Fishery Data Series No. 17-26

Sonar Estimation of Summer Chum and Pink Salmon in the Anvik River, Alaska, 2016

by

Jody D. Lozori

June 2017

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 *Oncorhynchus gorbuscha* passage in the Anvik River from June 16 to July 26, 2016. Apportionment to species was determined from data collected from tower counts. A total of 337,819 summer chum and 663,617 pink salmon were estimated to have passed the sonar site. A beach seine sample fishery was conducted to collect age, sex, and length information. Both sonar systems functioned well with minimal interruptions to operation. Range of ensonification was considered adequate for most fish that migrated upstream.

Key words: 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 salmon *Oncorhynchus keta* and pink salmon *O. gorbuscha* to the Anvik River drainage, believed to be the largest producer of summer chum salmon in the Yukon River drainage (Bergstrom et al. 1999). Additional major spawning populations of summer chum salmon occur in the following tributaries of the Yukon River: the Andreafsky River, Rodo River, Nulato River, Melozitna River, and Tozitna River. Spawning tributaries in the Koyukuk River drainage are the Gisasa River and Hogatza River; and in tributaries to the Tanana River drainage, which include the Chena River and the Salcha River (Figure 1).

Chinook salmon *O. tshawytscha* and pink salmon spawn in the Anvik River concurrently with summer chum salmon, with high abundance of pink salmon occurring on even years in the Yukon River drainage (Estensen et al. 2013). Apportionment of pink salmon passage on the Anvik River during even years is necessary to accurately access summer chum salmon escapement from the total sonar passage estimate. Fall chum, which are a later run of chum salmon (Estensen et al. 2013), and coho salmon *O. kisutch* have also been reported to spawn in the Anvik River drainage during the fall.

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 for downstream subsistence and commercial harvest. Subsistence and commercial fishery openings and closures may be based in part upon this assessment.

From 1972 to 1979, Anvik River summer chum and pink salmon escapements were partially estimated from visual counts made at counting towers above the confluence of the Anvik and Yellow rivers, (Figure 2). A site 9 km above the Yellow River, on the mainstem Anvik River, was used from 1972 to 1975 (Lebida[1]; Trasky 1974, 1976; Mauney 1977). From 1976 to 1979, a site on the mainstem Anvik River, near the confluence of Robinhood Creek and the Anvik River, was used (Mauney 1979, 1980; Mauney and Geiger 1977). Since 1979, the Anvik River sonar project has been located 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. The land is public, managed by the Bureau of Land Management (BLM), and leased to the Alaska Department of Fish and Game (ADF&G) for public purposes until 2023. Aerial survey data indicate summer chum salmon spawn primarily upstream of this sonar site.

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

Shore based sonar, capable of detecting migrating salmon along the banks, was first used at the current Anvik River sonar site in 1979 to determine the feasibility of using sonar to enumerate summer chum passage (Sandone 1993). Bendix sonar equipment was used for escapement estimates from 1980 to 2003.[2] In 2003, a side-by-side comparison was done with Hydroacoustic Technology Incorporated (HTI) split-beam sonar equipment where it was found that the Bendix and HTI produced similar abundance estimates (Dunbar and Pfisterer 2007). In 2004, the project changed to HTI sonar equipment for estimates. In 2006, a side-by-side comparison was done between HTI 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 that the DIDSON abundance estimate was 61% higher than the split-beam abundance estimate (McEwen 2007). DIDSON has been used in the Yukon and Kenai rivers (Lozori 2015; Miller et al. 2014) 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 change was made to DIDSON sonar.[3]

The Anvik River sonar project provides timely and accurate information to Yukon River fishery managers. DIDSON equipment is used to collect salmon passage data and tower estimates are used to apportion the counts to summer chum or pink salmon during even years when pink salmon are abundant. Beach seines are used to collect age, sex, and length (ASL) data. HOBO data loggers are used to monitor water temperature daily. This report presents data collected in 2016 and compares the results to previous years.

OBJECTIVES

The goal of this project in 2016 was to provide daily inseason estimates of adult summer chum and pink salmon escapement into the Anvik River to fishery managers. Primary objectives included the following:

1. Estimate daily summer chum and pink salmon abundance in the Anvik River from approximately June 16 through July 26, using DIDSON and tower counts for apportionment, and determine if the summer chum salmon BEG was met.
2. Operate DIDSON such that 95% of migrating salmon are detected within three-quarters of the ensonified range on both banks.

Secondary objectives included the following:

3. 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 are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).
4. Collect daily weather and water measurements representative of the study area.

[2] ADF&G. [Internet]. Alaska fisheries sonar: sonar technology tools. www.adfg.alaska.gov/index.cfm?adfg=sonar.sonartools (Accessed: November 15, 2016).

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

METHODS

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). This narrow runoff stream has a substrate of mainly gravel and cobble. Bedrock is exposed in some of the upper reaches. The Yellow River (Figure 2) is a major tributary of the Anvik drainage and is located approximately 100 km upstream from the mouth of the Anvik River. 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 water clarity of the Anvik River below their 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. As with past years, we were able to use the same location this season due to the site's stability. 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 28 m from shore, and the left bank sloped steeply to the thalweg approximately 14 m from shore depending on water level (Figure 3).

HYDROACOUSTIC EQUIPMENT

A long range DIDSON operating at frequency of 1.2 MHz (high frequency option using 48 beams) was deployed on the right bank, and a standard DIDSON operating at frequency of 1.1 MHz (low frequency option using 48 beams) was deployed on the left bank (Table 1). Because of the shallow nature of the right bank bottom profile, a concentrator lens (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 Hummingbird 998C SI fathometer with GPS capabilities and plotted (Figure 3).

Both banks were ensonified on July 16, and operations ran continuously through 1200 on July 26. The DIDSONs were mounted on aluminum frames and aimed using manual crank-style rotators (Figure 5). The DIDSONs were placed offshore in a fixed location with the beams directed perpendicular to current flow, approximately 10 m from the right bank and approximately 3 m from the left bank. 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. Both banks were ensonified approximately 20 m from the DIDSON. Approximately 95% of the river was ensonified, depending on water level. Daily visual inspections of the sonar pods and images confirmed proper placement and

orientation of the DIDSONs, and alerted operators when they needed to be repositioned to accommodate changing water levels.

Partial weirs were erected perpendicular to the current and extended from the shore out 1 m to 3 m beyond each DIDSON (Figures 3 and 6). 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 passage of small, resident, nontarget species 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 min, 24 h per day, and 7 days per week, except for short periods when the generator was serviced or adjustments were made to the sonars. Operators opened each 30 min data file in an echogram viewer program (Echotastic, developed by ADF&G staff) and marked each upstream fish track with a computer mouse. All fish were counted except for small fish (<400 mm), which were assumed not to be salmon. Fish length measurements were made using DIDSON software marking tools. Upstream direction of travel was verified using the Echotastic video feature which displayed the raw acoustic fish images. The 30 min counts were saved as text files and also recorded on a paper count form.

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

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

where h_{dsp} is the fraction of the hour sampled on day (d), stratum (s), period (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 auto-correlated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed (Wolter 1985). The variance for the passage estimate for stratum (s) on day (d) is estimated as:

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

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

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

MISSING DATA

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

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

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

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

SPECIES APPORTIONMENT

Tower counts were conducted 4 times per day (0730, 1300, 1700, and 2000) for 15 min 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 with polarized sunglasses and counted salmon by species passing the sonar. Non-salmon species, which would be excluded from the sonar estimate, were not counted or recorded. Because the numbers of Chinook and sockeye salmon are so low at this project, only summer chum and pink salmon counts are included in the apportionment process.

Prior to this season, tower counts used for species apportionment were entered into a Microsoft Excel spreadsheet. The spreadsheet calculated the estimated proportion (p) of species (a) by summing tower counts (c) within a single day (d) over all tower count periods (i) for bank (z) and dividing by the total by the sum of the tower counts of all species (a) for the day (d) across all periods (i) and bank (z).

$$p_{dza} = \frac{\sum_{i} c_{diza}}{\sum_{a}\sum_{i} c_{diza}} \,. \tag{5}$$

Historically, tower count data was used for apportionment regardless of the number of fish observed or visibility from the transducer. This season, a more robust method was used to compensate for days for which there was insufficient data from tower counts to accurately estimate species proportions. For each bank, report units (r) were assigned such that each reporting unit contained at least 2 tower counting periods 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. Combining days into report periods

makes it possible to remove questionable or biased data (due to poor visibility) from the estimation process and ensures there are a minimum of 2 sample periods in order to compute the sampling variance. Water clarity was determined by visual observations during tower counts, and was entered into a database as meter of visibility offshore from the transducer. With the exception of a few days at the start of the season, the number of samples were adequate and there was no need to group multiple days.

Species proportions for each usable sampling period (*i*) were calculated by dividing the count (*c*) for species (*a*) on day (*d*) and bank (*z*) by the count summed over all species in the same period.

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

The estimated proportion $\hat{p}$ for each report period, bank, and species was computed as the mean of the individual proportions in the report period:

$$\hat{p}_{rza} = \frac{\sum_d \sum_i p_{rdiza}}{n_{ri}} . \tag{7}$$

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

$$\hat{y}_{dza} = \hat{y}_{dz} \cdot \hat{p}_{rza} . \tag{8}$$

The main advantage to the change in estimating species proportions is that it makes it possible to compute the sampling variance. The variance of the estimated proportions was computed based on the difference of the individual observations from the mean within the reporting unit:

$$Var(\hat{p}_{rza}) = \frac{\sum_i (\bar{p}_{rza} - \hat{p}_{riza})^2}{n(n-1)} . \tag{9}$$

Sonar-derived estimates of total fish passage were independent of the tower count estimates of species proportions. Therefore the variance of their product (daily passage estimates) was estimated as the variance of the product of 2 independent variables (Goodman 1960):

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

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

$$\hat{y}_{da} = \sum_z \hat{y}_{dza} , \tag{11}$$

and passage estimates were summed over both banks and all days to obtain a seasonal estimate for species y_a

$$\hat{y}_a = \sum_d \sum_z \hat{y}_{dza} . \tag{12}$$

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

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

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

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

AGE, SEX, AND LENGTH SAMPLING

Temporal strata, used to characterize the age and sex composition of the summer chum salmon escapement, were defined as dates on which 25%, 50%, 75%, and 100% of the total run had passed the sonar site. To determine inseason ASL sampling dates, historical mean quartile ASL dates were used (Table 2). The strata represent an attempt to sample the escapement in proportion to the total run.

