Fishery Data Series No. 23-26

Sonar Estimation of Summer Chum and Pink Salmon in the Anvik River, Alaska, 2021

by

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August 2023

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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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, 2021. Apportionment to species was determined from data collected from tower counts. A total of 18,819 (SE 273) summer chum and 0 pink salmon were estimated to have passed the sonar site. A beach seine sample fishery was conducted to collect age, sex, and length information; however, high water prevented fishing for part of the season. 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 is observed on even years in the Yukon River drainage (Estensen et al. 2018), 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 on even years beginning in 1994 (Sandone 1995). Because of missing or incomplete data, no pink salmon

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[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 29, 2021).

estimates were produced in 1996 and 2006 (Fair 1997; McEwen 2007). In 2017, the project began producing pink salmon estimates on 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 it was found 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 to 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 (AYKDBMS[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 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 age, sex, and length (ASL) data at the sonar site (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 was operated through 2006 and from 2008 through 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: January 21, 2022). Hereafter cited as AYKDBMS.

OBJECTIVES

The goal of this project in 2021 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 and 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 to 45 m from shore, and the left bank sloped steeply to the thalweg approximately 15 to 20 m from shore, depending on the 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. A laptop computer running DIDSON software controlled each DIDSON, and an external hard drive was 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 from bank-to-bank transects using a boat-mounted Humminbird 998C SI fathometer with GPS capabilities and plotted. Both banks have been observed to have stable bottom profiles since the project began operating at the current site.

Both banks were ensonified on June 15, and operations ran continuously through 1200 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 (Figure 5). 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 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 60–75% 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 6). 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 with 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 sampled hourly passage rates and then multiplying by the number of hours in a day as follows:

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

where h_{dsp} is the fraction of the hour sampled on day (d), stratum (s), 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:

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

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 1 or more days were missed, a daily passage was interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

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

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 were sent to managers.

Species Apportionment

Tower counts were conducted 4 times per day (0730, 1300, 1700, and 2000) for 15 minutes on each bank to apportion the number of summer chum and pink salmon migrating past the sonar site. On both banks, a 4.5 m tower was anchored in the river just downstream of the sonar at the end of the weir (Figure 6). Technicians stood on top of the towers using polarized sunglasses and counted salmon by species passing the sonar. The number of salmon species for each bank and the visible range (meters from the transducer, 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 clarity of 2.0 m for the right bank and 1.0 m for the left bank. Water clarity 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:

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

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 days of insufficient tower count data 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 between 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:

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

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 2010 to 2019 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 was 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 regional 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) was 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 mideye 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 for 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 on 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; however, the right bank counting tower was removed for 6 days in July because of high water. Despite this event, the objective of estimating salmon passage in the Anvik River was met.

The total summer chum salmon passage estimate at the sonar site was 18,819 (SE 273) from June 15 through July 26 (Table 2). The first quarter point occurred on July 8, the midpoint on July 15, and the third quarter point on July 20. The peak daily passage of 2,385 summer chum salmon occurred on July 20, and 612 summer chum salmon (approximately 3% of the run) passed the sonar on July 26, the last day of sonar operation. When compared to the mean historical run timing from 2010 to 2019, the summer chum salmon migration was 5 days late at the first quartile and 7 days late at the third quartile (Table 3). The daily passage between the first and third quartile dates ranged from 144 (July 10) to 2,385 (July 20), and an estimated total of 10,442 summer chum salmon passed the sonar site during this time (Table 2). The 2021 summer chum salmon passage estimate was the lowest ever recorded, less than 5% of the mean Anvik River passage estimate of 418,173 fish (2010 to 2019), and substantially below the BEG of 350,000 to 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 7). 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 2019, the average contribution decreased to 21%. Of the 153,497 summer chum salmon that were estimated to have passed Pilot Station this season, approximately 12% were observed at the Anvik River sonar project (AYKDBMS).

There were no pink salmon observed from the counting towers, and the pink salmon estimate was 0 for the season (Table 4). 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, 2,449 minutes were missed, and on the right bank, 1,536 minutes were missed for a combination of these reasons, which resulted in a total of 337 fish and 487 fish being added to the estimates, respectively (Table 5).

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 17 minutes 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 73% of the total summer chum salmon passage (Table 2) occurred on the right bank.

The left bank displayed a slight diurnal pattern of fish passage at the Anvik River sonar site this season, with a small increase in passage from 1400 through 1900 hours (Figure 9). The right bank also displayed a slight diurnal pattern with a small increase from approximately 0100 to 0500 hours. When both banks were combined, neither pattern was evident.

SPECIES APPORTIONMENT

Summer chum salmon was the most prominent salmon species observed on both banks during tower counts. The right bank tower was installed on June 16, and the left bank tower was installed on June 17. The first summer chum salmon was observed on June 26 (Table 6). Proportionally, summer chum salmon accounted for approximately 82% (37 fish) of the total tower count on the left bank and 90% (212 fish) on the right bank.

Weather conditions were mostly favorable this season; however, because of safety concerns due to high water, the right bank counting tower was removed from July 7 through 12. In addition, the minimum range of visibility (2.0 m for the right bank and 1.0 m for the left bank) from the counting towers was not observed on July 10 and July 11 on the left bank. Insufficient tower counts of fish (fewer than 5) occurred on most days on the left bank, except for July 13 and July 14. On the right bank, insufficient tower counts occurred on most days from June 16 through July 12. 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 COMPOSITION

Beach seining was conducted on July 6 and July 9, but because of record low summer chum salmon passage as well as high water levels, it was discontinued for the remainder of the season. The objective of collecting a minimum of 162 samples during each temporal stratum was not met. A total of 6 summer chum salmon ASL samples were collected on July 6 and 1 sample on July 9. Of these samples, 6 scales were analyzed as ageable postseason; however, because the sample sizes were inadequate, the ASL analysis could not be completed.

CLIMATIC AND HYDROLOGIC OBSERVATIONS

The objective of monitoring weather and water parameters daily at the project site was met in 2021. In general, the water level decreased from the beginning of the project until early July (Figure 10). A rapid increase occurred from July 4 through July 10, after which the water level mostly decreased for the remainder of the season. Overall, between June 17 and July 25, the minimum and maximum water levels differed by 66 cm. Water temperatures at the project ranged from a low of 8.3°C on July 9 and 10 to a high of 14.7°C on July 19 (Figure 11). Air temperatures ranged from a low of 9.0°C on July 9 to a high of 25.2°C on July 12 (Table 7).

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TABLES AND FIGURES

Table 1.–Technical specifications for dual-frequency identification sonars (DIDSON) at the Anvik River sonar project, 2021.

	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, 2021.

