Fishery Data Series No. 15-08

Anvik River Sonar Chum Salmon Escapement Study, 2013

Final Report for Project 12-204
USFWS Office of Subsistence Management
Fisheries Information Services Division

by

Malcolm S. McEwen

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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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by

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ABSTRACT

The 2013 Anvik River sonar project operated from June 17 to July 26 to estimate the passage of summer chum salmon *Oncorhynchus keta*. Data from each bank was collected using a high frequency imaging sonar (DIDSON), which sampled 30 minutes of each hour, 24 hours per day, 7 days per week. The estimated chum salmon passage was 577,877 (SE 2,695). The summer chum salmon passage was within the escapement goal range for the Anvik River (350,000 to 700,000 chum salmon). Based on 1979–1985 and 1987–2012 mean quartile passage dates, timing of the 2013 chum salmon run was within 1–2 days of the average. A salmon diurnal migration pattern was observed this year, with the highest passage rates from 0100 to 0400. Females comprised 51.5% of the catch in beach seines. Age-0.3 and -0.4 fish comprised 98.4% of the chum salmon run in 2013.

Key words: chum salmon, *Oncorhynchus keta*, pink salmon, *O. gorbuscha*, sonar, DIDSON, Anvik River.

INTRODUCTION

The purpose of the Anvik River sonar project is to monitor escapement of summer chum salmon *Oncorhynchus keta* to the Anvik River drainage, which is 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, located at river kilometer (rkm) 167; the Rodo River (rkm 719); the Nulato River (rkm 777); the Melozitna River (rkm 938); and the Tozitna River (rkm 1,096). Spawning tributaries in the Koyukuk River (rkm 817) drainage are the Gisasa River (rkm 907) and the Hogatza River (rkm 1,255), as well as tributaries to the Tanana River (rkm 1,118) drainage, which include the Chena River (rkm 1,480) and the Salcha River (rkm 1,553) (Figure 1). Chinook salmon *O. tshawytscha* and pink salmon *O. gorbuscha* spawn in the Anvik River concurrently with summer chum salmon. Fall chum, which are a later run of chum salmon, and coho salmon *O. kisutch* have been reported to spawn in the Anvik River drainage during the fall.

Timely and accurate reporting of information from the Anvik River sonar project helps Yukon River fishery managers ensure the Anvik River biological escapement goal (BEG) of 350,000 to 700,000 summer chum salmon is met. This assessment is necessary to determine if summer chum salmon abundance will meet downstream harvest and upstream escapement needs. Fishery openings and closures may be based in part upon this assessment.

From 1972 to 1979, Anvik River 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, 5 km below Theodore Creek at lat 62°44.208′N, long 160°40.724′W. The land is public, managed by the Bureau of Land Management (BLM), and leased to ADF&G for public purposes until 2023. Aerial survey data indicate chum salmon spawn primarily upstream of this sonar site.

Side-looking sonar, capable of detecting migrating salmon along the banks, has been in place in the Anvik River since 1980. Bendix sonar equipment was used for escapement estimates from 1979 to 2003. In 2003, a side-by-side comparison was done with Hydroacoustic Technology

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

Incorporated (HTI)[2] split-beam sonar equipment where it was found that the Bendix and HTI produced similar abundance estimates (Dunbar and Pfisterer 2007). In 2004, the switch was made to HTI sonar equipment. In 2006 a side-by-side comparison was done between HTI and a dual frequency identification sonar (DIDSON). High water for most of the season prevented normal operation of the split-beam, but it was found the DIDSON abundance estimate was 61% higher than the split-beam abundance estimate (McEwen 2007). In 2007 the switch was made to DIDSON sonar.

Commercial and subsistence harvests of Anvik River chum salmon occur throughout the mainstem Yukon River, from the delta to the mouth of the Anvik River and within the first 19 km of the Anvik River. This section of the Yukon River includes Lower Yukon Area Districts 1, 2, and 3, and the lower portion of Subdistrict 4-A in the Upper Yukon Area (Figure 1). Most of the effort and harvest of this stock occurs in Districts 1 and 2, and in the lower portion of Subdistrict 4-A below the confluence of the Anvik and Yukon rivers.