To meet regional standards for the sample size needed to describe a salmon population, the initial seasonal ASL sample goal was 648 summer chum salmon, with a minimum of 162 summer chum salmon samples collected using beach seines during each temporal stratum (Bromaghin 1993). Sample size goals are based on a 95% confidence with an accuracy (d) and precision (α) objectives of d = 0.10 and α = 0.05, assuming 2 major age classes, and 2 minor age classes with a scale rejection rate of 15%. The beach seining goal for Chinook salmon was also developed to sample all fish captured while pursuing the summer chum salmon sampling goal.

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 and collect ASL data. 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 placed in a holding pen in the river and each were noted for sex, 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 adipose fin was clipped on each sampled summer chum salmon to prevent resampling. Chinook and sockeye salmon were sampled using the same methods as for summer chum salmon, except 4 scale samples were taken from each fish.

WEATHER AND WATER OBSERVATIONS

Climatic and hydrologic data were collected at approximately 1800 hours 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 0.0 cm. Water temperature was measured using a HOBO water temperature logger, which electronically recorded the temperature every hour on the hour for the duration of the project. Subjective notes on wind speed and direction, cloud cover, and precipitation were also recorded.

RESULTS

SUMMER CHUM AND PINK SALMON ESTIMATION

Overall there were no significant problems with estimation of salmon passage this season. The total summer chum salmon passage estimate at the Anvik River sonar site was 337,819 from June 16 to July 26, 2016. The first quarter point fell on June 28, the midpoint on July 5, and third quarter point on July 13. A peak daily passage estimate of 25,263 summer chum salmon occurred on July 14 and 3,465 summer chum salmon passed on July 26, the last day of sonar operation (Table 3). When compared to average historic run timing based on 2000–2015 runs, summer chum salmon passage dates were 7 days early at the first quartile and average at the third quartile (Table 2). Daily passage between the first and third quartile dates ranged from 6,040 (July 6) to 21,256 (July 13), and an estimated total of 184,947 summer chum salmon passed by the sonar site during this time. The 2016 summer chum salmon escapement estimate was less than the average (2000–2015) Anvik River escapement estimate of 408,368 fish, and was below the BEG of 350,000 to 700,000 summer chum salmon.

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). Approximately 18% of the summer chum salmon that were estimated to have passed Pilot Station (1,921,748)[4] were observed at the Anvik River sonar project; this is below the overall 1995 to 2015 contribution of 29%. 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 41%. From 2003 to 2015, the average contribution was 22%.

Because sonar operations end before the pink salmon migration does, calculations of quartile statistics are based on the proportion of the run during the time the sonar project is operational (Table 4). The total pink salmon passage estimate was 663,617 from June 26 to July 26, 2016. The first quarter point fell on July 14, the midpoint on July 21, and third quarter point on July 24. A peak daily passage estimate of 91,323 pink salmon occurred on July 26, which was also the last day of sonar operation. Based on 1994, 2000–2004, and 2008–2014 run timing estimates, the pink salmon migration was 3 days late on the first quartile and 5 days late at the third quartile (Table 5). The 2016 pink salmon escapement estimate was above the average Anvik River escapement of 402,355.

Total sonar passage estimates include expansions for sampling time missed. On the left bank, 1,172 min were missed, which accounted for an additional 35,731 fish or 8% of the total left bank estimate. On the right bank, 1,442 min were missed, which accounted for an additional 32,426 fish or 6% of the total right bank estimate (Table 6). A majority of the total expanded fish passage estimate fell on July 26 (47,394 fish), which was the last day of sonar operation, and the sonars turned off at noon. Proportionally, summer chum salmon only accounted for 6% of the total passage estimate that day (Table 7).

The objective of estimating summer chum and pink salmon abundance in the Anvik River using DIDSON from approximately June 16 through July 26 was met.

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[4] ADF&G. [Internet]. Yukon River (Pilot Station) chum – summer for 2016. http://www.adfg.alaska.gov/sf/FishCounts/index.cfm?ADFG=main.displayResults (Accessed: October 11, 2016).

SPATIAL AND TEMPORAL DISTRIBUTION

Overall, fish were shore oriented on both banks (Figure 8). On the left bank, approximately 95% of the fish were detected within 5 m of the transducer, and 99% within 14 m. On the right bank, 95% of the fish were detected within 15 m of the transducer, and 99% within 19 m. Approximately 79% of the total summer chum and 46% of the total pink salmon passage occurred on the right bank, which is consistent with the most recent 10 year passage trends.

This was the first season the left bank range was extended from 10 m to 20 m. This increase in range contributed 4,916 fish, or approximately 2.5% of the total left bank passage estimate.

The objective to operate imaging sonar such that 95% of the migrating salmon are detected within three-quarters of the ensonified area on both banks was met.

Overall, when considering both banks combined, there was a diurnal pattern of fish passage on the Anvik River this season, and a higher proportion of passage occurred during darker hours of the day (Figure 9). Although the right bank passage was relatively consistent with this pattern, passage on the left bank was sporadic throughout the day and the most significant increase began at approximately 1600 and peaked at 2100.

SPECIES APPORTIONMENT

Summer chum and pink salmon were the most prominent salmon species observed on both banks during tower counts. Tower counts began on June 20, and the first pink salmon was observed June 26 (Table 7). Proportionally, summer chum salmon accounted for 18% of the total tower count on the left bank and 48% on the right bank

Weather conditions were favorable this season and there were only 3 days that the minimum range of visibility was not met because of rain and high water, which required pooling report periods.

SUMMER CHUM AGE AND SEX COMPOSITION

From June 24 through July 22, a total of 724 ASL samples were obtained and, from these samples, 675 scales were analyzed as ageable postseason.[5] Strata were defined in 2016 as: June 16–June 30, July 01–July 08, July 09–July 15, and July 16–July 26 (Table 8).

Scale sample analysis indicated that there were 2 major age classes, age 0.3 (73%) and age 0.4 (24%), as well as 2 minor classes, age 0.2 and 0.5, both of which combined contributed approximately 3% to the summer chum salmon run (Tables 8 and Figure 10).

Age and sex composition of summer chum salmon passing the sonar site usually changes through the duration of the run, with an increasing proportion of younger salmon and a higher proportion of female salmon as the run progresses (Fair 1997). Although an increase in the proportion of females was consistent with this pattern this season, age composition remained fairly constant after the second stratum (Figure 10). Female summer chum accounted for approximately 61% of the entire run, which is above to the 1972–2015 average of 56% (Figure 11).

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[5] AYKDBMS [Arctic-Yukon-Kuskokwim Database Management System] Home Page. Available from: http://www.adfg.alaska.gov/CommFishR3/WebSite/AYKDBMSWebsite/Default.aspx (Accessed: November 22, 2016).

The objective of collecting a minimum of 162 summer chum salmon scale samples in each of 4 temporal strata was met this season.

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The objective of monitoring hydrological parameters daily at the project site was met in 2016. Except for June 21, the water level remained below the zero datum mark and the lowest level was recorded on July 17–18 (Figure 12). Overall, between June 20 and July 27, minimum and maximum water level differed by 62 cm. Water temperatures at the project ranged from 10.6°C on June 19, to a high of 20.7°C on July 14 (Figure 13). The average air temperature was 20°C and temperatures ranged from a high of 30°C on July 13–14 to a low of 13°C on June 18 and July 21 (Appendix A).

DISCUSSION

Comparisons between the new (2016) and older (2014) methods to apportion passage and estimate variance (both which occurred during even year pink salmon runs) concluded that summer chum salmon passage estimates were relatively similar, and each estimate was within the 95% confidence interval of the other estimate for that year (Figure 14).

Future considerations should be made as far as increasing the minimum clarity parameters for report periods on each bank. Increasing these parameters should be feasible, and will increase confidence in apportionment of pink and summer chum salmon because the range will include a higher proportion of the passage. Postseason review of report periods indicated that there were very few instances that report periods were pooled because of reduced visibility (Table 9) and of these; the mean clarity from all observations was approximately 4.7 m on the left bank and approximately 8.9 m on the right bank (Figure 15). Considering the current minimal clarity parameters (left bank = 1 m; right bank = 2 m), and reviewing the passage distributions by bank this season (Figure 8), only 9% of the left bank and 11% of the right bank passage fell within the range of these minimum parameters. In comparison, when increasing the minimal parameters to the mean clarity values by bank from this season, approximately 36% of the right bank and 97% of the left bank total passage are represented.

Obviously water levels as well as other environmental conditions such as wind and precipitation are not possible to predict when considering what values to increase clarity parameters to in the future. It should, however, be feasible to at least double the current parameters without experiencing a large increase of pooled report periods and days because of reduced visibility.

Within the last 4 even years, there has been a trend of high pink salmon escapement into the Anvik River (Table 5). Because of uncertainty of the spatial distribution caused by interactions between high abundance of pink and summer chum salmon migrating past the sonar site, the range of ensonification on the left bank was extended from the traditional range of 10 m to 20 m this season (Figure 3). Overall, passage estimates were low beyond 10 m, and the range from 11 m to 20 m only accounted for approximately 2.5% (4,916 fish) of the total left bank passage estimate (Figure 8).

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REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 2004. Escapement goal review of select AYK region salmon stocks. Division of Commercial Fisheries, Regional Information Report 3A04-01, Anchorage.

Belcher, E. O., W. Hanot, and J. Burch. 2002. Dual-frequency identification sonar. Pages 187-192 [*In*]: Proceedings of the 2002 International Symposium on underwater technology. Tokyo, Japan, April 16–19.

Bergstrom, D. J., K. C. Schultz, V. Golembeski, B. M. Borba, D. Huttunen, L. H. Barton, T. L. Lingnau, R. R. Holder, J. S. Hayes, K. R. Boeck, and W. H. Busher. 1999. Annual management report Yukon Area, 1998. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A99-26, Anchorage.

Bromaghin, J. F. 1993. Sample size determination for interval estimation of multinomial probabilities. The American Statistician 47(3):203–206.

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

Dunbar, R. D., and C. Pfisterer. 2007. Anvik River sonar chum salmon escapement study, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 07-15, Anchorage.

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

Fair, L. F. 1997. Anvik River salmon escapement study, 1996. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A97-19, Anchorage.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Lozori, J. D. 2015. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2013. Alaska Department of Fish and Game, Fishery Data Series No. 15-14, Anchorage.

Mauney, J. L. 1977. Yukon River king and chum salmon escapement studies. Anadromous fish conservation act technical report for period July 1, 1975 to June 30, 1976. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Mauney, J. L. 1979. Yukon River salmon studies. Anadromous fish conservation act technical report for period July 1, 1977 to June 30, 1978. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Mauney, J. L. 1980. Yukon River salmon studies. Anadromous fish conservation act technical report for period July 1, 1978 to June 30, 1979. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Mauney, J. L., and M. F. Geiger. 1977. Yukon River anadromous fish investigations. Anadromous fish conservation act completion report for period July 1, 1974 to June 30, 1977. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

McEwen, M. S. 2007. Anvik River sonar chum salmon escapement study, 2006. Alaska Department of Fish and Game, Fishery Data Series No. 07-67, Anchorage.

