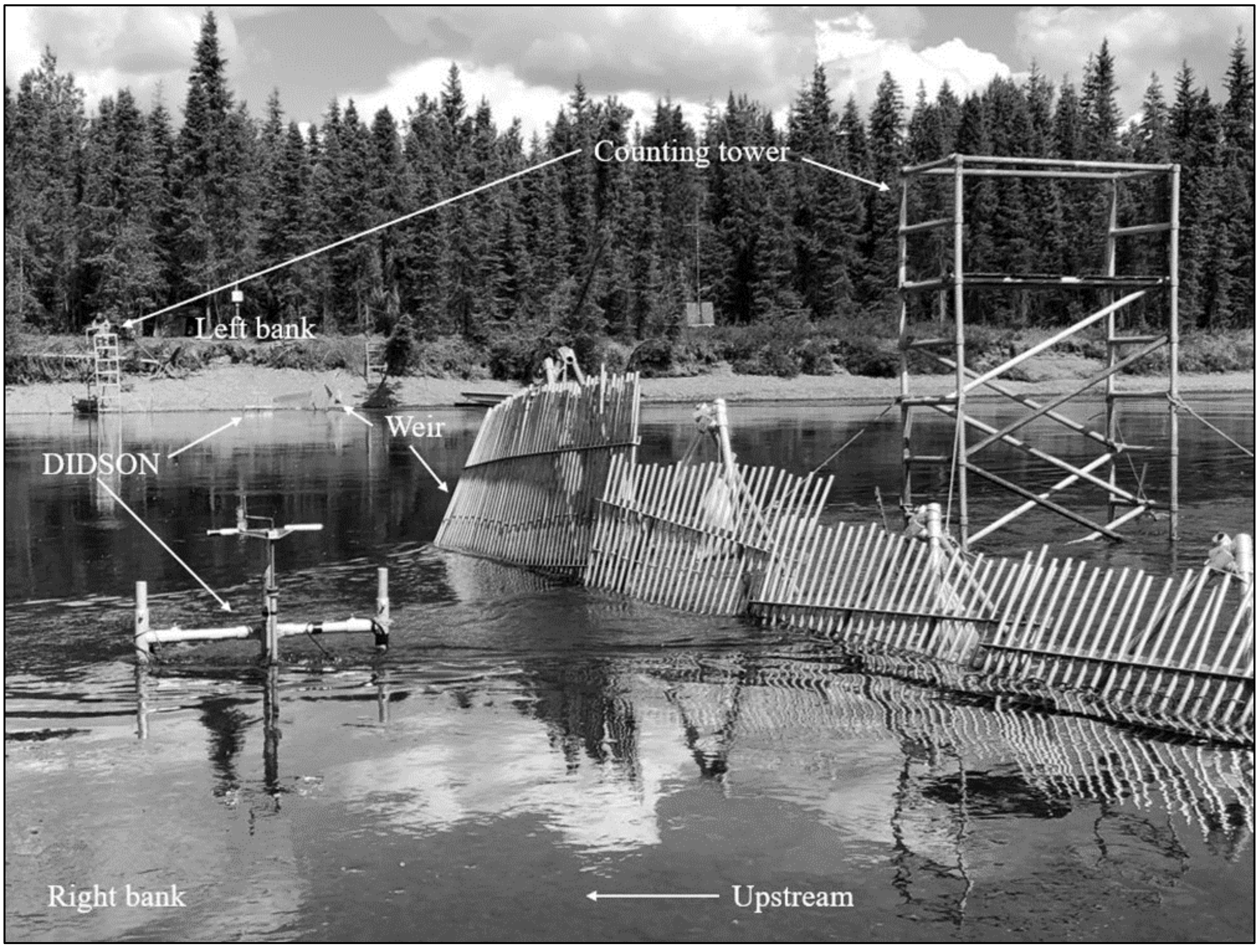


Figure 5.–Anvik River sonar project site illustrating locations of sonars, weirs, and counting towers, 2022.