Increased market demand prompted allocation disputes between fishermen in different districts. In February of 1990, the Alaska Board of Fish (BOF) established a guideline harvest range of 400,000 to 1,200,000 summer chum salmon for the entire Yukon River, allocated by district and subdistrict based on the average harvests of the previous 15 years (ADF&G 1990). Summer chum salmon escapement to the Anvik River exceeded the lower range of the Anvik River BEG (Clark and Sandone 2001) of 400,000 salmon by an average of 233,000 salmon from 1979 to 1993. In 2004, the BOF established a BEG for the Anvik River of 350,000–700,000 (ADF&G 2004).

In 1994, the BOF adopted the Anvik River chum salmon fishery management plan, which permits a commercial harvest of summer chum salmon in the terminal Anvik River Management Area (ARMA, ADF&G 1994) to allow commercial exploitation of surplus chum salmon returning to the Anvik River. In 1996, the BOF established a harvest limit of 100,000 pounds of chum salmon roe for the ARMA (JTC 1996).

A more complete history and background information can be found in *Annual management report, Yukon area* published each year by the Alaska Department of Fish and Game (ADF&G).

The Anvik River sonar project provides timely and accurate information to Yukon River fishery managers. DIDSON sonars were used to collect salmon passage, beach seines were used to collect age, sex, and length (ASL) data, and HOBO temperature loggers were used to monitor selected climatic and hydrologic parameters daily. This report presents data collected in 2013, and compares the results to previous years.

OBJECTIVES

The objectives of the Anvik River sonar project are to:

1. Estimate chum salmon abundance in the Anvik River using DIDSON sonar from approximately June 16 through July 26.
2. Collect a minimum of 162 chum salmon samples during each of 4 strata (corresponding to passage quartiles) throughout the season to estimate the age, sex, and length (ASL) composition of the Anvik River chum salmon passage,

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

such that simultaneous 95% confidence intervals of age composition in each sample are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).

3. Monitor selected climatic and hydrologic parameters daily at the project site for use as baseline data.

METHODS

STUDY AREA

The Anvik River originates at an elevation of 400 m and flows in a southerly direction approximately 200 km to its mouth at rkm 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, due to the site's stability. The river substrate at the sonar site is fine, smooth gravel, sand, and silt. The right bank slopes gradually to the thalweg at roughly 60–67 m, while the left bank river bottom slopes steeply to the thalweg at about 10–17 m (Figure 3), depending on water level.

HYDROACOUSTIC DATA ACQUISITION

Equipment

Two DIDSON units were deployed at the Anvik sonar site, 1 for each bank. Each DIDSON was mounted on an aluminum pod and manually aimed. A laptop computer running version 5.25 of the DIDSON software controlled each DIDSON unit.

The right bank sonar, operated at 1.2 MHz, and a 152.4 m cable transferred power and data between a "topside box" and the DIDSON unit in the water. An Ethernet cable routed data to a laptop computer. A RAID enclosure was connected to the laptop for storing data (Figure 4). The enclosure was configured as RAID 1 allowing redundant copies of the data on 2 separate hard drives within the enclosure in the event 1 of the hard drives failed. A Honda model EU-2000 generator provided power for all equipment.

The left bank sonar electronic equipment was housed in a portable tent and the equipment was powered by a single Honda model EU-1000 generator. The sonar operated at 1.8 MHz and a 33 m cable transferred power and data between a "topside box" and the DIDSON unit in the water. A wireless Ethernet router (D-Link DWL-2100AP) transferred the data from the left bank to the controlling laptop on the right bank where the data were saved to a RAID drive (Figure 4).

Equipment Settings

The DIDSON is a high frequency, multi-beam sonar with a unique acoustic lens system designed to focus the beam to create high resolution images. Sound pulses were generated by the sonar at center frequencies of 1.2 MHz for the long range DIDSON operated on the right bank and 1.8 MHz for the standard DIDSON on the left bank. DIDSON units simultaneously transmit on and then receive from sets of 12 beams. Images or frames are built in sequences of these sets of pings. At frequencies of 1.2 MHz, 48 beams (4 sets of 12) 0.6° apart from each other on a horizontal plane are utilized to form the image. At frequencies of 1.8 MHz 96 beams (8 sets of 12) 0.3° apart from each other on a horizontal plane are utilized to form the image. The right bank sampled at a range from 0.83 m to 20 m, the left bank sampled at a range from 0.83 to 10 m, and the sample rate was set to 6 frames per second on both banks.