REFERENCES CITED (Continued)

Miller, J. D., D. L. Burwen, and S. J. Fleischman. 2014. Estimates of Chinook salmon passage in the Kenai River using split-beam and dual-frequency identification sonars, 2011. Alaska Department of Fish and Game, Fishery Data Series No. 14-18, Anchorage.

Sandone, G. J. 1993. Anvik River salmon escapement study, 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fisheries Report No. 93-08, Juneau.

Trasky, L. L. 1974. Yukon River anadromous fish investigations. Anadromous fish conservation act technical report for period July 1, 1973 to June 30, 1974. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

Trasky, L. L. 1976. Yukon River king and chum salmon escapement studies. Anadromous fish conservation act technical report for period July 1, 1974 to June 30, 1975. Alaska Department of Fish and Game, Division of Commercial Fisheries, Juneau.

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

TABLES AND FIGURES

Table 1.–Technical specifications for dual-frequency identification sonars (DIDSON) at the Anvik River sonar, 2016.

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

Table 2.–Annual passage estimates and passage timing for summer chum salmon runs, at the Anvik River sonar, 2000–2016.

						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
2000	196,349	6/21	7/08	7/11	7/13	17	3	2	5
2001	224,058	6/26	7/06	7/10	7/15	10	4	5	9
2002	459,058	6/22	7/03	7/07	7/12	11	4	5	9
2003	256,920	6/21	7/05	7/10	7/15	14	5	5	10
2004	365,353	6/22	6/29	7/05	7/09	7	6	4	10
2005	525,391	6/26	7/04	7/10	7/15	8	6	5	11
2006	605,485	6/28	7/03	7/06	7/12	5	3	6	9
2007	460,121	6/26	7/05	7/10	7/17	9	5	7	12
2008	374,928	6/18	7/05	7/08	7/16	17	3	8	11
2009	191,566	6/18	7/04	7/09	7/15	16	5	6	11
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	8
2016	337,819	6/16	6/28	7/05	7/13	12	7	8	15
Average	408,368	6/20	7/4	7/8	7/13	14	4	5	10
Median	397,984	6/19	7/4	7/8	7/14	15	5	5	10
SD	137,003	3.9	2.6	2.4	2.6	4.8	1.2	1.5	1.7

Table 3.–Summer chum salmon daily and cumulative counts, at the Anvik River sonar, 2016.

				Cumulative	
Date	Left bank	Right bank	Daily total	Count	Proportion
6/16	138	972	1,110	1,110	0.003
6/17	133	4,509	4,642	5,752	0.017
6/18	90	2,100	2,190	7,942	0.024
6/19	32	484	516	8,458	0.025
6/20	343	1,454	1,797	10,255	0.030
6/21	534	1,456	1,990	12,245	0.036
6/22	830	4,710	5,540	17,785	0.053
6/23	236	4,560	4,796	22,581	0.067
6/24	141	1,943	2,084	24,665	0.073
6/25	2,250	12,072	14,322	38,987	0.115
6/26	2,142	19,025	21,167	60,154	0.178
6/27	1,042	14,201	15,243	75,397	0.223
6/28 [a]	998	13,555	14,553	89,949	0.266
6/29	1,528	15,118	16,647	106,596	0.316
6/30	1,068	12,061	13,129	119,725	0.354
7/01	1,814	11,732	13,546	133,272	0.395
7/02	860	10,616	11,476	144,748	0.428
7/03	909	7,777	8,687	153,435	0.454
7/04	1,028	12,752	13,780	167,215	0.495
7/05 [b]	657	11,672	12,329	179,544	0.531
7/06	624	5,416	6,040	185,583	0.549
7/07	629	6,927	7,556	193,139	0.572
7/08	703	5,691	6,394	199,533	0.591
7/09	1,041	6,953	7,993	207,527	0.614
7/10	1,045	9,010	10,056	217,582	0.644
7/11	1,200	7,730	8,931	226,513	0.671
7/12	3,690	8,884	12,574	239,087	0.708
7/13 [c]	10,331	10,924	21,256	260,342	0.771
7/14	16,827	8,437	25,263	285,606	0.845
7/15	4,702	1,313	6,015	291,620	0.863
7/16	2,923	1,329	4,252	295,872	0.876
7/17	1,443	1,933	3,376	299,248	0.886
7/18	738	2,979	3,718	302,966	0.897
7/19	20	2,293	2,313	305,279	0.904
7/20	1,119	2,940	4,059	309,338	0.916
7/21	1,839	6,428	7,273	316,612	0.937
7/22	412	6,000	6,840	323,452	0.957
7/23	362	1,190	6,363	329,814	0.976
7/24	1,099	1,911	2,288	332,103	0.983
7/25	1,107	1,145	2,252	334,354	0.990
7/26	980	2,485	3,465	337,819	1.000
Total	69,607	268,211	337,819		

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

[a] First quarter point.

[b] Midpoint.

[c] Third quarter point.

Table 4.–Pink salmon daily and cumulative counts, at the Anvik River sonar, 2016.

				Cumulative	
Date	Left bank	Right bank	Daily total	Count	Proportion
6/16	0	0	0	0	0.000
6/17	0	0	0	0	0.000
6/18	0	0	0	0	0.000
6/19 [a]	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	37	37	37	0.000
6/27	0	27	27	64	0.000
6/28	0	41	41	106	0.000
6/29	8	171	178	284	0.000
6/30	0	53	53	337	0.001
7/01	0	166	166	502	0.001
7/02	0	470	470	972	0.001
7/03	75	285	359	1,331	0.002
7/04	374	546	920	2,251	0.003
7/05	605	1,314	1,919	4,170	0.006
7/06	430	2,096	2,526	6,697	0.010
7/07	277	5,403	5,680	12,377	0.019
7/08	1,139	5,815	6,954	19,331	0.029
7/09	1,109	7,987	9,097	28,427	0.043
7/10	7,532	9,206	16,737	45,165	0.068
7/11	9,772	10,020	19,791	64,956	0.098
7/12	13,774	8,872	22,646	87,602	0.132
7/13	32,119	10,532	42,651	130,253	0.196
7/14 [b]	27,219	9,853	37,073	167,325	0.252
7/15	25,452	6,553	32,005	199,331	0.300
7/16	15,723	5,935	21,658	220,989	0.333
7/17	16,139	10,749	26,888	247,877	0.374
7/18	7,124	24,125	31,248	279,125	0.421
7/19	4,304	22,989	27,293	306,418	0.462
7/20	4,653	15,427	20,080	326,498	0.492
7/21 [c]	12,057	17,799	29,857	356,354	0.537
7/22	21,841	21,052	42,893	399,247	0.602
7/23	19,200	19,653	38,852	438,100	0.660
7/24	34,776	22,796	57,573	495,672	0.747
7/25 [d]	55,278	21,343	76,621	572,294	0.862
7/26	49,804	41,519	91,323	663,617	1.000
Total	360,784	302,834	663,617		

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 (even years), at the Anvik River sonar, 1994–2016.

						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,b]	ND	7/01	ND	ND	ND	ND	ND	ND	ND
1998[c]	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[b,d]	ND	ND	ND	ND	ND	ND	ND	ND	ND
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	9	12	5	17
2016	663,617	6/26	7/14	7/21	7/25	18	7	4	11
Average	402,355	6/30	7/11	7/16	7/20	12	4	4	8
Median	379,254	6/30	7/11	7/16	7/21	11	4	4	8
SD[b]	331,532	3	5	2	2	5	2	1	3

Note: ND = No data

[a] Because sonar operations end before the pink salmon migration does, calculations of quartile statistics are based on the proportion of the run during the time the sonar project is operational.

[b] Total pink salmon passage was not estimated.

[c] Because of missing data and incomplete passage estimates in 1996, 1998, and 2006, run timing statistics were excluded from the calculation of the overall mean, timing statistics, and associated standard deviation (SD).

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

Table 6.–Number of minutes by bank and day that were adjusted to calculate the daily salmon passage, and the resulting number of fish added to the estimate, at the Anvik River sonar, 2016.

	Left bank		Right bank	
Date	Minutes	Fish	Minutes	Fish
6/16	480	92	480	648
6/17	-61[a]	-11[a]	-60[a]	-376[a]
6/18	53	7	0	0
6/19	17	1	330	222
6/20	-49[a]	-23[a]	0	0
6/21	0	0	0	0
6/22	0	0	0	0
6/23	0	0	0	0
6/24	18	4	10	28
6/25	0	0	0	0
6/26	0	0	0	0
6/27	0	0	0	0
6/28	0	0	0	0
6/29	30	64	30	637
6/30	0	0	0	0
7/01	0	0	0	0
7/02	0	0	0	0
7/03	0	0	0	0
7/04	0	0	0	0
7/05	0	0	0	0
7/06	0	0	0	0
7/07	0	0	0	0
7/08	0	0	0	0
7/09	0	0	0	0
7/10	60	715	32	805
7/11	0	0	0	0
7/12	0	0	0	0
7/13	0	0	0	0
7/14	0	0	0	0
7/15	30	1,256	0	0
7/16	0	0	0	0
7/17	0	0	0	0
7/18	0	0	0	0
7/19	0	0	0	0
7/20	61	491	60	1,531
7/21	0	0	0	0
7/22	22	686	8	298
7/23	60	1,630	102	3,634
7/24	62	3,079	90	2,998
7/25	30	2,349	0	0
7/26	360	25,392	360	22,002
Total	1,172	35,731	1,442	32,426

[a] Negative estimates are a result of sonar counting periods greater than 30 minutes.

Table 7.–Salmon species and proportion of summer chum salmon observed during tower counts by day and bank at the Anvik River sonar, 2016.