Date	Left bank	Right bank	Daily total	Cumulative Estimate	Cumulative Proportion
6/15	32	16	48	48	0.003
6/16[a]	92	8	100	148	0.008
6/17	74	88	162	310	0.016
6/18	74	100	174	484	0.026
6/19	58	31	89	573	0.030
6/20	78	69	147	720	0.038
6/21	52	50	102	822	0.044
6/22	66	94	160	982	0.052
6/23	104	110	214	1,196	0.064
6/24	94	115	209	1,405	0.075
6/25	68	110	178	1,583	0.084
6/26	61	81	142	1,725	0.092
6/27	73	123	196	1,921	0.102
6/28	70	140	210	2,131	0.113
6/29	90	127	217	2,348	0.125
6/30	34	119	153	2,501	0.133
7/01	79	226	305	2,806	0.149
7/02	65	158	223	3,029	0.161
7/03	42	360	402	3,431	0.182
7/04	36	268	304	3,735	0.198
7/05	21	159	180	3,915	0.208
7/06	58	264	322	4,237	0.225
7/07	129	312	441	4,678	0.249
7/08[b]	37	180	217	4,895	0.260
7/09	24	154	178	5,073	0.270
7/10	14	130	144	5,217	0.277
7/11	16	432	448	5,665	0.301
7/12	167	414	581	6,246	0.332
7/13	306	694	1,000	7,246	0.385
7/14	251	900	1,151	8,397	0.446
7/15[c]	378	642	1,020	9,417	0.500
7/16	276	438	714	10,131	0.538
7/17	156	496	652	10,783	0.573
7/18	189	456	645	11,428	0.607
7/19	246	1,061	1,307	12,735	0.677
7/20[d]	520	1,865	2,385	15,120	0.803
7/21	210	726	936	16,056	0.853
7/22	180	442	622	16,678	0.886

-continued-

Table 2.–Page 2 of 2.

Date	Left bank	Right bank	Daily total	Cumulative	
				Estimate	Proportion
7/23	204	533	737	17,415	0.925
7/24	108	284	392	17,807	0.946
7/25	124	276	400	18,207	0.967
7/26	156	456	612	18,819	1.000
Total	5,112	13,707	18,819		
Variance			74,356		
SE			273		
Lower 90% CI			18,370		
Upper 90% CI			19,268		

Note: Confidence interval (CI), 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, 2010–2021.

						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
2010	396,173	6/16	7/08	7/12	7/18	22	4	6	10
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
Mean	418,173	6/16	7/03	7/08	7/13	17	5	5	10
Median	397,984	6/16	7/02	7/07	7/13	17	5	5	9
SD	114,371	0.9	3.6	3.3	2.9	3.3	1.6	1.5	2.3

Note: Mean, median, and standard deviation (SD) calculations include data from 2010 to 2019.

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

Table 4.–Annual passage estimates and passage timing for pink salmon runs at the Anvik River sonar project, 1994–2021.

						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]	[a]	[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]
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
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 in 2006.

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

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

Table 5.–Sampling time missed, and the resulting number of fish added to the estimate at the Anvik River sonar project, 2021.

	Left bank		Right bank	
Date	Minutes	Fish	Minutes	Fish
6/15	540.1	24	540.1	12
6/16	0.5	0	0.5	0
6/17	0.5	0	0.5	0
6/18	0.5	0	0.5	0
6/19	30.5	2	30.5	1
6/20	0.5	0	30.5	3
6/21	0.5	0	0.5	0
6/22	0.5	0	0.5	0
6/23	0.5	0	0.5	0
6/24	0.5	0	5.8	1
6/25	0.5	0	0.5	0
6/26	30.5	3	30.5	3
6/27	30.5	3	30.5	5
6/28	0.5	0	0.5	0
6/29	0.5	0	11.7	2
6/30	0.5	0	90.4	15
7/01	30.5	3	0.5	0
7/02	30.5	3	0.5	0
7/03	0.5	0	0.5	0
7/04	30.5	2	0.5	0
7/05	307.2	9	150.4	33
7/06	65.8	5	0.5	0
7/07	39.1	7	0.5	0
7/08	210.4	11	0.5	0
7/09	0.5	0	0.5	0
7/10	0.5	0	0.5	0
7/11	0.5	0	0.5	0
7/12	30.5	7	0.5	0
7/13	0.5	0	0.5	0
7/14	60.4	21	30.5	38
7/15	0.5	0	0.5	0
7/16	0.5	0	0.5	0
7/17	250.0	54	0.5	0
7/18	180.4	47	0.5	0
7/19	0.5	0	0.5	1
7/20	0.5	0	0.5	1
7/21	0.5	0	0.5	0
7/22	120.4	30	150.4	92
7/23	90.4	26	60.4	45
7/24	0.5	0	0.5	0
7/25	0.5	0	0.5	0
7/26	360.2	78	360.2	228
Total	2,449.2	337	1,535.7	487

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 6.–Salmon species and proportion of summer chum salmon observed migrating upstream during tower counts by day and bank at the Anvik River sonar project, 2021.

	Left bank				Right bank			
Date	Chum	Chinook	Sockeye	Proportion chum	Chum	Chinook	Sockeye	Proportion chum
6/16	ND	ND	ND	ND	0	0	0	0.000
6/17	0	0	0	0.000	0	0	0	0.000
6/18	0	0	0	0.000	0	0	0	0.000
6/19	0	0	0	0.000	0	0	0	0.000
6/20	0	0	0	0.000	0	0	0	0.000
6/21	0	0	0	0.000	0	0	0	0.000
6/22	0	0	0	0.000	0	0	0	0.000
6/23	0	0	0	0.000	0	0	0	0.000
6/24	0	0	0	0.000	0	0	0	0.000
6/25	0	0	0	0.000	0	0	0	0.000
6/26	0	0	0	0.000	2	0	0	1.000
6/27	0	0	0	0.000	1	0	0	1.000
6/28	0	0	0	0.000	0	0	0	0.000
6/29	1	0	0	1.000	0	0	0	0.000
6/30	0	0	0	0.000	0	0	0	0.000
7/01	0	0	0	0.000	0	0	0	0.000
7/02	0	0	0	0.000	0	0	0	0.000
7/03	0	0	0	0.000	4	0	0	1.000
7/04	0	0	0	0.000	8	0	0	1.000
7/05	0	0	0	0.000	0	0	0	0.000
7/06	0	0	0	0.000	1	0	0	1.000
7/07	0	0	0	0.000	ND	ND	ND	ND
7/08	0	0	0	0.000	ND	ND	ND	ND
7/09	0	0	0	0.000	ND	ND	ND	ND
7/10	0	0	0	0.000	ND	ND	ND	ND
7/11	0	0	0	0.000	ND	ND	ND	ND
7/12	0	0	0	0.000	ND	ND	ND	ND
7/13	12	1	0	0.923	7	0	0	1.000
7/14	19	0	1	0.950	12	0	0	1.000
7/15	0	1	0	0.000	9	1	1	0.818
7/16	1	0	0	1.000	18	0	1	0.947
7/17	0	0	0	0.000	12	0	0	1.000
7/18	2	0	0	1.000	16	0	2	0.889
7/19	0	1	0	0.000	37	0	7	0.841
7/20	0	0	1	0.000	28	2	7	0.757
7/21	1	0	2	0.333	11	0	0	1.000
7/22	0	1	0	0.000	10	0	1	0.909
7/23	1	0	0	1.000	16	0	0	1.000
7/24	0	0	0	0.000	15	0	0	1.000
7/25	0	0	0	0.000	5	2	0	0.714
7/26	0	0	0	0.000	0	0	0	0.000
Total	37	4	4	0.822	212	5	19	0.898

Note: ND means no data. No pink salmon were observed from the counting towers in 2021. The left-bank tower was installed on June 17. The right-bank tower was removed because of high water from July 7 through July 12.

Table 7.–Climatic observations recorded daily at 1800 at the Anvik River sonar project site, 2021.