Transducer Deployment

The transducers were attached to an aluminum pod, deployed on each bank, and oriented perpendicular to the current. 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. Transducers were placed offshore 24 to 28 m from the right bank, and 1 to 3 m from the left bank. Daily visual inspections confirmed proper placement and orientation of the transducers and alerted operators as to when the transducers needed to be repositioned to accommodate changing water levels. The majority of the river (68–75%), depending on water level, was ensonified by using the right bank transducer to sample outwards 20 m and the left bank transducer to sample outward 10 m.

Partial weirs were erected perpendicular to the current and extended from the shore out 1 to 3 m beyond the transducers. These devices diverted chum salmon, Chinook salmon, and other large fish offshore and in front of the transducers to prevent them from passing undetected behind the transducers. The 4.4 cm gap between weir pickets was selected to divert large fish (primarily chum and Chinook salmon) while allowing passage of small, resident, non-target species (Arctic grayling *Thymallus arcticus*, northern pike *Esox lucius*, longnose sucker *Catostomus catostomus*, and whitefish *Coregonus* spp.).

Sampling Procedures

The Anvik River sonar project runs from mid-June to the end of July which covers the majority of the summer chum salmon run and provides a minimum escapement estimate. Sonar project activities commenced on June 17 and ended on July 26, 2013. Hydroacoustic sampling began at 0001 hours on June 17 on right and left bank and ran every day until 2359 hours on July 26. Passage estimates were available to fishery managers in Emmonak at 0810 hours daily.

Acoustic sampling was conducted on both banks at the top of each hour for 30 minutes, 24 hours per day, 7 days per week, except for short periods when the generator was serviced or transducer adjustments were made. This sampling was consistent with previous field seasons. Three fishery technicians operated and monitored equipment at the sonar site while rotating through shifts (1 person per shift) at hours 0600–1400, 1000–1800, and 1600–0100. The technicians identified and tallied fish traces from the echogram recordings. The first shift counted fish from 0000–0759, the second shift counted fish from 0800–1559, and the third shift counted fish from 1600–2359. All fish were counted except for very small fish (< 400 mm), which are assumed not to be salmon. Counting was done manually using the echogram and marking fish traces with the computer mouse. The video was used to verify fish target, fish size, and direction of travel. The number of fish traces were then summed over the 30-minute periods and recorded onto forms. Completed data forms were entered into a Microsoft Excel spreadsheet and checked over by the crew leader. All sonar data were saved to the RAID drive in 30-minute intervals during the 8-hour shift for later review.

The crew recorded all project activities in a project logbook. The logbook was used to document daily events of sonar activities and system diagnostics. During each shift, crew members were required to do the following: 1) read the log from the previous shift; 2) record equipment problems, factors contributing to problems, and resolution of problems; 3) record equipment setting adjustments and their purpose; 4) record observations concerning weather, wildlife, boat traffic, etc.; and 5) record visitors to the site, including their arrival and departure times.

ANALYTICAL METHODS

Abundance Estimation

Daily passage $\hat{y}_{dz}$ on day *d* and bank *z* was estimated by first calculating the hourly passage rate $\hat{y}_{dzp}$ for each period *p*:

$$\hat{y}_{dzp} = x_{dzp}\left(60 / m_{dzp}\right), \tag{1}$$

where the rate is calculated by expanding the count x_{dzp} by the inverse of the fraction of the hour sampled, and where m_{dzp} is the minutes counted. Normally this is equivalent to doubling the 30-minute count (i.e., 60 / 30 = 2). The daily passage for each bank was estimated by summing the 24 hourly samples:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \hat{y}_{dzp} \,. \tag{2}$$