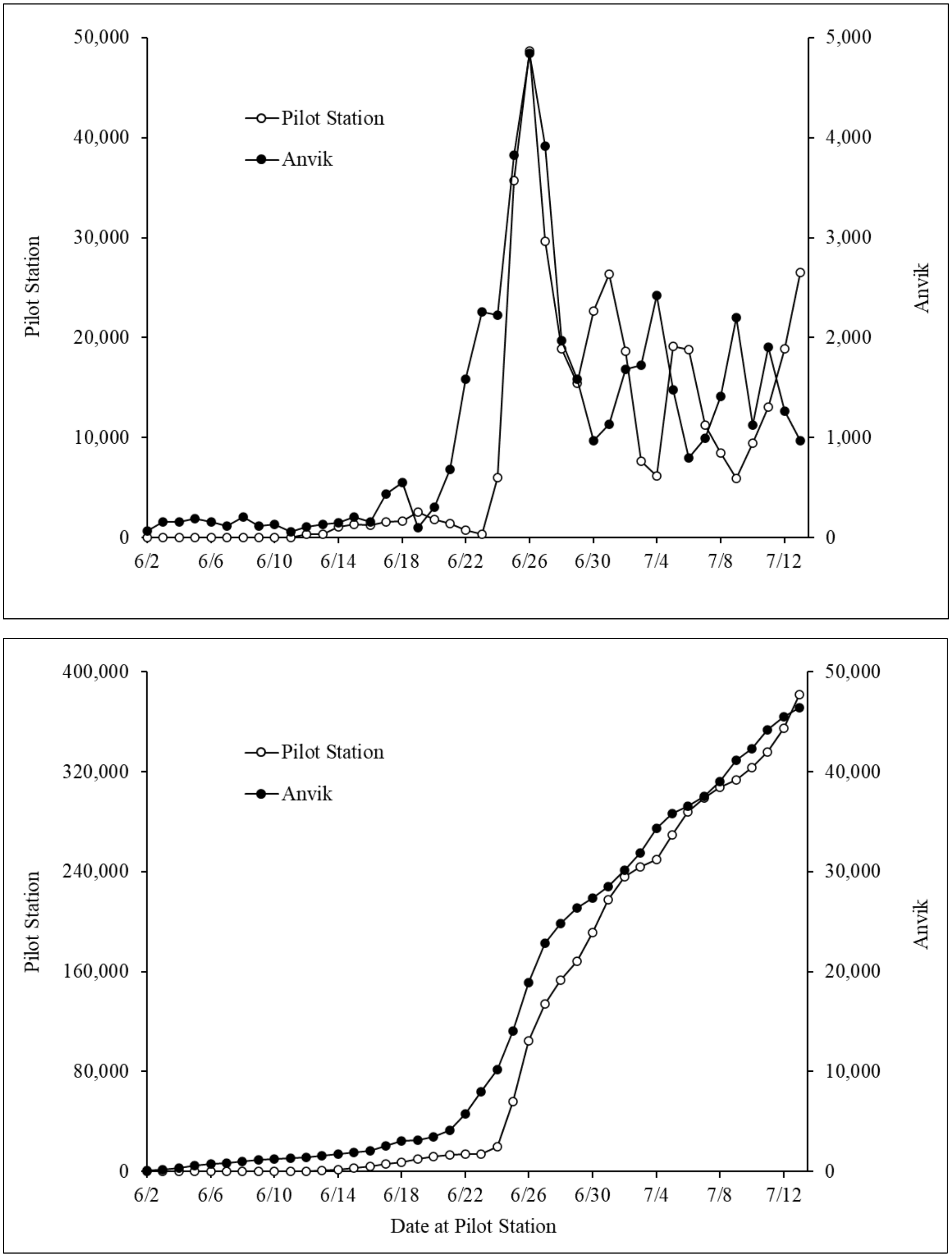


Figure 6.–Daily summer chum salmon passage at the Anvik River sonar project and the sonar project near the village of Pilot Station (top) and cumulative summer chum salmon passage at both projects (bottom), 2022.

Note: The timing of Anvik River summer chum salmon was lagged by 13 days to align with Pilot Station.