Date	Precipitation (code)[a]	Wind Direction[b]	Wind Velocity (kph)	Sky (code)[c]	Air temperature (°C)
6/17	B	N	1.6	O	15.7
6/18	A	W	2.2	S	20.2
6/19	A	N	2.6	B	20.6
6/20	B	SW	3.6	B	22.3
6/21	B	SW	1.9	B	23.7
6/22	B	NE	0.8	B	19.9
6/23	A	NE	2.2	O	22.1
6/24	A	E	1.2	S	15.9
6/25	B	NE	3.9	O	17.1
6/26	A	N	2.0	O	15.5
6/27	B	SW	1.6	O	14.6
6/28	B	SW	3.5	O	13.1
6/29	A	SW	1.6	B	22.0
6/30	A	NE	0.6	S	16.1
7/01	A	NE	1.0	O	20.2
7/02	B	NE	2.2	B	18.2
7/03	B	N	1.5	O	15.1
7/04	B	N	1.0	B	15.0
7/05	C	NE	1.0	O	12.0
7/06	A	NE	1.8	B	13.8
7/07	A	W	1.3	O	14.5
7/08	A	NE	1.2	O	12.0
7/09	B	SW	4.5	O	9.0
7/10	A	NE	0.5	S	17.5
7/11	A	NA	0.0	S	20.0
7/12	A	SW	0.8	C	25.2
7/13	A	SW	1.4	C	24.3
7/14	A	SW	2.5	C	20.0
7/15	A	SW	1.4	S	21.4
7/16	A	SW	3.5	S	22.6
7/17	A	SW	4.6	B	17.8
7/18	A	NA	0.0	C	23.2
7/19	A	N	1.1	S	24.9
7/20	B	SW	1.8	O	15.3
7/21	A	SW	1.5	O	17.4
7/22	A	SW	0.9	O	16.4
7/23	A	SW	1.7	O	13.4
7/24	A	SW	1.6	B	14.0
7/25	A	SW	1.2	B	15.8

[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 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.