Finally, the total daily passage $\hat{y}_d$ was estimated by adding the daily passage for the 2 banks:

$$\hat{y}_d = \sum_{z} \hat{y}_{dz} \,. \tag{3}$$

Sonar sampling periods were spaced at regular (systematic) intervals. Treating the systematically sampled sonar counts as a simple random sample may overestimate the variance of the total since sonar counts can be highly autocorrelated (Wolter 1985). To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was utilized. This estimator was adapted from the estimator used at the Yukon River sonar project (Pfisterer 2002). The variance for the passage estimate for bank *z* on day *d* was estimated as follows:

$$\hat{V}ar_{y_{dz}} = 24^2 \cdot \frac{1 - f_{dz}}{n_{dz}} \cdot \frac{\sum_{p=24}^{n_{dz}} \left(y_{dzp} - y_{dz,p-1}\right)^2}{2\,n_{dz}\left(n_{dz} - 1\right)}, \tag{4}$$

where n_{dz} is the number of periods sampled in the day (generally 24), and f_{dz} is the fraction of the day sampled (12 / 24 = 0.5). Finally, since the passage estimates are assumed independent between zones and among days, the total variance was estimated as the sum of the variances:

$$\hat{Var}\left(\hat{y}\right)=\sum_{d}\sum_{z}\hat{Var}\left(\hat{y}_{dz}\right). \tag{5}$$

Missing Data

Depending on the amount of time that was missed, the crew used different methods to make up for incomplete or missing counts. If less than 25 minutes were missed, the passage rate for the period within that interval was used to estimate passage for the non-sampled portion of the interval as in Equation (1).

If data from 1 or more complete samples were missing, counts were interpolated by averaging counts from samples before and after the missing sample(s):

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

where s is the number of missed samples, n is the number of samples used for interpolation (half before and half after the missing sample(s)), and x_i is the count for each sample i.

If more than 4 samples were missed, an XY scatterplot with a regression line was plotted using the known fish counts for the day from both left bank and right bank. The linear regression equation of the line was then used to calculate missing fish counts for each missing sample s:

$$\hat{y}_s = a + bx_s, \tag{7}$$

where a and b are the regression coefficients, x equals the count for sample s on the opposite bank, and $\hat{y}_s$ is the estimated passage for missing sample s.

Species Apportionment

Tower counts were attempted 4 times per day (0730, 1300, 1700, and 2000 hours) for 15 minutes on each bank in order to determine numbers passing by species. On right bank, a 15 ft tower was erected and anchored in the river just downstream of the sonar at the end of the weir. A crew member would stand on top with polarized sunglasses to count and identify salmon by species passing the sonar. On left bank, the crew member would stand on the bank just upriver of the sonar with polarized sunglasses. For each bank the technician would look out into the water as far as possible and still be able to identify salmon and count the number of salmon by species going upstream. The number of salmon species for each bank and the visible range was entered into an Excel spreadsheet; non-salmon species were not counted or recorded.

Daily sonar passage estimates y by species a were apportioned to either pink or chum salmon by applying the estimated proportion p to the unadjusted daily passage estimate for each bank z:

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

With only 2 species apportioned for, the variance of the proportion followed the binomial distribution:

$$Var(\hat{p}_{dza}) = \hat{p}_{dza} \cdot (1 - \hat{p}_{dza})/(n-1)\,. \tag{9}$$

The variance of the species passage estimate was calculated as follows:

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

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

$$\hat{y}_{da} = \sum_{z} \hat{y}_{dza}\,. \tag{11}$$

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:

$$\hat{V}ar(\hat{y}_{a}) = \sum_{d} \sum_{z} \hat{V}ar(\hat{y}_{dza})\,. \tag{13}$$

Assuming normally distributed errors, 90% confidence intervals were calculated as follows:

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

AGE, SEX, AND LENGTH SAMPLING

Temporal strata, used to characterize the age and sex composition of the 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 current year ASL sampling dates, we used the historical mean quartile ASL dates (Table 1). The 2013 sampling strata were determined postseason based on run timing data. They represent an attempt to sample the escapement for ASL information in proportion to the total run. In 2013, these strata were defined as follows: June 17–July 1, July 2–8, July 9–15, and July 16–26.

To meet regionwide standards for the sample size needed to describe a salmon population, the initial seasonal ASL sample goal was 648 chum salmon, with a minimum of 162 chum salmon samples collected during each temporal stratum (Bromaghin 1993). Sample size goals were 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 to sample all fish captured while pursuing the 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 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. Chum salmon were placed in a holding pen and each was noted for sex, measured to the nearest 1 mm from mideye to tail fork, and 1 scale was taken for age determination. Where possible, scales were removed 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 chum salmon to prevent resampling. If any Chinook salmon were caught, they were sampled using the same methods as for chum salmon, except 3 scale samples were taken from each fish.