	Left bank					Right bank				
Date	Chum	Chinook	Pink	Sockeye	Proportion of chum	Chum	Chinook	Pink	Sockeye	Proportion of chum
6/20[a]	5	0	0	0	1.00	24	0	0	0	1.00
6/21	1	0	0	0	1.00	12	0	0	0	1.00
6/22	1	0	0	0	1.00	59	0	0	0	1.00
6/23	1	0	0	0	1.00	84	0	0	0	1.00
6/24	17	0	0	0	1.00	69	0	0	0	1.00
6/25	62	0	0	0	1.00	478	0	0	0	1.00
6/26	23	1	0	0	0.96	527	0	1	3	0.99
6/27	29	0	0	0	1.00	284	3	1	0	0.99
6/28	26	0	0	0	1.00	448	7	1	0	0.98
6/29	110	1	1	0	0.98	518	1	5	3	0.98
6/30	47	0	0	0	1.00	832	6	2	0	0.99
7/01	57	2	0	0	0.97	295	5	5	1	0.96
7/02	14	0	0	0	1.00	249	1	5	1	0.97
7/03	53	0	3	0	0.95	269	3	9	2	0.95
7/04	23	0	5	1	0.79	334	3	13	1	0.95
7/05	10	0	8	0	0.56	324	2	32	2	0.90
7/06	26	0	25	0	0.51	184	7	64	6	0.70
7/07	7	0	4	0	0.64	170	3	129	8	0.55
7/08	15	0	17	0	0.47	244	1	234	1	0.51
7/09	9	0	15	0	0.38	214	2	247	1	0.46
7/10	64	0	348	1	0.15	237	4	288	3	0.45
7/11	58	0	353	4	0.14	198	5	367	5	0.34
7/12	241	2	775	5	0.24	268	6	346	1	0.43
7/13	524	8	1,311	7	0.28	275	12	512	4	0.34
7/14	462	7	923	3	0.33	248	3	358	3	0.41
7/15	169	0	813	2	0.17	107	2	351	2	0.23
7/16	173	0	741	3	0.19	35	0	163	1	0.18
7/17	50	0	524	2	0.09	58	1	322	0	0.15
7/18	17	0	238	0	0.07	111	1	959	2	0.10
7/19	2	0	165	0	0.01	84	0	821	4	0.09

-continued-

Table 7.–Page 2 of 2.

	Left bank					Right bank				
Date	Chum	Chinook	Pink	Sockeye	Proportion of chum	Chum	Chinook	Pink	Sockeye	Proportion of chum
7/20	48	0	167	1	0.22	109	0	609	3	0.15
7/21	20	0	76	0	0.21	127	0	358	0	0.26
7/22	1	0	110	0	0.01	19	0	177	2	0.10
7/23[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
7/24	39	0	1,315	2	0.03	54	0	987	4	0.05
7/25	43	0	2,070	2	0.02	29	0	548	1	0.05
7/26	28	0	1,485	1	0.02	14	0	311	0	0.04

Note: ND = No data

[a] First day of tower counts.

[b] Tower counts not conducted because of limited visibility.

Table 8.–Age and sex composition of summer chum salmon, Anvik River sonar, 2016.

Sample dates (Strata)	Samples (*n*)	Sex	Brood year (age) 2014 (0.2) Estimate	%	2013 (0.3) Estimate	%	2012 (0.4) Estimate	%	2011 (0.5) Estimate	%	Total Estimate	%
6/24–30	195	Male	614	0.51	28,243	23.59	19,647	16.41	2,456	2.05	50,960	42.56
(6/16–30)		Female	1,228	1.03	49,732	41.54	15,963	13.33	1,842	1.54	68,766	57.44
		Subtotal	1,842	1.54	77,975	63.24	35,611	29.74	4,298	3.59	119,726	100.00
7/02–05	158	Male	505	0.63	23,235	29.11	10,607	13.29	0	0.00	34,348	43.04
(7/01–08)		Female	1010	1.27	36,368	45.57	8,082	10.13	0	0.00	45,460	56.96
		Subtotal	1,515	1.90	59,603	74.68	18,689	23.42	0	0.00	79,808	100.00
7/09–13	154	Male	0	0.00	24,517	26.62	6,578	7.14	0	0.00	31,095	33.77
(7/09–15)		Female	598	0.65	45,446	49.35	13,753	14.94	1,196	1.30	60,993	66.23
		Subtotal	598	0.65	69,963	75.97	20,331	22.08	1,196	1.30	92,088	100.00
7/16–7/22	168	Male	0	0.00	9,350	20.24	3,025	6.55	275	0.60	12,650	27.38
(7/16–7/26)		Female	825	1.79	26,949	58.33	5,775	12.50	0	0.00	33,549	72.62
		Subtotal	825	1.79	36,299	78.57	8,800	19.05	275	0.60	46,199	100.00
Season	675	Male	1,001	0.30	83,579	24.74	37,536	11.11	2,502	0.74	124,618	36.89
		Female	4,004	1.19	163,656	48.44	43,041	12.74	2,502	0.74	213,203	63.11
		Total	5,005	1.48	247,235	73.19	80,577	23.85	5,005	1.48	337,821	100.00

Note: Number fish per stratum and age class are based on the sonar estimate multiplied by percent of fish in age class.

Table 9.–Reporting units and tower counts pooled at the Anvik River sonar, 2016.

Date	Left bank		Right bank		Reason for combining report period [a]
	Report Period	Number of useable tower counts	Report Period	Number of useable tower counts	
6/16	34	2	71	3	NF
6/17	34	2	71	3	NF
6/18	34	2	71	3	NF
6/19	34	2	71	3	NF
6/20	33	5	70	2	NF
6/21	33	5	69	3	NF
6/22	33	5	68	4	NF
6/23	33	5	67	4	NF
6/24	32	3	66	4	NF
6/25	31	4	65	4	
6/26	30	3	64	4	
6/27	29	2	63	4	
6/28	28	3	62	4	
6/29	27	2	61	4	
6/30	26	3	60	4	
7/01	25	2	59	4	
7/02	24	3	58	4	
7/03	23	4	57	4	
7/04	22	4	56	4	
7/05	21	4	55	4	
7/06	20	4	54	4	
7/07	19	3	53	4	
7/08	18	4	52	4	
7/09	17	3	51	4	
7/10	16	4	50	4	
7/11	15	4	49	4	
7/12	14	4	48	4	
7/13	13	4	47	4	
7/14	12	4	46	4	
7/15	11	4	45	4	
7/16	10	4	44	4	
7/17	9	4	43	4	
7/18	8	4	42	4	
7/19	7	4	41	4	
7/20	6	4	40	4	
7/21	5	4	39	5	MV
7/22	4	2	39	5	MV
7/23	4	2	39	5	MV
7/24	3	4	38	4	
7/25	2	4	37	4	
7/26	1	2	36	2	

[a] NF denotes that the minimum of 2 tower counting periods with at least 5 fish in each period were not observed in tower counts. MV denotes the minimum range of visibility during tower counts was not met.