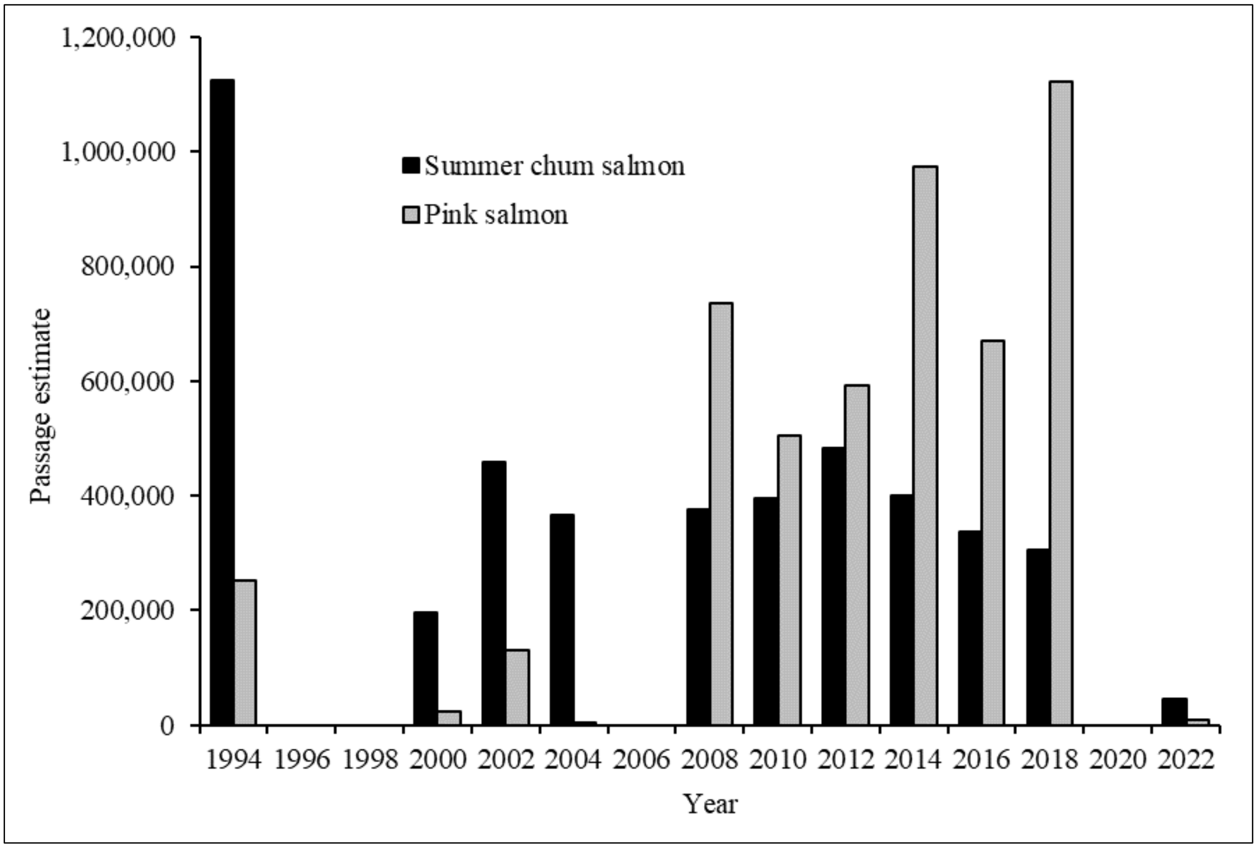
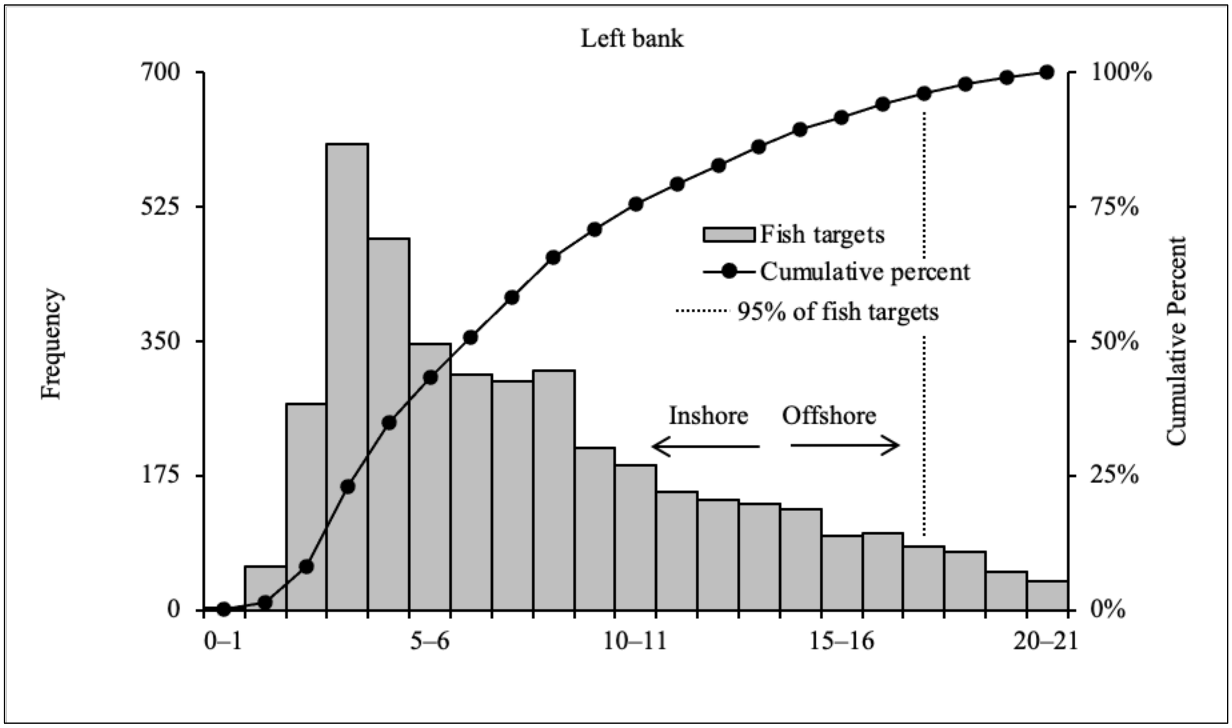