CLIMATIC AND HYDROLOGIC SAMPLING

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 and air temperature was measured using a HOBO water temp logger, which electronically recorded the temperature every hour on the hour for the duration of the project. These data were downloaded to a computer at the end of the season. Daily maximum and minimum air temperatures were recorded in degrees Celsius. Subjective notes on wind speed and direction, cloud cover, and precipitation were recorded.

RESULTS

ESCAPEMENT ESTIMATES AND RUN TIMING

The objective of collecting fish abundance data using sonar was met. Full sonar operations on both banks began at midnight on June 17, and both transducers collected data through July 26. The 2013 summer chum salmon passage estimate was 577,877 salmon (Table 2). This includes estimates for missing sector or hourly counts and expansions for missing data. For the right bank, a total of 3,030 min sampling time was missed, and on the left bank, 1,590 min sampling time was missed (Table 3).This missed sampling time accounted for 2.1% and 1.1% respectively of the overall time. Most of the estimates for missing counts were due to high water and the weir panels getting blown out and then having to reaim the sonar.

Summer chum salmon passage dates were 1 to 2 days earlier at the first and third quartile when compared to the historic run timing, based on 1979–1984 and 1987–2012 runs (Table 1). The central half of the run passed between July 2 and July 11, and the duration of 9 days was about equal to the historic mean of 10 days. The daily passage between the first and third quartile dates ranged from 19,847 (July 4) to 47,986 (July 10) with an estimated total of 326,108 summer chum salmon passing by the sonar site during this time (Table 2). The peak daily passage of 47,986 summer chum occurred on July 10 (Table 2; Figure 5). The 2013 chum salmon escapement estimate of 577,877 was less than the average Anvik River escapement estimate of 587,822 fish, (Table 1). This year's escapement was within the BEG of 350,000 to 700,000 summer chum salmon.

SPATIAL AND TEMPORAL DISTRIBUTION

For 2013 season, the right bank sonar detected 82% (472,270) of the chum salmon (Table 2). There was a diel pattern of salmon migration on the Anvik River this season (Figure 6). The lowest passage rates occurred during the daytime from 0800 to 1500, and the highest passage rate occurred from 0100 to 0400. On left bank, total fish passage ranged from a minimum of 3,298 fish at 1300 hours to a maximum of 7,005 fish per hour at 2000 hours. On the right bank, total fish passage ranged from a minimum of 16,231 fish at 0900 hours to a maximum of 23,304 fish at 2300 hours (Figure 7).

SPECIES APPORTIONMENT

Tower counts were conducted, and 15 Chinook salmon were observed over the season. No pink salmon were observed. Therefore, Chinook and pink salmon passage was considered negligible compared to chum salmon passage, and all counts were attributed to summer chum salmon.

AGE AND SEX COMPOSITION

The objective of collecting between 162 and 210 chum salmon scale samples in each strata was met. From June 27 through July 20, a total of 729 ASL samples from migrating chum salmon were obtained, and from these samples 582 scales were analyzed as ageable postseason. The scale sample analysis indicated that there were 2 major age classes (0.3 and 0.4) and 1 minor age class (0.5). Age-0.4 chum salmon accounted for 70.3% of the entire run, ranging from 46.7% to 89.5% throughout the run (Table 4; Figure 8). Age-0.3 chum salmon accounted for 28.1% of the entire run. Age-0.5 chum salmon accounted for 1.6% of the entire run, and there were no age-0.2 chum salmon. The average age of the 2013 run was 4.7 years, which is greater than the 1972–2012 average of 4.4 years (Figure 9). The percentage of female chum salmon increased throughout the run from 41.0% at the beginning to 60.8% by the end of the run. Overall there were 51.5% females (Table 4), which is below the 1972–2012 average of 55.9% and the 5 year running average of 53.4 % (Figure 9). Other species caught during ASL sampling were: Chinook salmon, sockeye salmon, whitefish, and grayling.