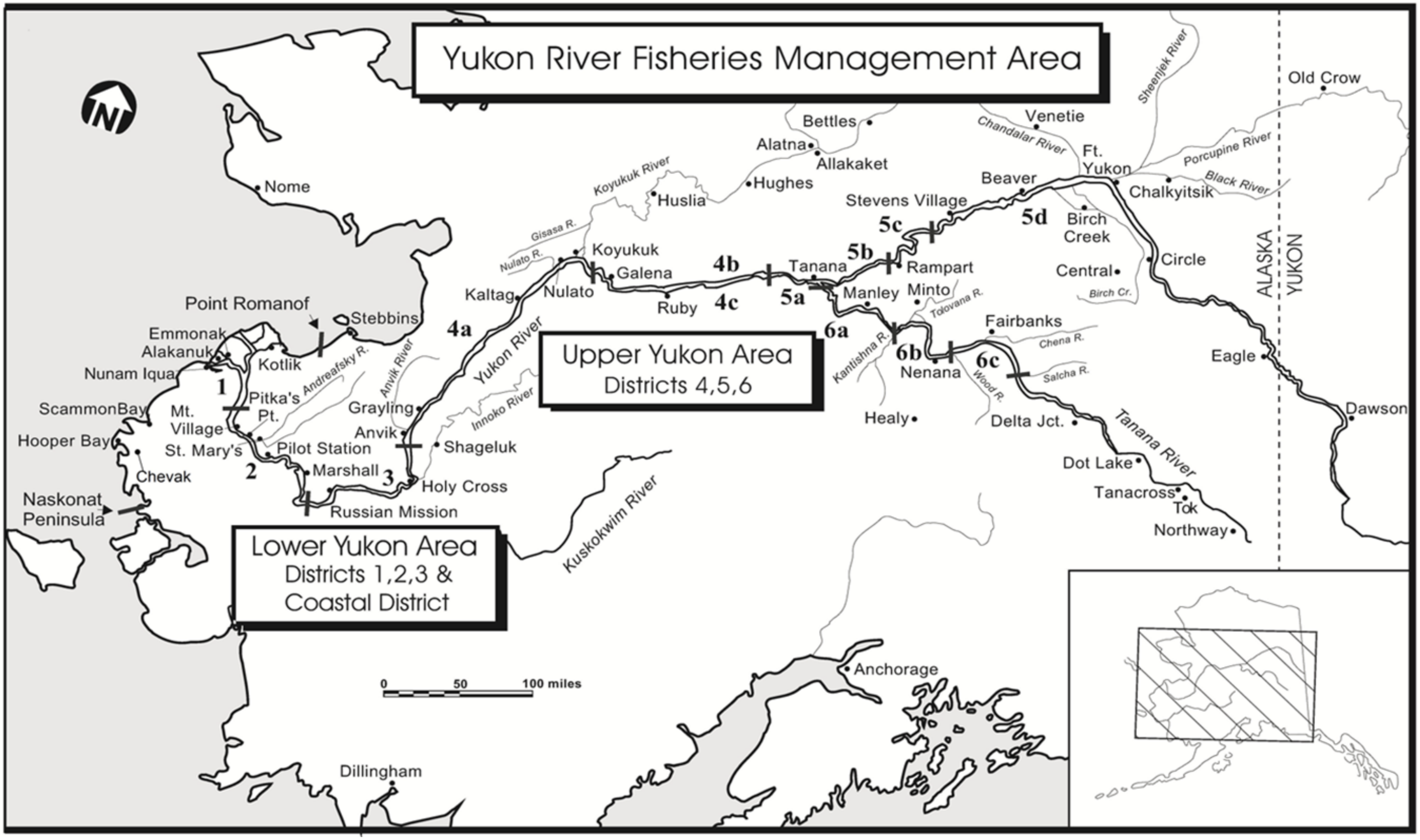

Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

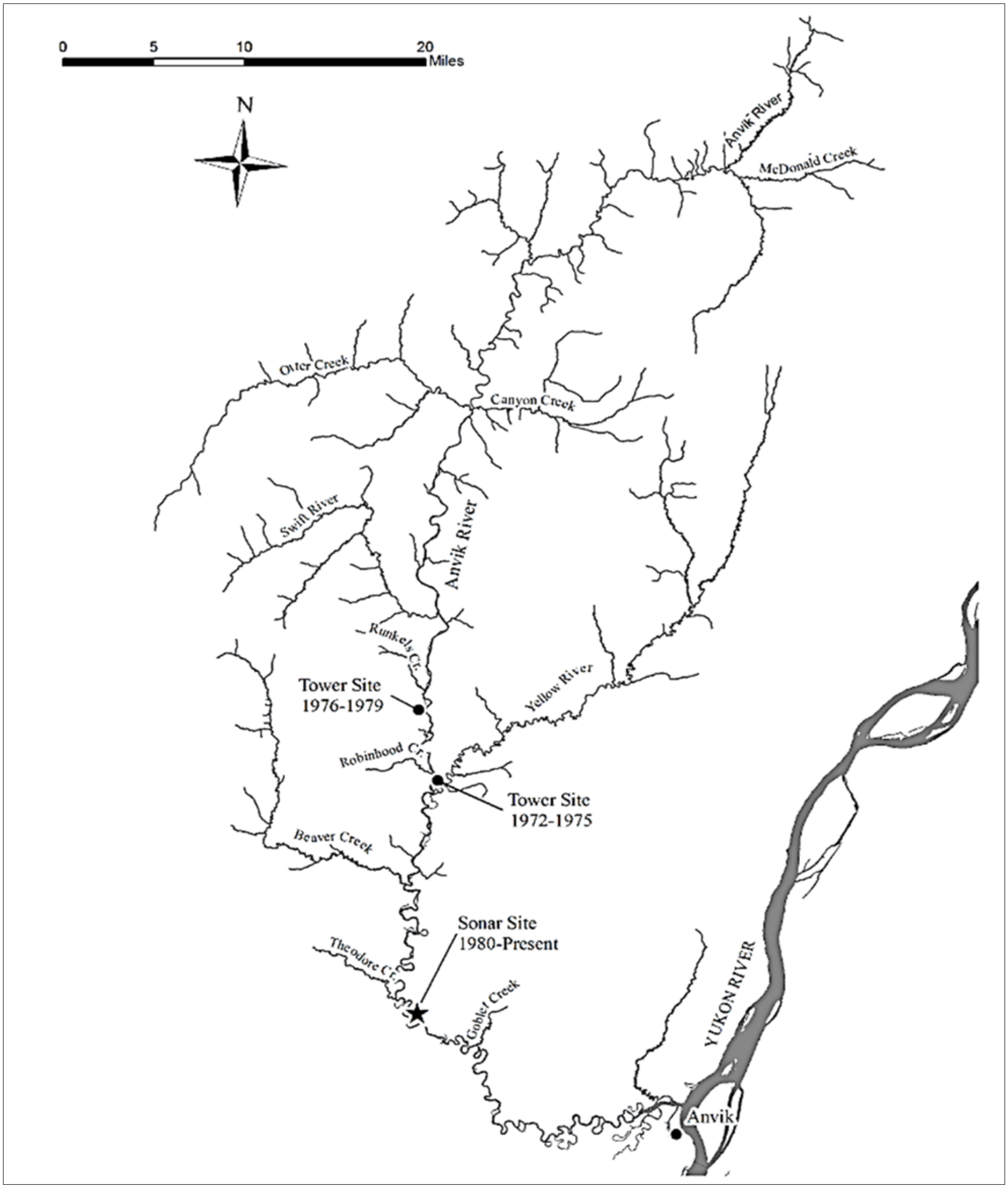

Figure 2.–Anvik River drainage with historical summer chum salmon escapement project locations.

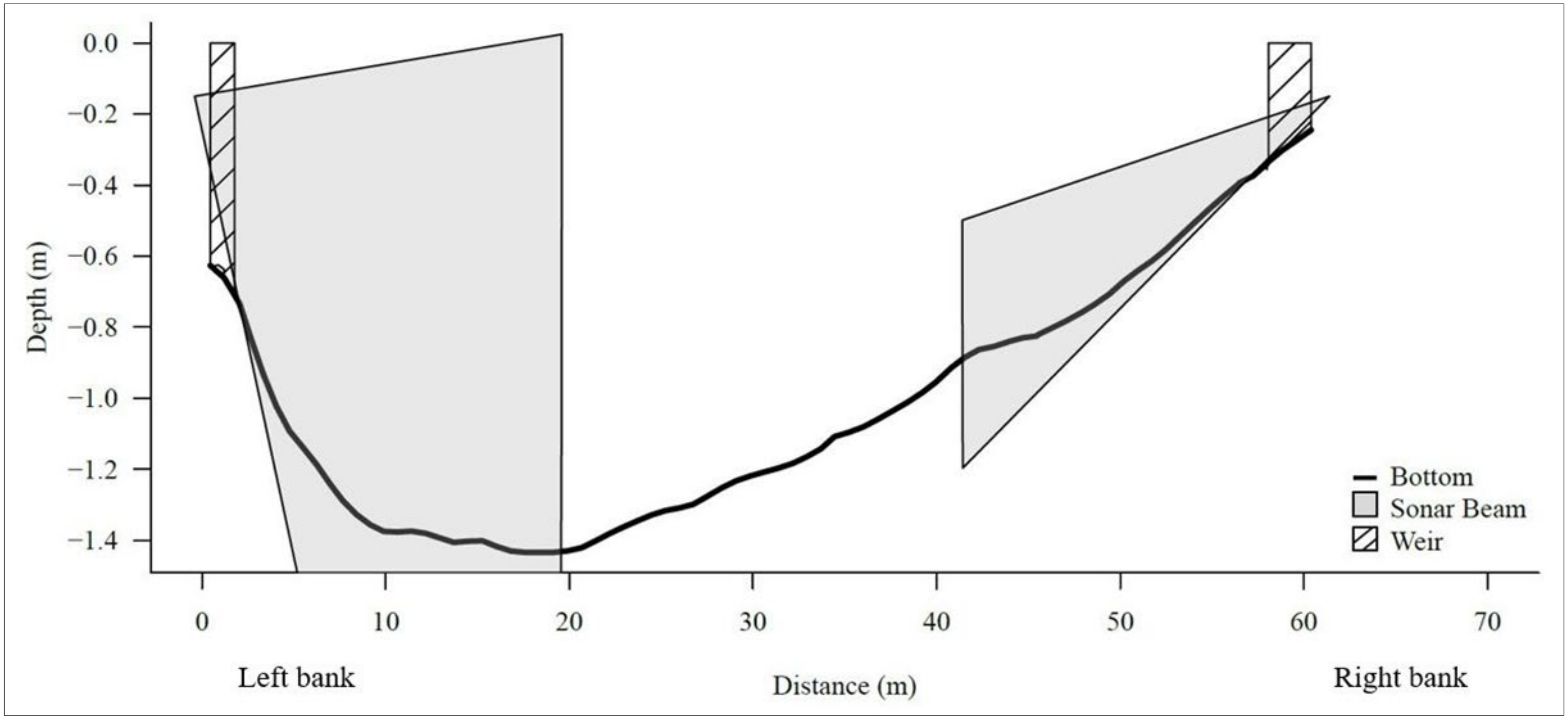

Figure 3.–Depth profile of the Anvik River and approximate sonar ranges (not to scale) at the Anvik River sonar project, June 15, 2021.