Figure 7.–Summer chum and pink salmon passage estimates during even years from 1994 through 2022 at the Anvik River sonar project.

Note: Pink salmon passage estimates were either incomplete or missing for 1996, 1998, and 2006. The project did not operate in 2020 because of the COVID-19 pandemic.



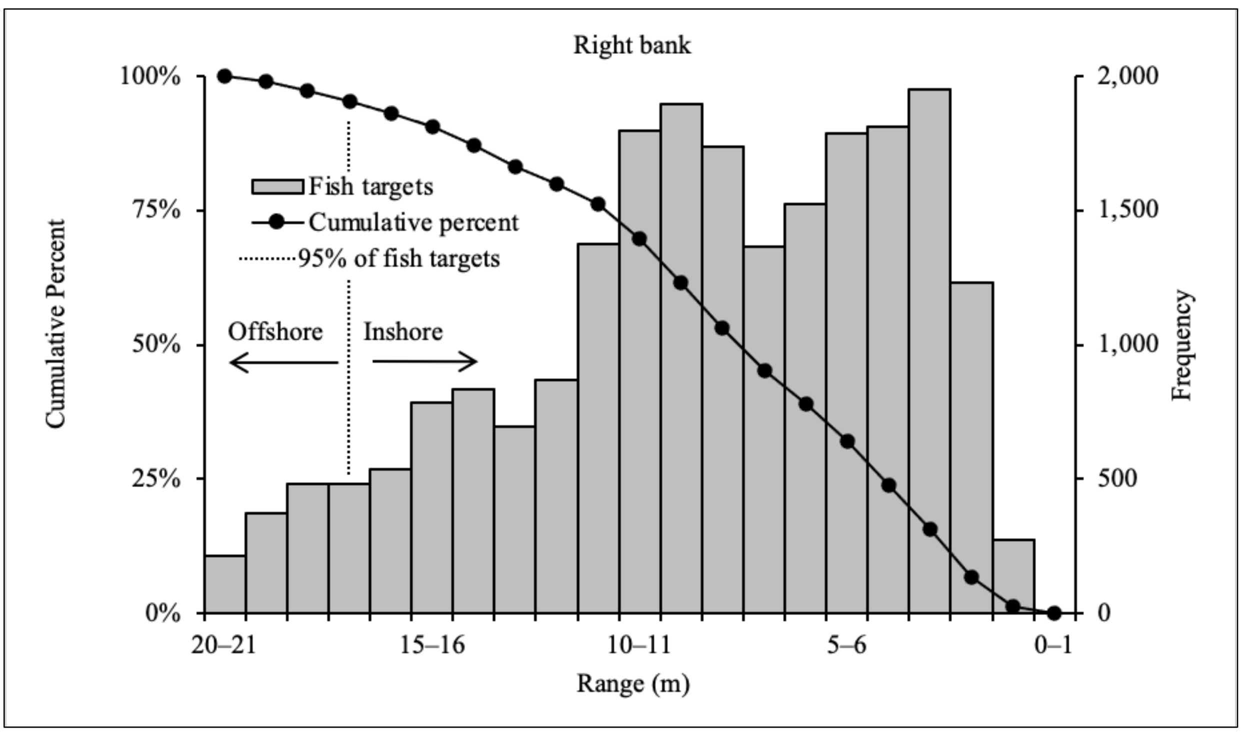


Figure 8.–Left and right bank horizontal distribution of unexpanded fish targets at the Anvik River sonar project, June 15 through July 26, 2022.