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The objective of monitoring selected climatic and hydrological parameters daily at the project site was met, and the summer of 2013 saw mild temperatures and wet conditions on the Anvik River. When the water gauge was put in on June 17, the water level was similar to previous years, and for the next 2 weeks the water level went steadily down 38 cm. The beginning of July brought rain, and the water level climbed 67 cm to its highest level for the season on July 8 (Figure 10). For the next 9 days the water level dropped 56 cm. On July 18, the water level climbed for 4 days to the same level as the start of the season and then dropped 38 cm by the end of the season on July 26. The minimum air temperature was 4.1°C (July 11), and the maximum temperature was 31.7°C (June 18) (Figure 11). The minimum water temperature was 8.1°C (July 6 and July 9), and the maximum temperature was 18.7°C (June 26) (Figure 12).

DISCUSSION

The 2013 Anvik River summer chum salmon escapement estimate of 577,877 was 2.0% below the 1979–2012 average escapement of 587,822. The 2013 summer chum salmon escapement was above the 2003–2012 average of 430,244. The timing of the summer chum salmon run into the Anvik River in 2013 was roughly similar to the pattern observed at Pilot Station (Figure 13). In addition, 21.0% of the summer chum salmon that were estimated to have passed Pilot Station were observed at the Anvik River sonar project (Figure 14). Historically the percentage of Yukon River summer chum salmon bound for the Anvik River has fluctuated. Although the overall contribution from 1995 to 2013 is 33.5%, this can be broken into 2 distinct periods. During the period from 1995 to 2002, the average contribution was 49.6%. From 2003 to present, the average contribution is 23.2%, which is slightly greater than this year's percentage. In spite of the improvement in relative contribution of the Anvik River in 2010 and 2011, the overall contribution remains low (relative to years prior to 2003) at this site and does not yet indicate an overall improvement in the contribution of summer chum salmon on the Anvik River to the Yukon River run. The productivity (return per spawner) on the Anvik River for the last complete 5 years (2003–2007) was an average of 1.16 (Table 5) compared to the last 5 years of the 1990s (1995–1999), when the average was 0.54. The return per spawner for 2008 and 2009, while the data are incomplete, does show an increase over the 5-year average of 2003–2007. We will need a few more years of data to conclude if the productivity of Anvik stocks, or the contribution relative to the rest of the Yukon River drainage, is improving in the Anvik River.

Age and sex composition of the Anvik River chum salmon passing the sonar site changes through the duration of the run. Usually, the trend is an increasing proportion of younger salmon and a higher proportion of female salmon as the run progresses (Fair 1997). The 2013 run was consistent with this pattern. The age composition observed at the Anvik River sonar project was similar to the rest of the Yukon River drainage. Age-0.4 and age-0.3 summer chum salmon were the dominant age groups throughout the Yukon River drainage at 62.4% and 36.9% respectively. Age-0.4 summer chum salmon from the other escapement projects comprised 80.1% of the East Fork Andreafsky River escapement, 35.9% of the Henshaw Creek escapement, 70.3% of the Anvik River escapement, and 63.1% of the Gisasa River escapement. Age-0.3 summer chum salmon from these projects comprised 19.7% of the East Fork Andreafsky River escapement, 64.0% of the Henshaw Creek escapement, 28.1% of the Anvik River escapement, and 35.9% of the Gisasa River escapement (Shane Eaton, Commercial Fisheries Biologist, ADF&G, Anchorage; personal communication).

Return for each brood year was determined by summing the return for the appropriate age groups in subsequent years. Chum salmon return to the Anvik River as age 3- to 6-year-olds and occasionally as age 7. Anvik River summer chum salmon return per spawner ranged from a low of 0.17 for the 1995 brood to a high of 5.57 for the 2001 brood, and the average over the 20-year period 1987 to 2007 was 1.40 (Table 5). The high degree of variability in return per spawner indicates the degree to which population and environmental factors may affect summer chum salmon production. Three possible factors, among many, that may affect the spawner-recruit relationship are abundance of spawners, winter incubation temperatures, and water level at time of spawning. At low abundance, individual spawners face reduced competition for optimum spawning substrate, while at high abundance competition is increased and redd sites may be disturbed by subsequent spawners. While a large return may result from a large parent year escapement, production by each spawner may be relatively low.