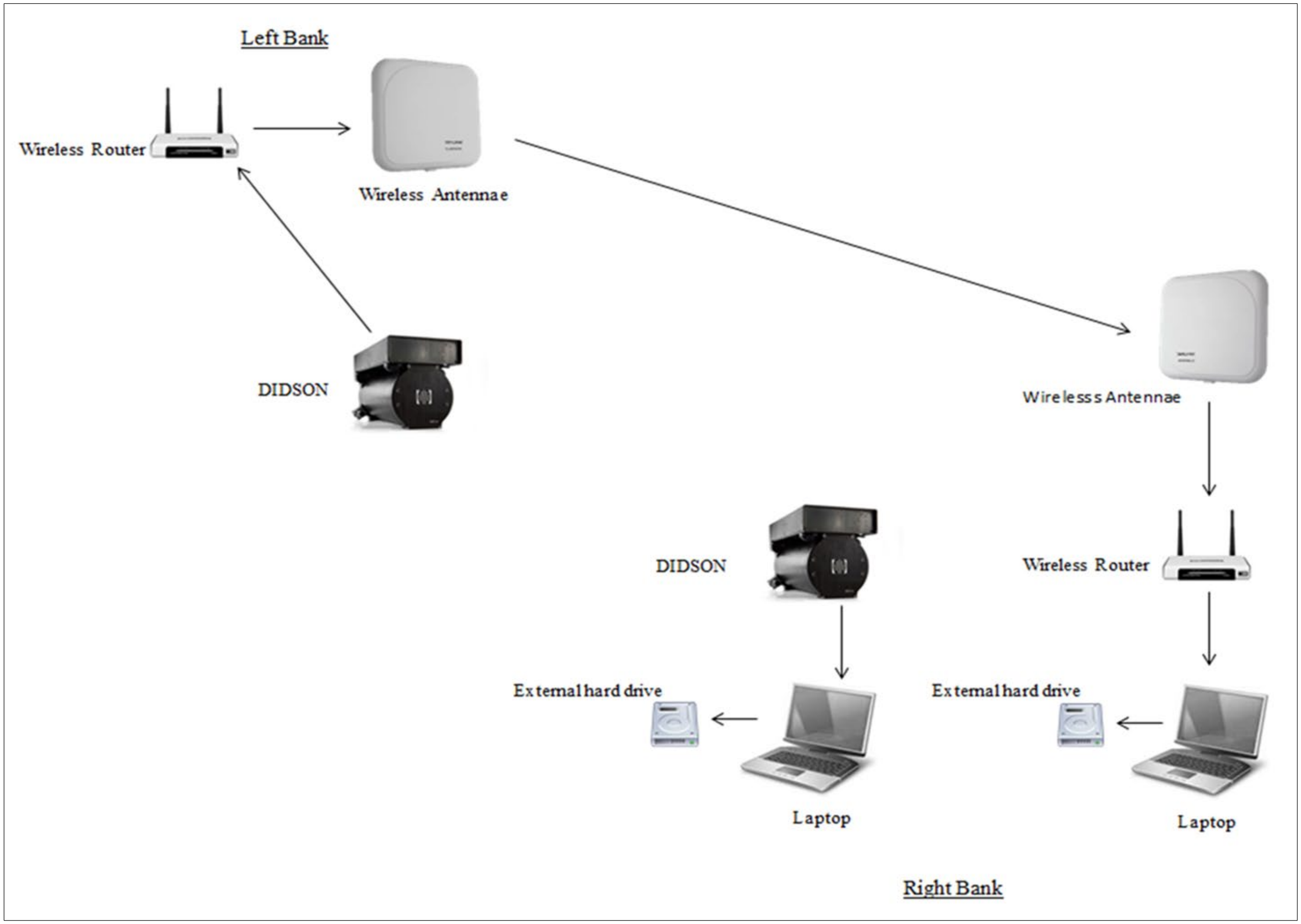

Figure 4.–Dual-frequency identification sonar (DIDSON) equipment schematic at the Anvik River sonar project, 2021.

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

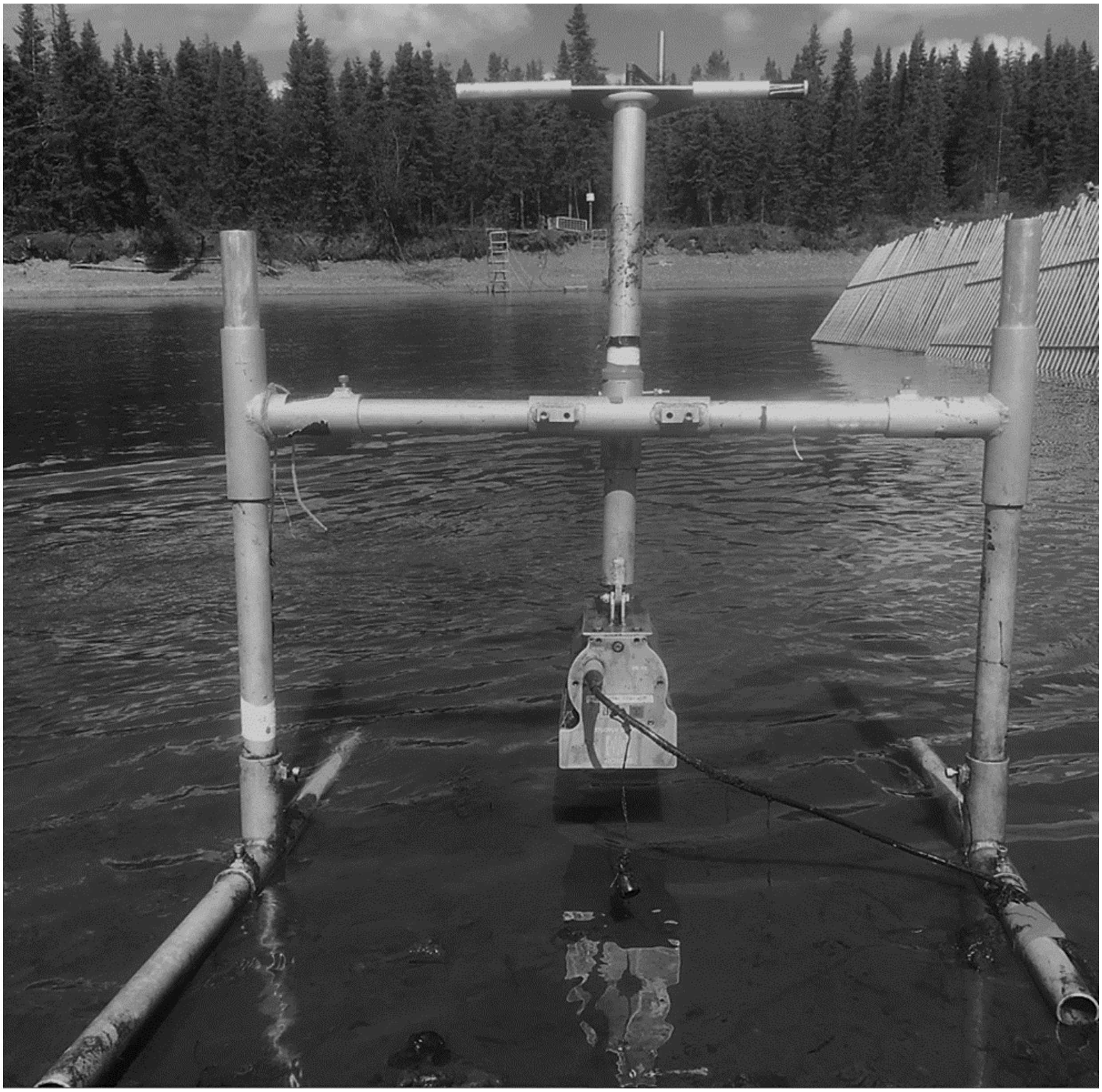

Figure 5.–View of a dual-frequency identification sonar (DIDSON) mounted to aluminum H-mount with manual crank-style rotator at the Anvik River sonar project.