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

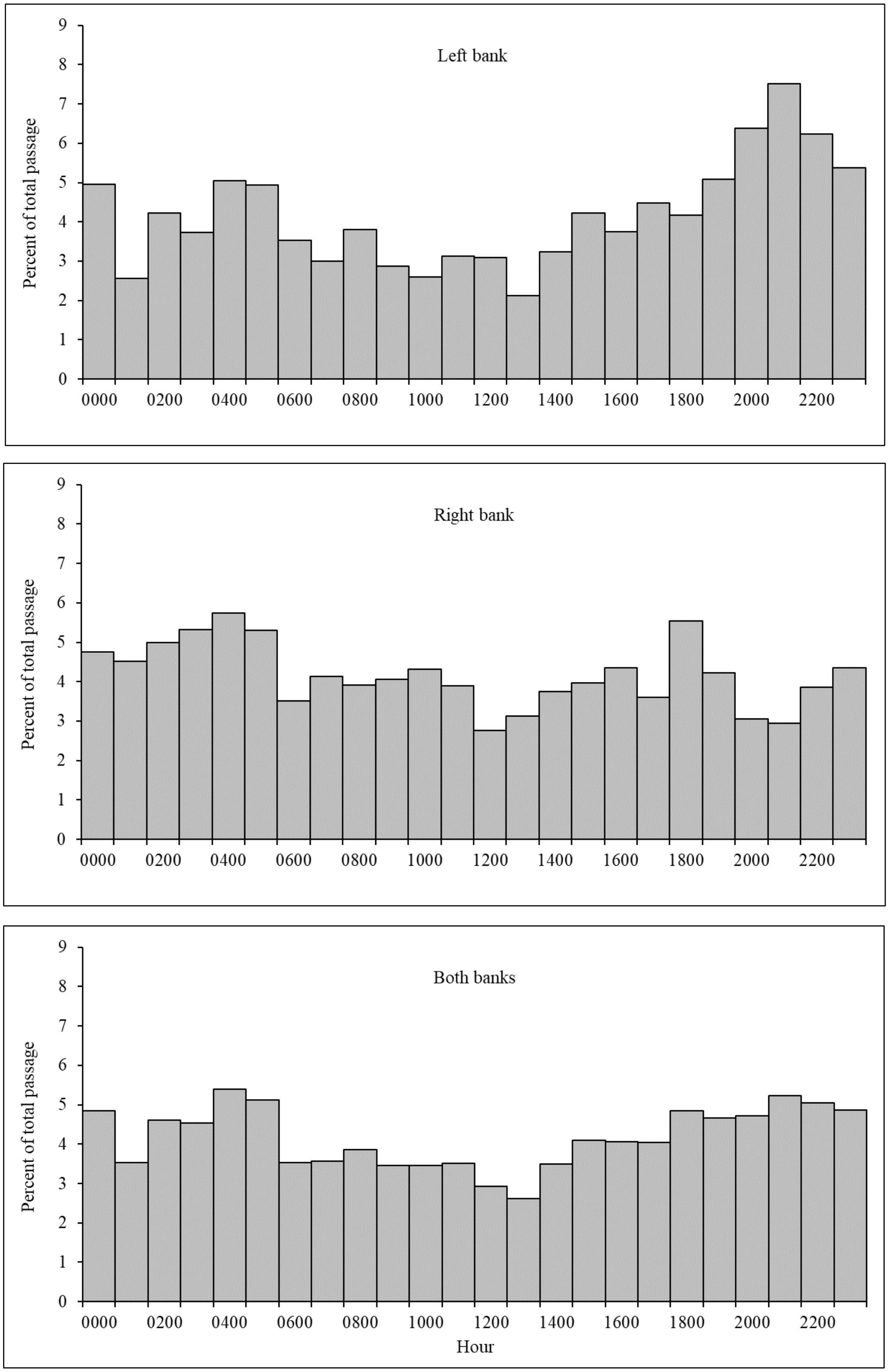


Figure 9.–Percent of total passage, by hour, observed on the left bank, right bank, and both banks combined at the Anvik River sonar project, 2022.