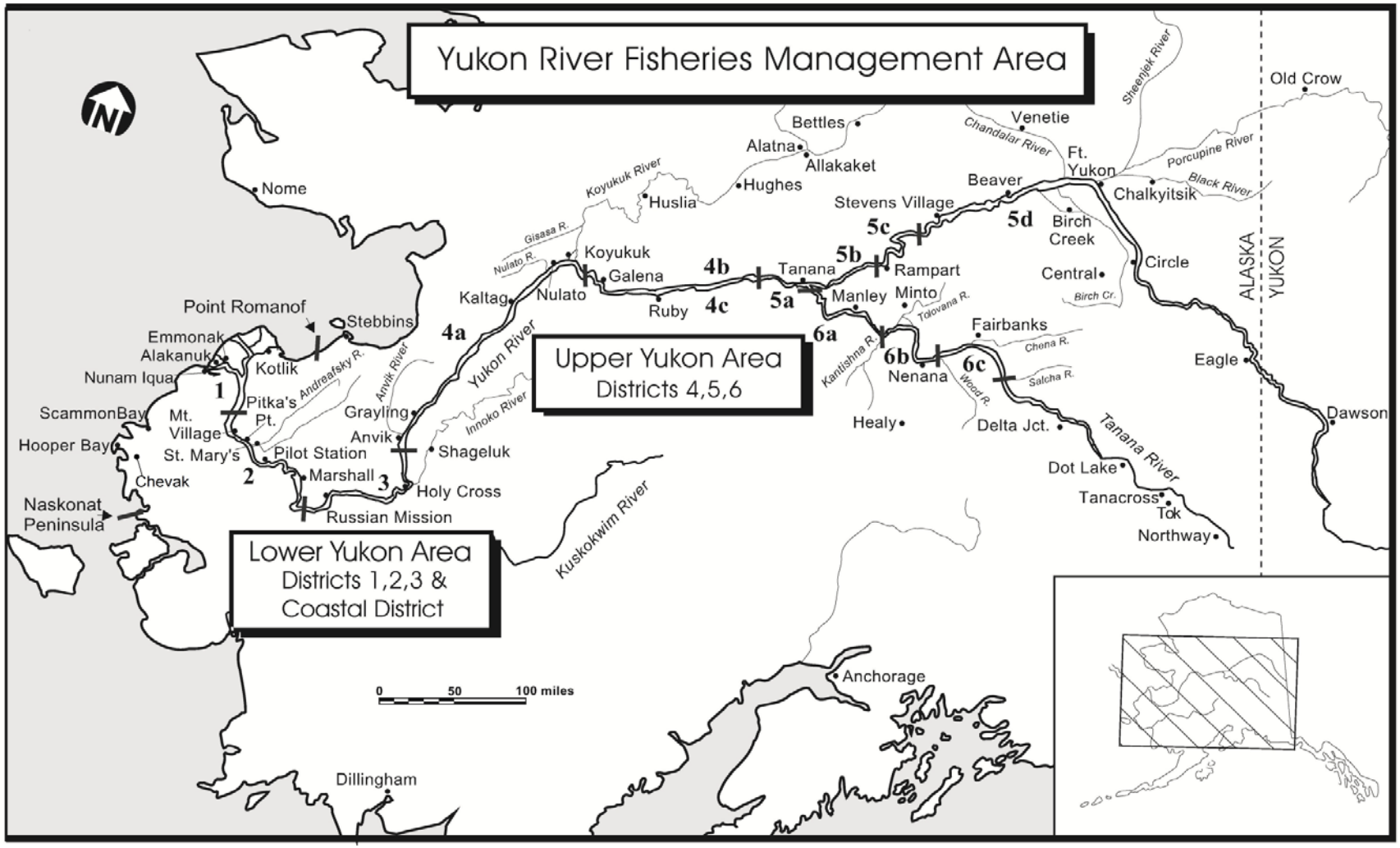

Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

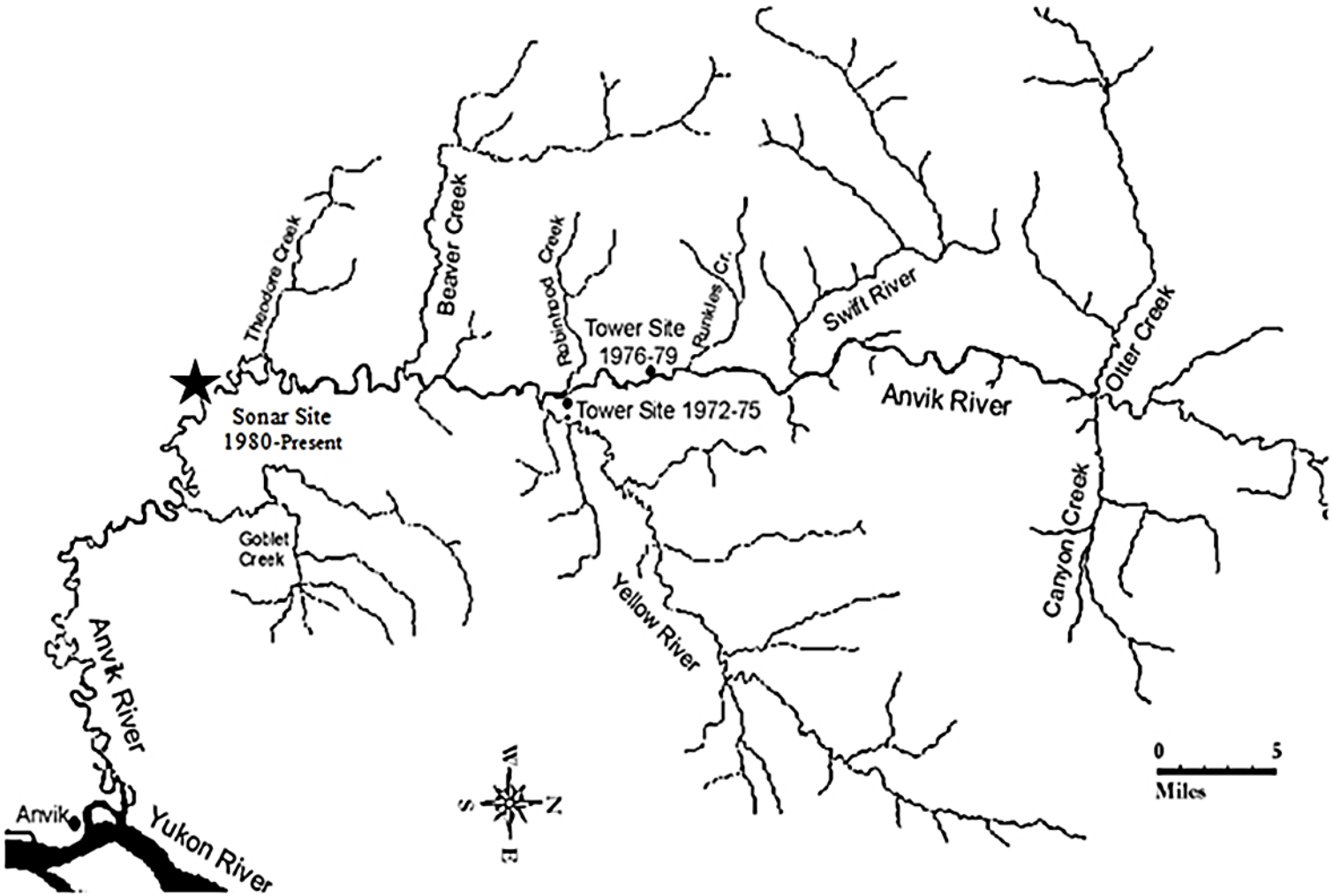

Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

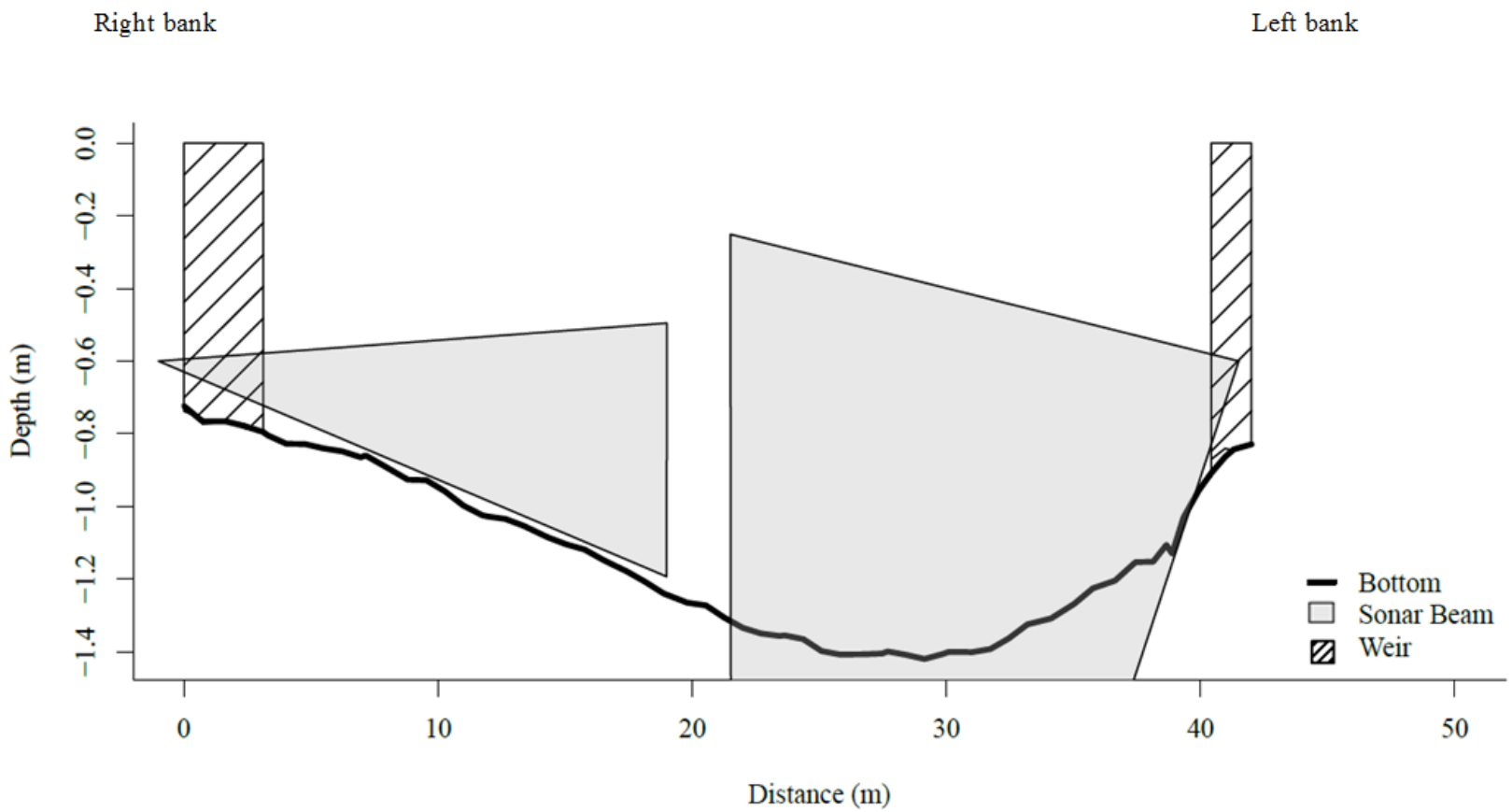

Figure 3.–Depth profile of the Anvik River, and approximate sonar ranges (not to scale) at the Anvik River sonar project, 2016.

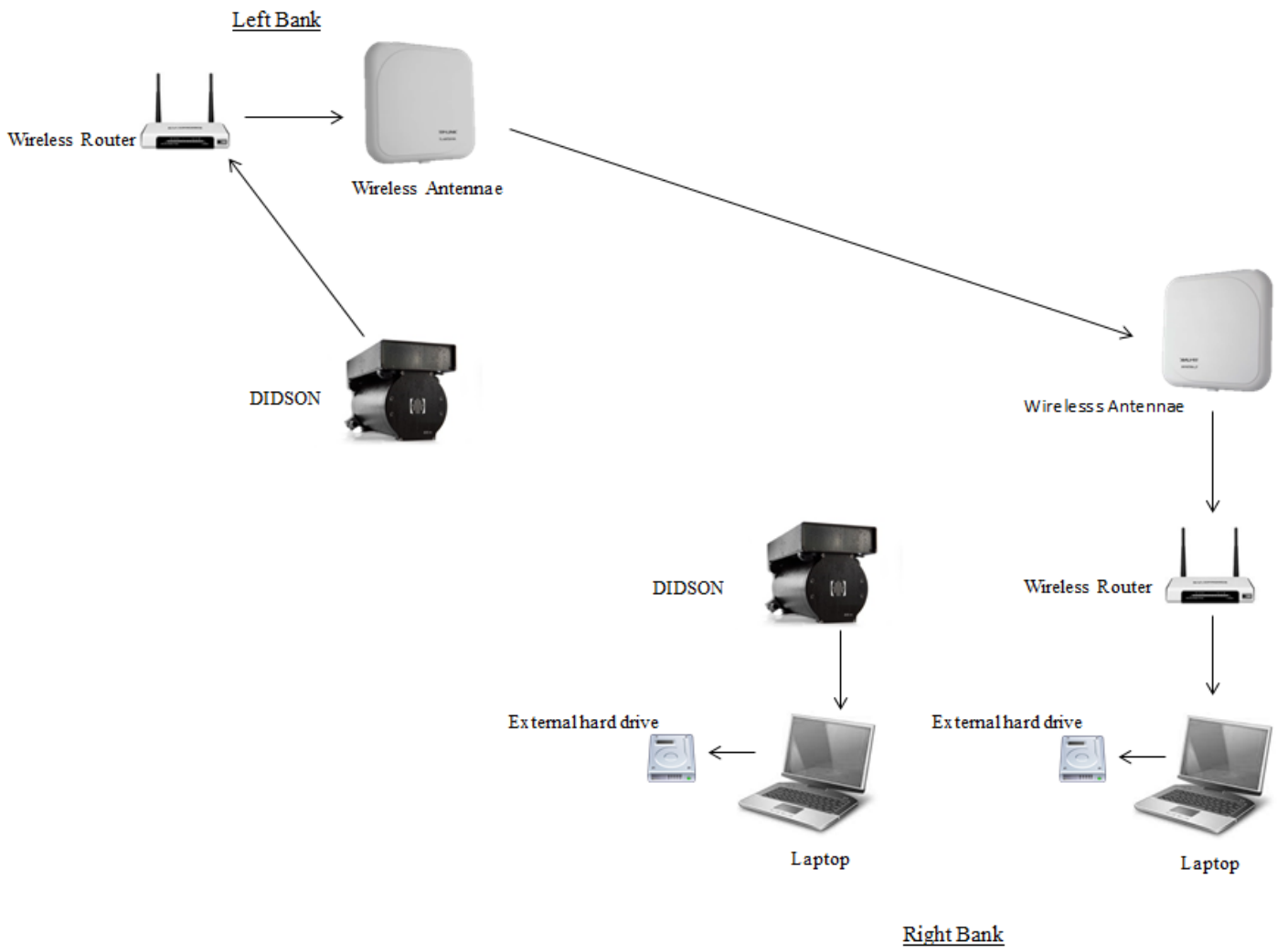

Figure 4.–DIDSON sonar equipment schematic, Anvik River sonar, 2016. Both the left bank and right bank laptops are housed in the right bank sonar tent.