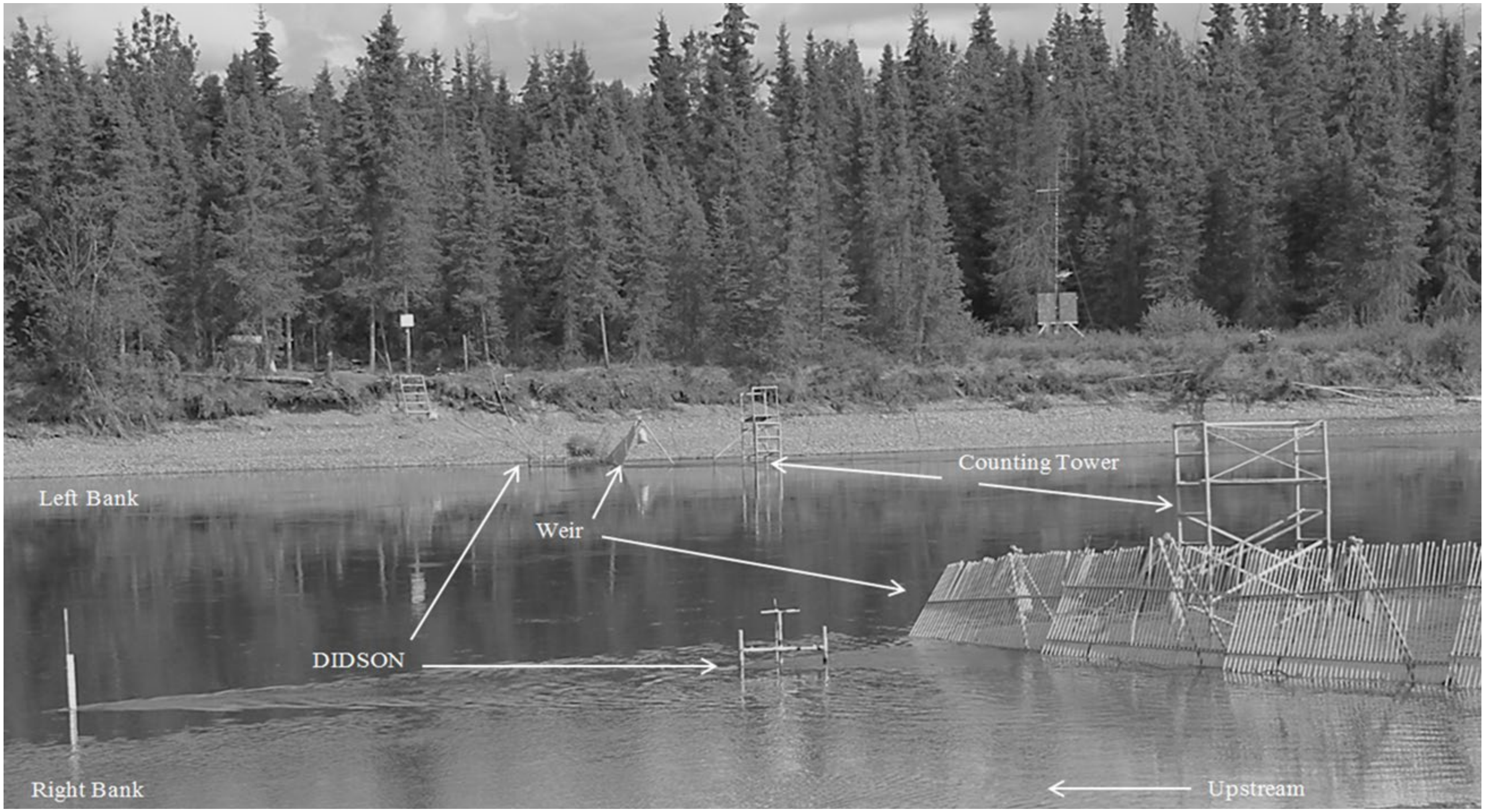

Figure 6.–Anvik River sonar project site illustrating locations of sonars, weirs, and counting towers.

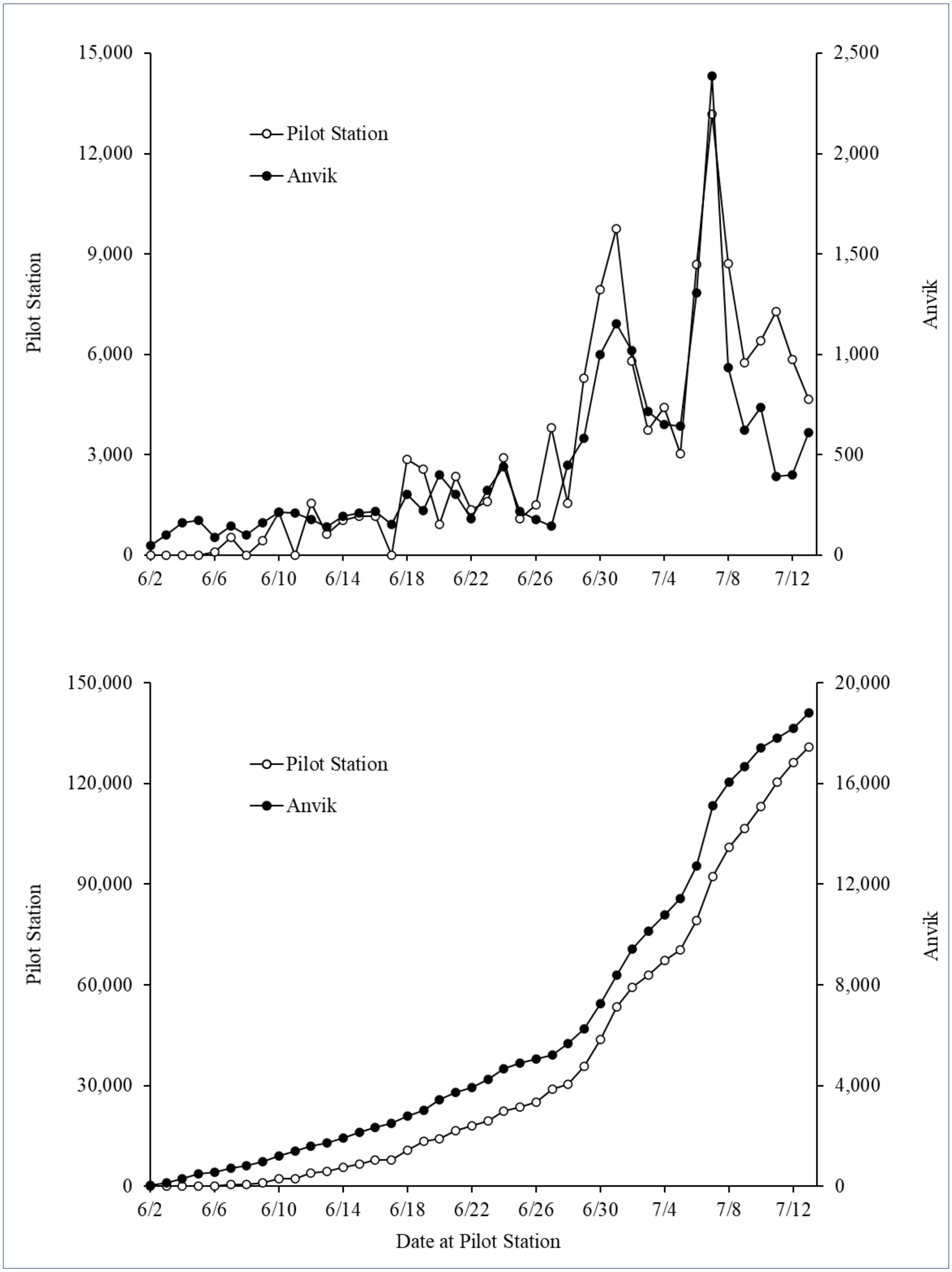

Figure 7.–Daily summer chum salmon passage at the Anvik River sonar project and the sonar project near the village of Pilot Station (top) and cumulative summer chum salmon passage at both projects (bottom), 2021.