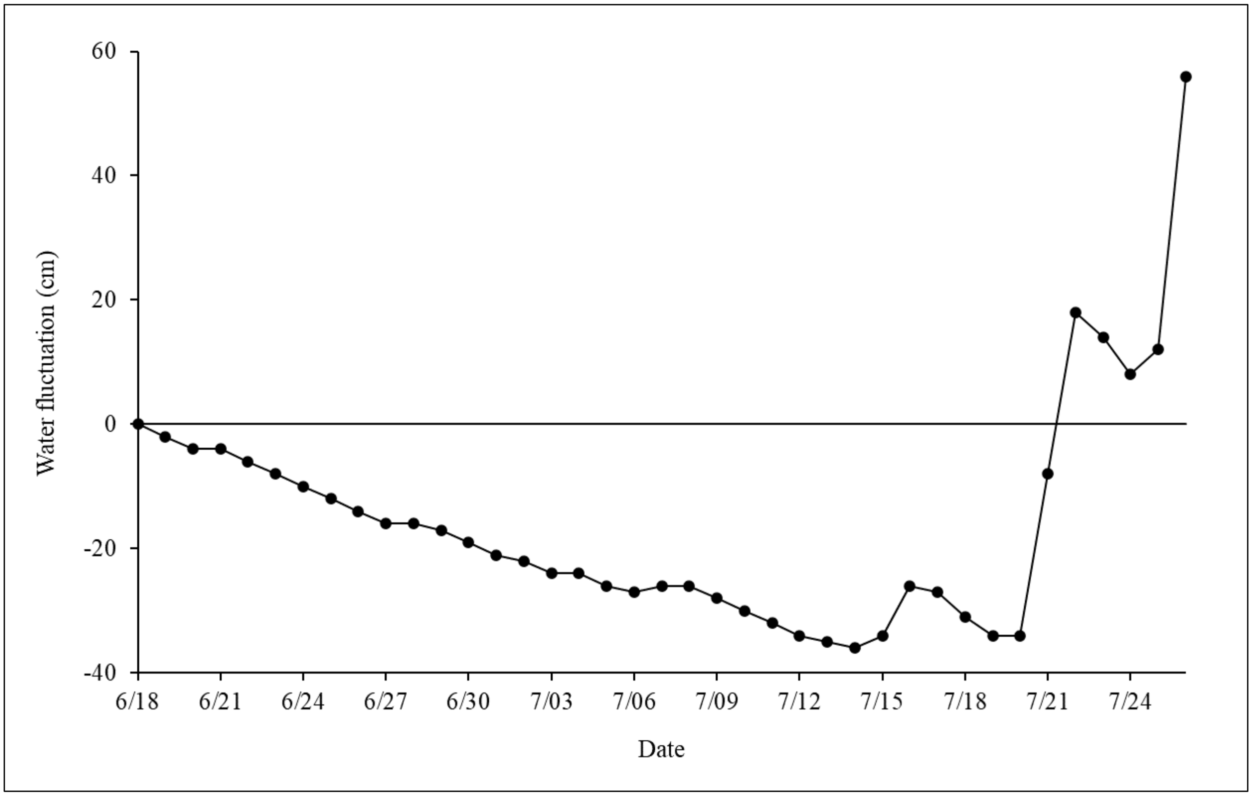


Figure 10.–Change in daily water elevation, relative to June 18, measured at the Anvik River sonar project, 2022.

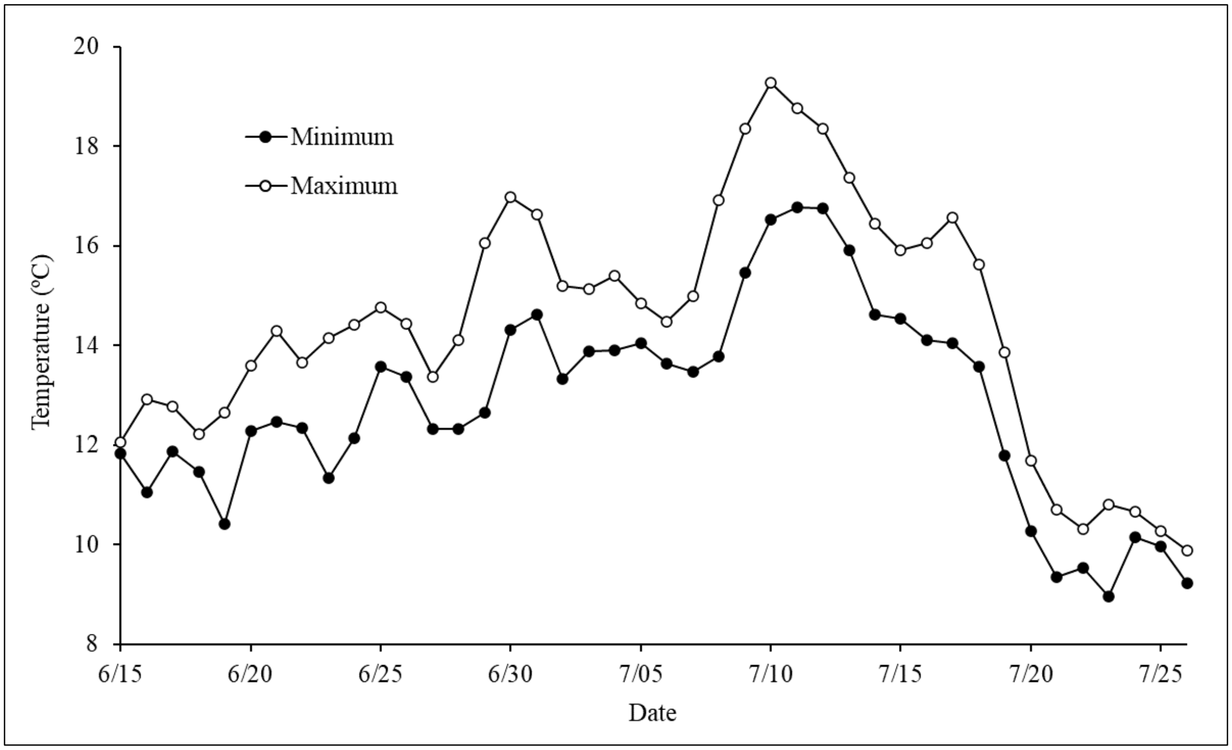


Figure 11.–Daily water temperatures on the left bank at the Anvik River sonar project, 2022.

Note: Water temperature was measured using a HOBO data logger, which electronically recorded the temperature every hour, on the hour.