Figure 5.–View of a DIDSON mounted to aluminum H-mount with manual crank-style rotator at the Sheenjek sonar project.

Note: This mount is comparable to the one used at the Anvik River sonar project.

Figure 6.–Anvik River sonar site, illustrating locations of sonars, weirs, and counting towers, 2016.

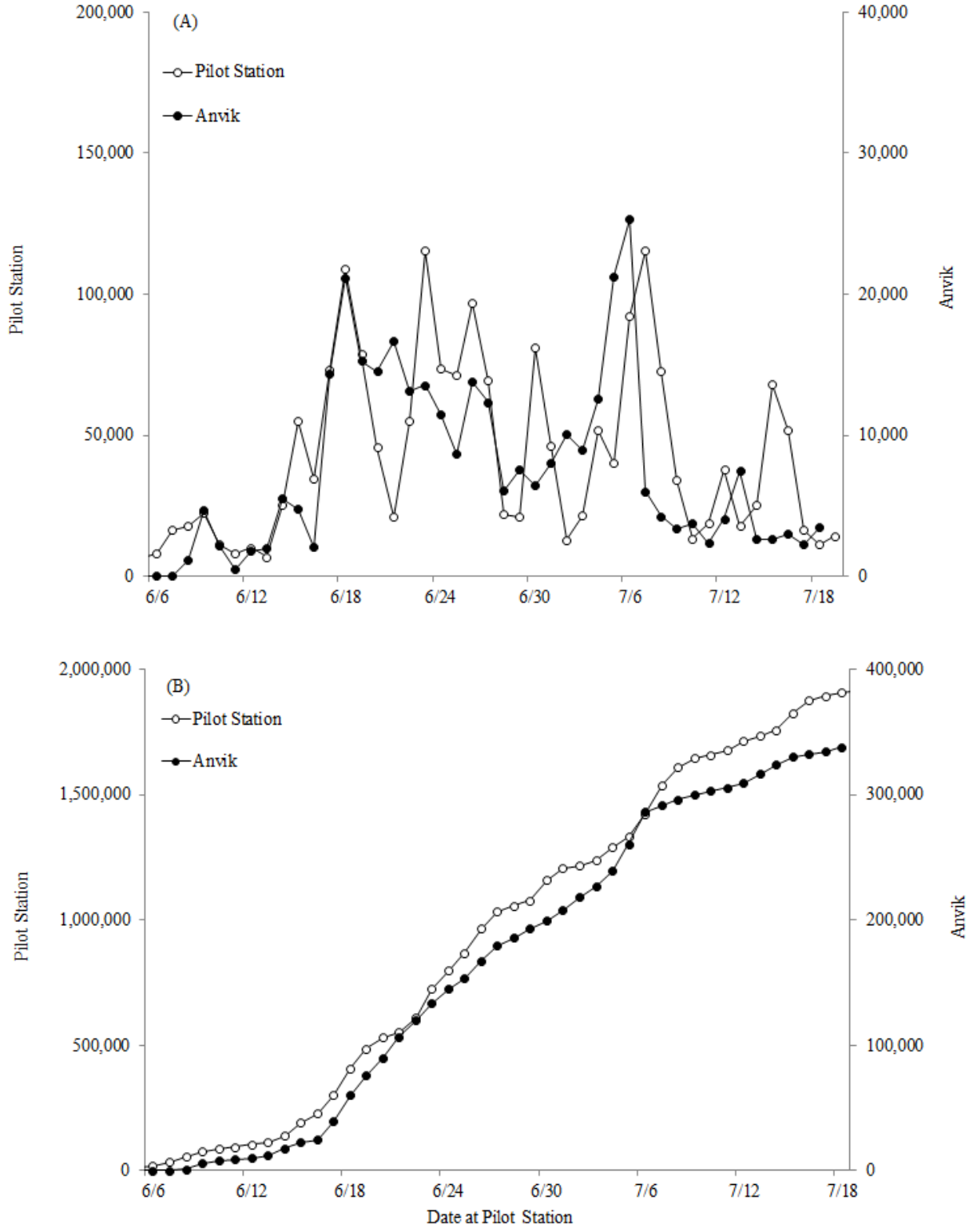

Figure 7.–Daily summer chum salmon passage at the Anvik River sonar and the sonar project near the village of Pilot Station (A), and cumulative summer chum salmon passage at both projects (B), 2016.

Note: The timing of Anvik summer chum salmon is lagged back 10 days to align with Pilot Station.

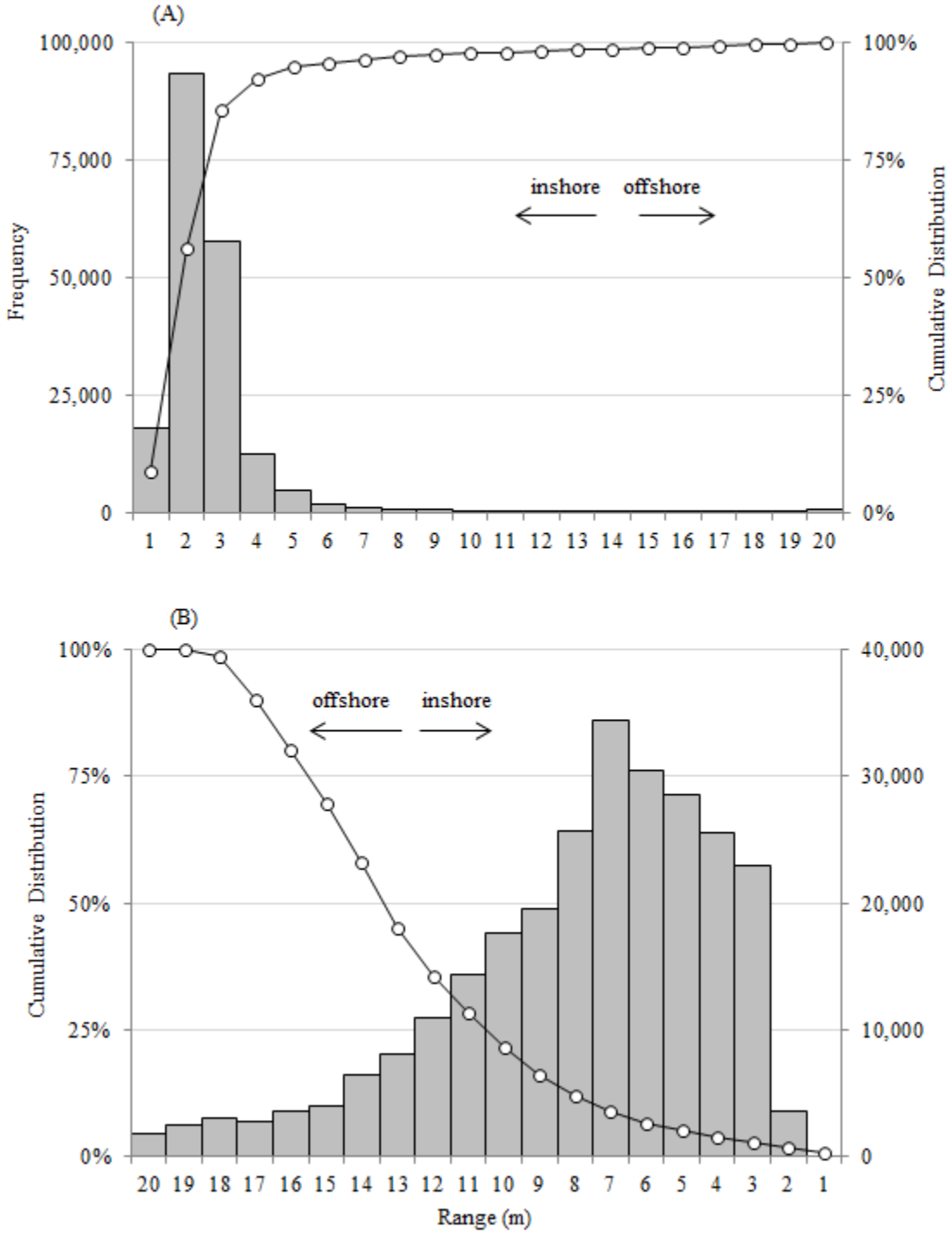

Figure 8.–Left bank (A) and right bank (B) horizontal distribution of unexpanded upstream salmon passage at the Anvik River sonar project, June 16 through July 26, 2016.

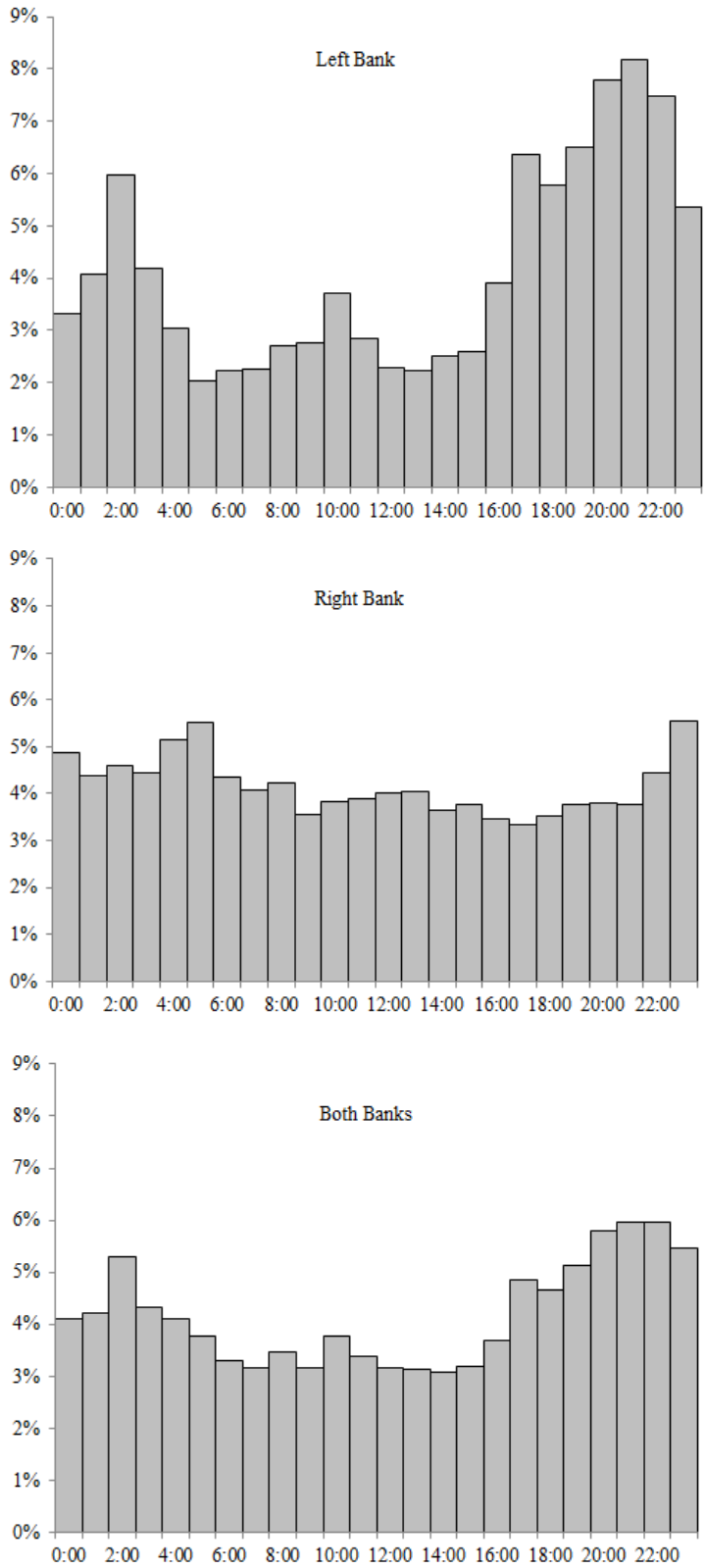

Figure 9.–Percentage of total passage, by hour, observed on the left bank (top), right bank (middle), and both banks combined (bottom) at the Anvik River sonar project, 2016.