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

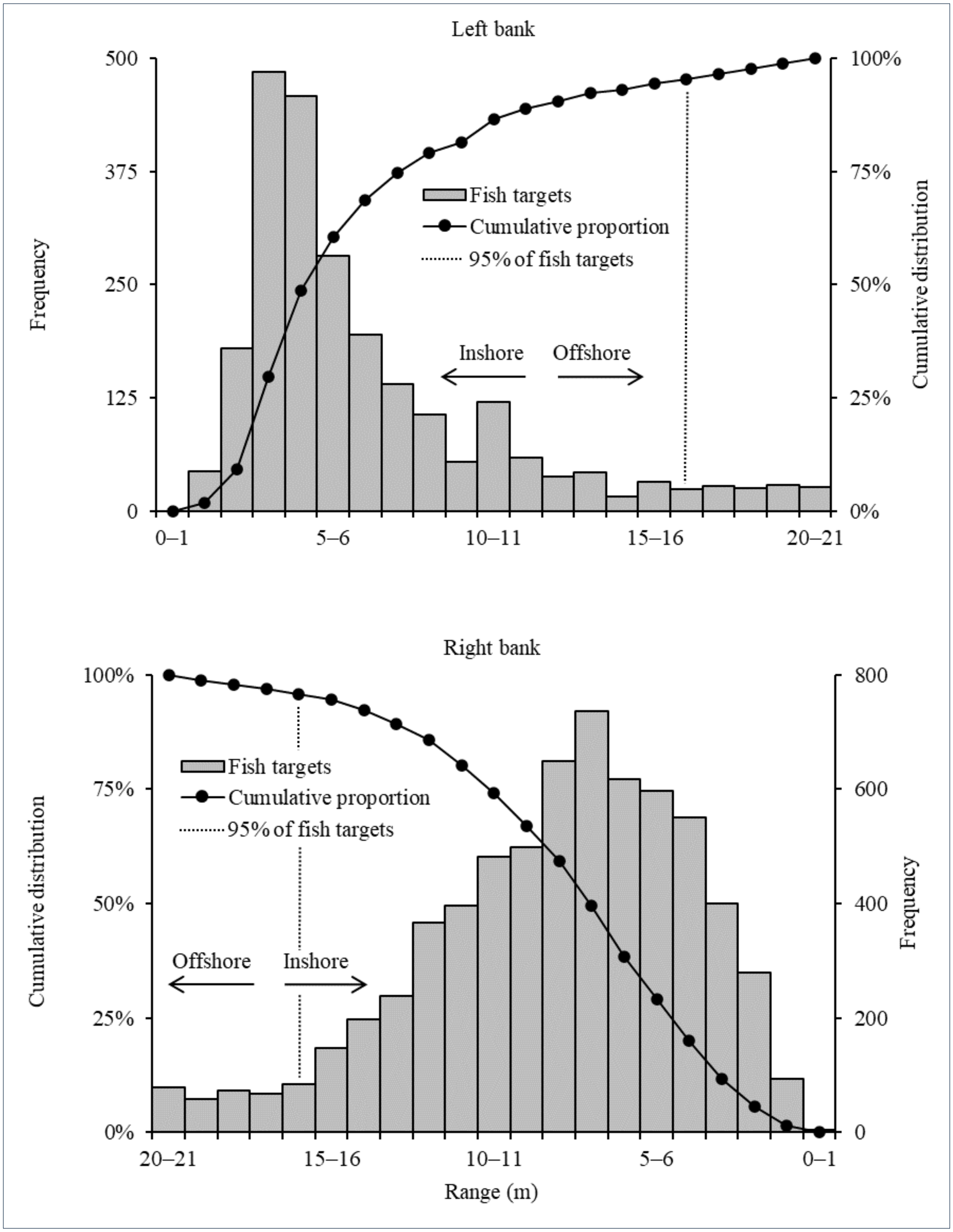

Figure 8.–Left- and right-bank horizontal distribution of unexpanded fish targets at the Anvik River sonar project, June 15 through July 26, 2021.

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

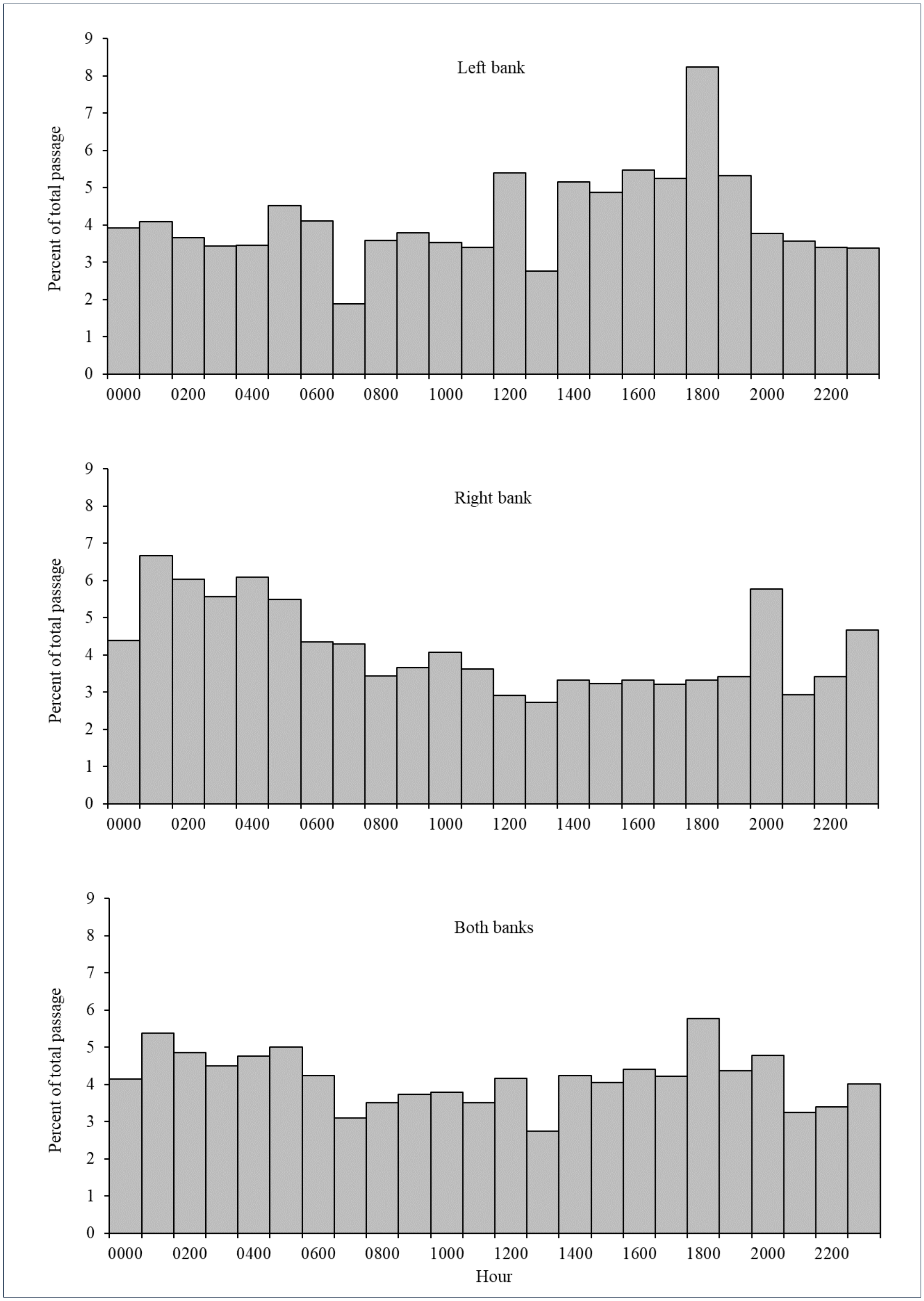

Figure 9.–Percent of total passage, by hour, observed on the left bank, right bank, and both banks combined at the Anvik River sonar project, 2021.