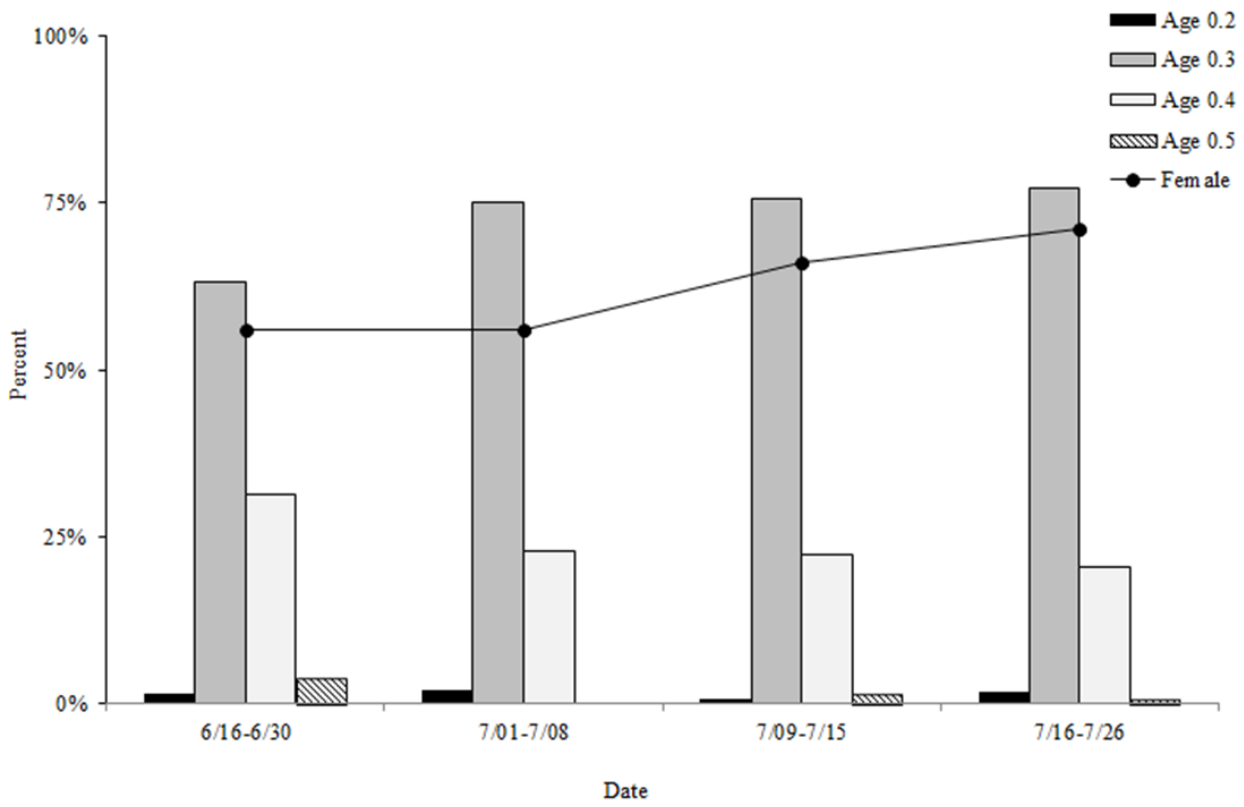

Figure 10.–Summer chum salmon age and percent female composition by sampling stratum at the Anvik River sonar, 2016.

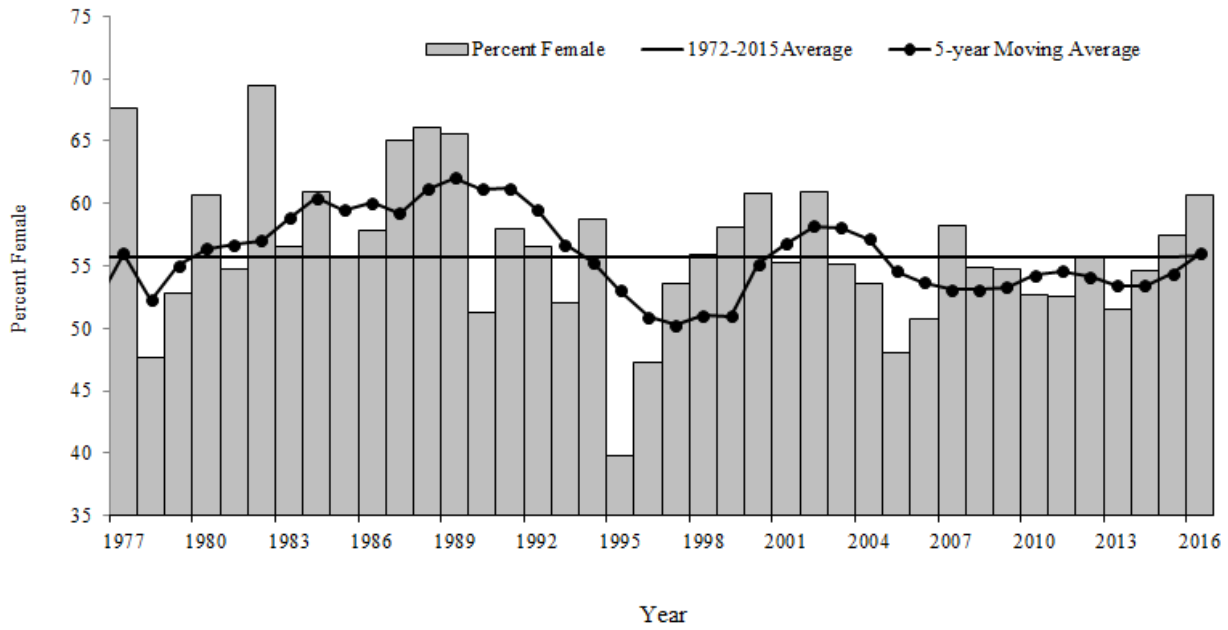

Figure 11.–Percent of female summer chum salmon escapement estimated at the Anvik River sonar project 1972–2016.

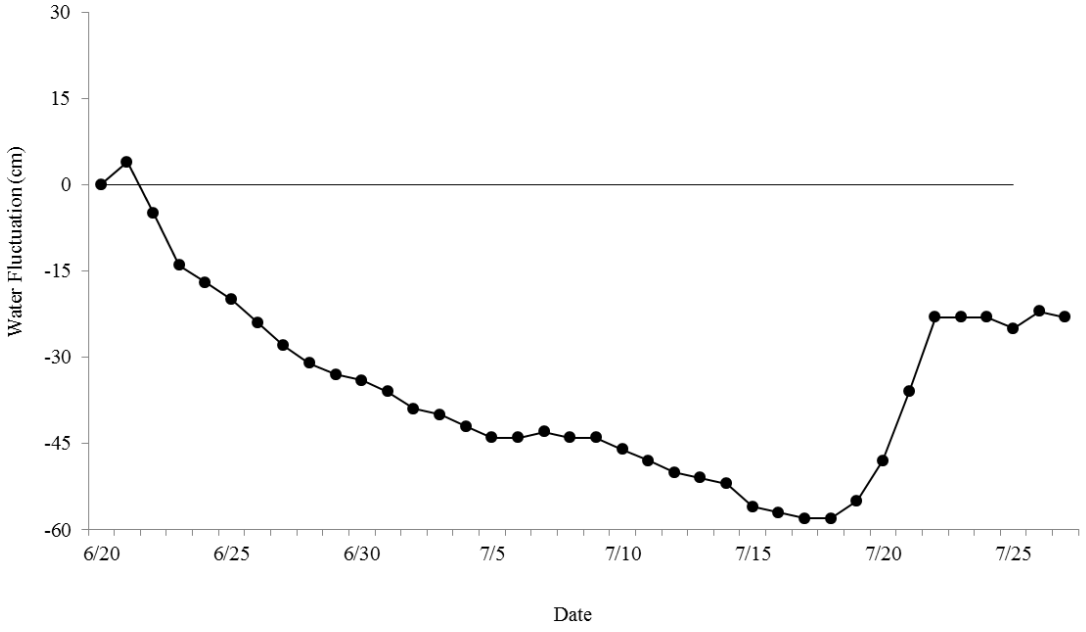

Figure 12.–Change in daily water elevation, relative to June 19, measured at the Anvik River sonar project, 2016.