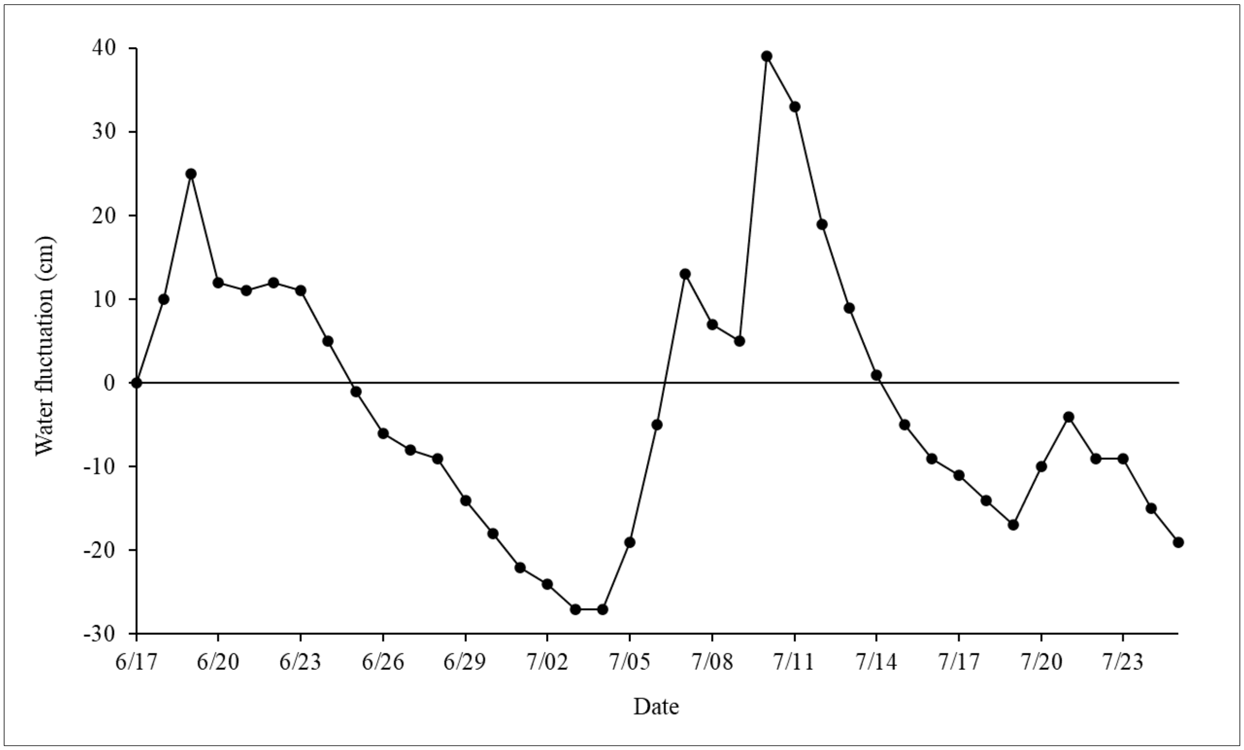

Figure 10.–Change in daily water elevation, relative to June 17, measured at the Anvik River sonar project, 2021.

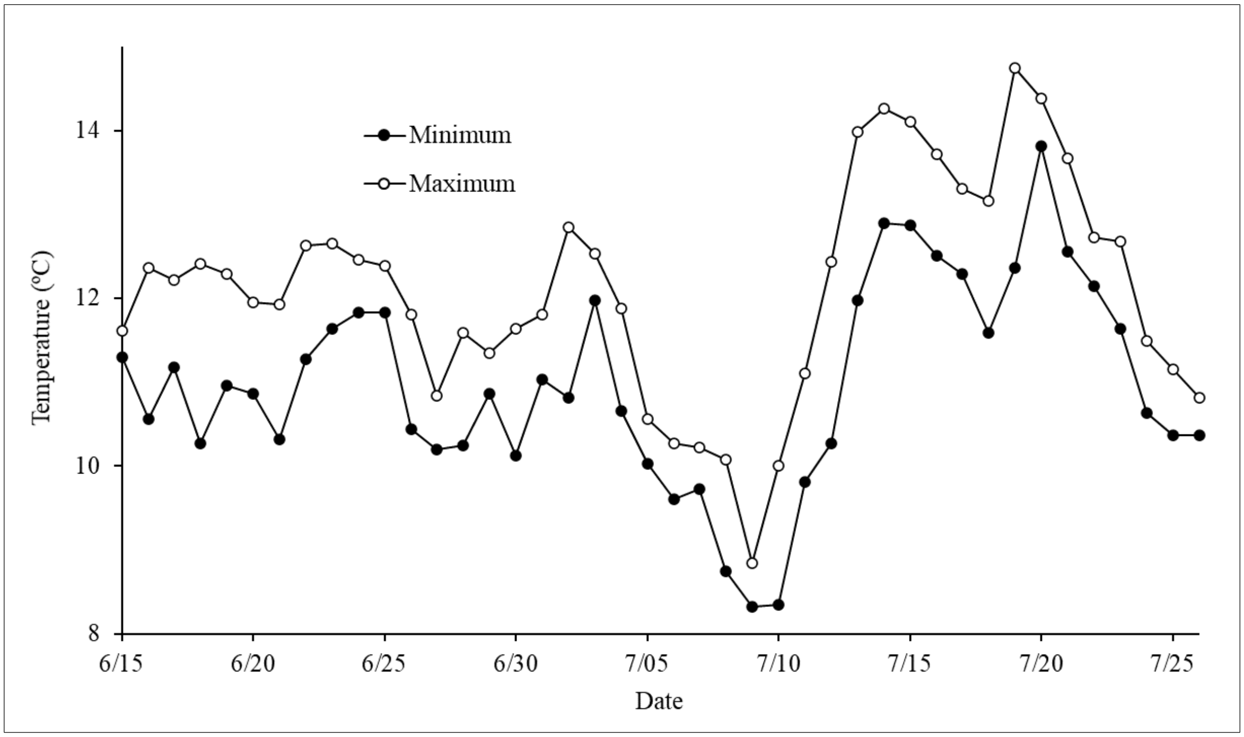

Figure 11.–Daily water temperatures on the left bank at the Anvik River sonar project, 2021.

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