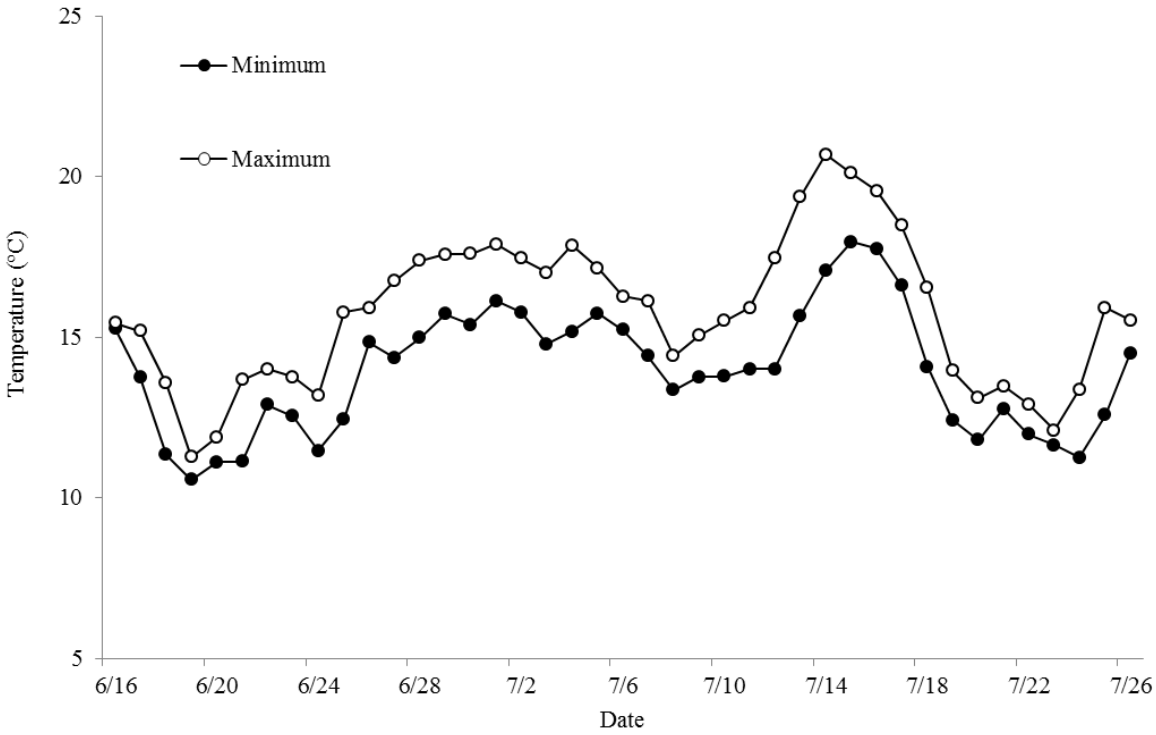

Figure 13.–Daily water temperatures at the Anvik River sonar, 2016.

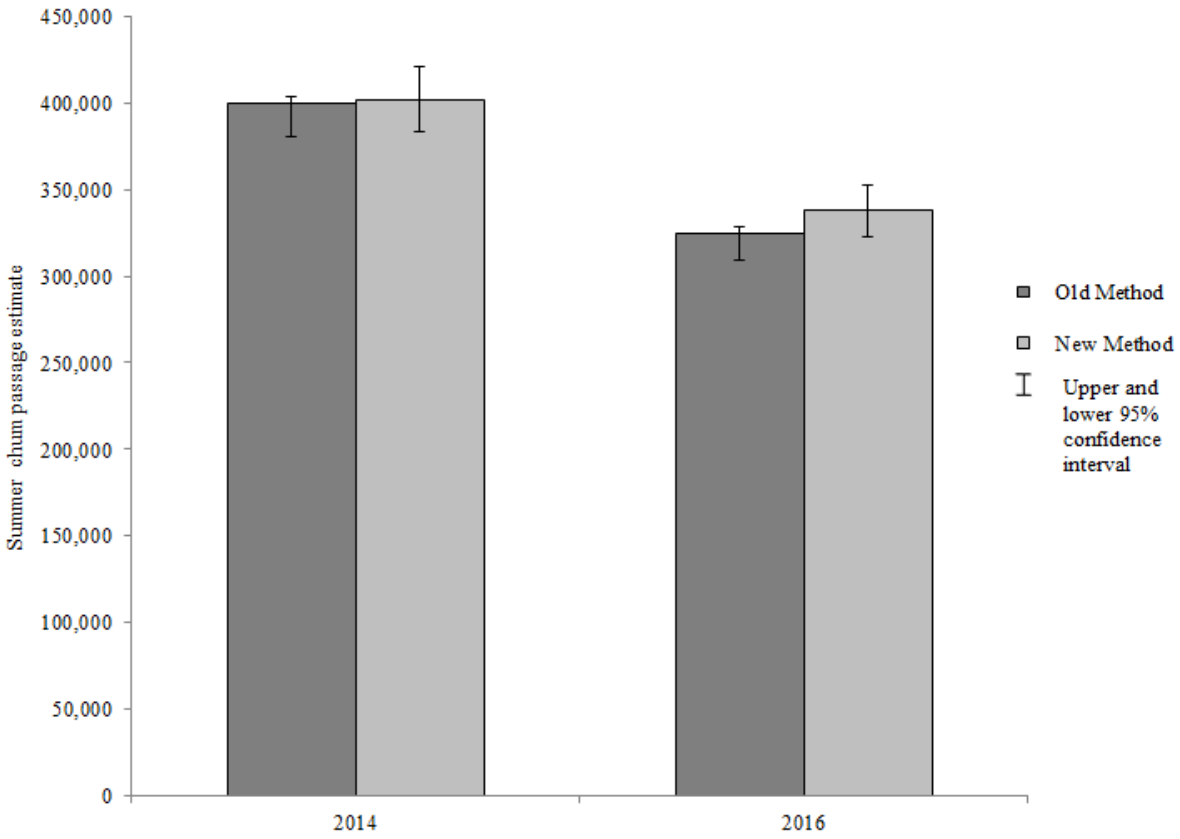

Figure 14.–Comparison of 2014 and 2016 summer chum passage estimates using new and older methods of proportioning passage at the Anvik River sonar project, 2016.

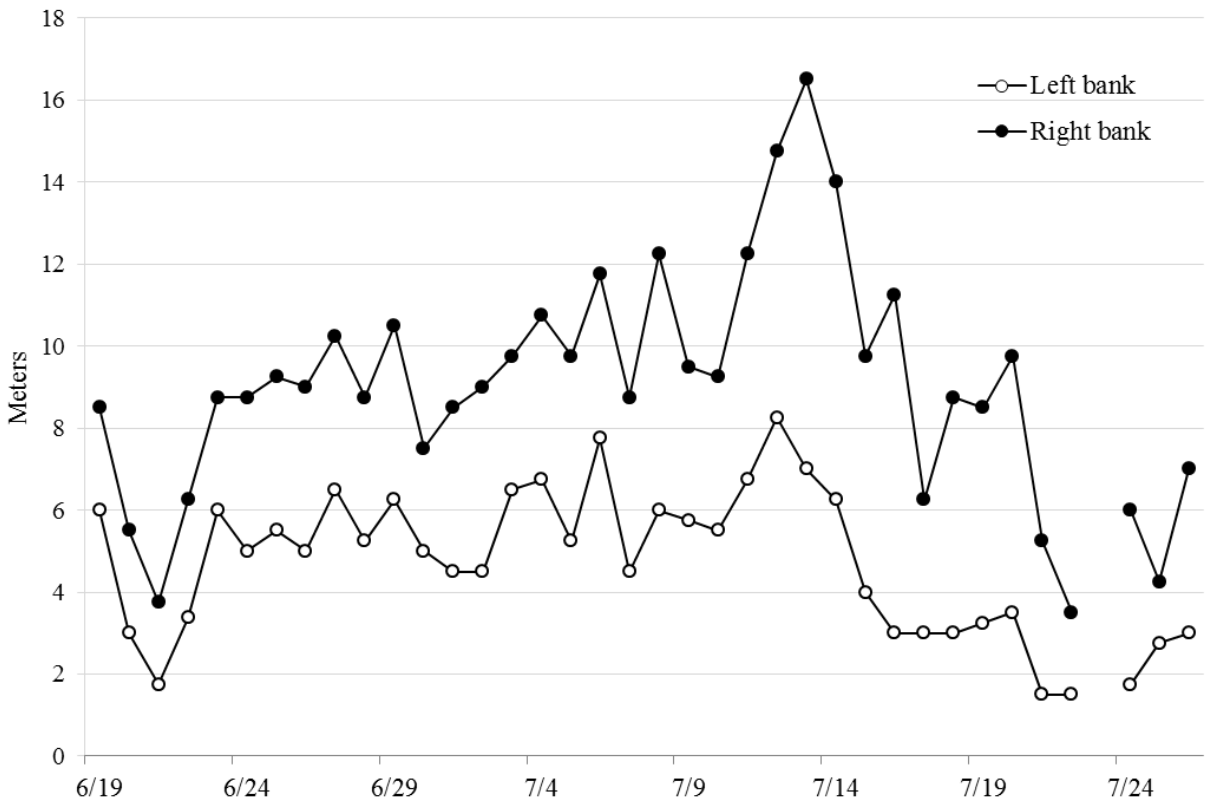

Figure 15.–Mean clarity by day (distance of visibility offshore from transducer) observed during tower counts at the Anvik River sonar project, 2016.

Note: Tower counts were not conducted on July 23 because of zero visibility caused by rain.

APPENDIX A: CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climatic observations recorded daily at 1600 hours, at the Anvik sonar project site, 2016.

Date	Precipitation (code)[a]	Wind Direction[b]	Wind Velocity (kph)	Sky (code)[c]	Air Temperature (°C)
6/17	A	W	6.3	B	16.4
6/18	B	W	1.9	O	13.1
6/19	B	W	1.4	O	14.3
6/20	A	WSW	2.7	B	16.9
6/21	A	W	4.5	S	22.0
6/22	A	W	10.5	O	21.4
6/23	A	W	4.0	O	13.5
6/24	A	E	11.3	B	19.1
6/25	A	E	8.0	S	26.0
6/26	A	E	4.5	B	23.6
6/27	A	W	7.6	S	23.5
6/28	A	W	6.3	S	24.5
6/29	A	W	2.4	B	22.1
6/30	A	W	6.6	S	24.6
7/01	A	W	12.2	B	23.0
7/02	A	E	3.5	O	21.0
7/03	A	ND	0.0	O	26.2
7/04	A	E	1.8	B	24.2
7/05	B	W	3.2	B	18.5
7/06	B	E	3.1	O	17.3
7/07	A	W	3.9	O	14.6
7/08	A	W	1.3	O	18.1
7/09	B	W	3.4	O	17.0
7/10	B	W	5.1	S	18.2
7/11	A	E	<1.6[d]	S	15.5
7/12	A	E	4.5	C	27.0
7/13	A	E	2.7	C	30.4
7/14	A	NE	3.5	S	30.0
7/15	A	W	6.8	B	23.2
7/16	A	W	2.4	S	24.6
7/17	B	W	8.9	O	18.6
7/18	A	W	4.8	O	14.2
7/19	B	W	3.7	O	13.7
7/20	B	E	<1.6[d]	O	14.6
7/21	B	W	3.5	O	13.1
7/22	B	W	2.9	O	14.2
7/23	B	W	<1.6[d]	O	14.4
7/24	B	E	<1.6[d]	S	20.8
7/25	A	E	<1.6[d]	C	25.2

[a] Precipitation code for the preceding 24h 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.

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

[d] Minimum anemometer velocity reading = 1.6 kph.