Low temperatures during incubation can reduce chum salmon egg survival (Raymond 1981). We do not have any overwinter climatological data (e.g., water and air temperatures) for the Anvik River prior to 2008. In the summer of 2008, in cooperation with the Aquatic Restoration and Research Institute, we started collecting air and water temperature year round using HOBO temperature loggers left at the sonar site. These data are still being collected, but some preliminary results show that the river freezes in mid-October and thaws in mid-May. Air temperature over the past 5 years from October through April ranged from a low of -47.6°C during the winter of 2011–2012 to a high of 14.0°C during the winter of 2008–2009. The overall average during this 5-year time period is -12.1°C (Figure 15). High water levels during spawning period may result in chum salmon spawning in less than ideal habitat away from the main channel. Subsequent drops in water levels in the autumn may result in desiccation of redd sites and extensive egg mortality. We are not able to compare water levels between years, and we do not know what the normal water level is in the fall, but spawning may be confined to the main channel in years of low water.

In 2013, chum salmon spatial migration followed historical trends with 82% of the fish passing on the right bank. Prior to 2013, passage has been associated with the right bank, with the exception of 3 years: 1992, 1996, and 1997. In these years only 43%, 45%, and 39% of the adjusted passage occurred on the right bank, respectively (Sandone 1994; Fair 1997; Chapell 2001). The shift to the left bank in those years was attributed to low water conditions that affected chum salmon migration patterns at the sonar site. Although there is no river stage benchmark at the site to allow direct comparison with previous years, subjectively, the water level at the beginning and end of the season for 2013 appeared to be about the same as in 2012. While the water level at the end of June was low, the rain in July caused the water level on the Anvik River to rise above what we have seen in previous years; also, the Yukon River was still high from the late breakup and did not start going down until mid-July.

Buklis (1982) first reported a distinct diurnal salmon migration pattern during the 1981 season, with a higher proportion of the migration passing the sonar site during darker hours of the night. Similar diurnal patterns were reported in 2010 and 2011. In 2012, high passage alternated between banks, with right bank passage highest during the night and left bank passage highest during the day. Distributions of sonar estimates in 2013 (Figure 6) do show a diurnal pattern overall. For the left bank, the highest passage occurred between the hours of 1900 to 0400 hours; for the right bank, passage was highest from 0100 to 0400 hours, which is consistent with previous observations.

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TABLES AND FIGURES

Table 1.–Annual passage estimates and passage timing for summer chum salmon runs, Anvik River sonar, 1979–2013.

						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
1979	277,712	23 Jun	2 Jul	8 Jul	12 Jul	9	6	4	10
1980	482,181	28 Jun	6 Jul	11 Jul	16 Jul	8	5	5	10
1981	1,479,582	20 Jun	27 Jun	2 Jul	7 Jul	7	5	5	10
1982	444,581	25 Jun	7 Jul	11 Jul	14 Jul	12	4	3	7
1983	362,912	21 Jun	30 Jun	7 Jul	12 Jul	9	7	5	12
1984	891,028	22 Jun	5 Jul	9 Jul	13 Jul	13	4	4	8
1985	1,080,243	5 Jul	10 Jul	13 Jul	16 Jul	5	3	3	6
1986	1,085,750	21 Jun	29 Jun	2 Jul	6 Jul	8	3	4	7
1987	455,876	21 Jun	5 Jul	12 Jul	16 Jul	14	7	4	11
1988	1,125,449	21 Jun	30 Jun	3 Jul	9 Jul	9	3	6	9
1989	636,906	20 Jun	1 Jul	7 Jul	13 Jul	11	6	6	12
1990	403,627	22 Jun	2 Jul	7 Jul	15 Jul	10	5	8	13
1991	847,772	21 Jun	1 Jul	10 Jul	16 Jul	10	9	6	15
1992	775,626	29 Jun	5 Jul	8 Jul	12 Jul	6	3	4	7
1993	517,409	19 Jun	5 Jul	12 Jul	18 Jul	16	7	6	13
1994	1,124,689	19 Jun	1 Jul	7 Jul	11 Jul	12	6	4	10
1995	1,339,418	19 Jun	1 Jul	6 Jul	11 Jul	12	5	5	10
1996	933,240	18 Jun	25 Jun	1 Jul	6 Jul	7	6	5	11
1997	605,752	19 Jun	28 Jun	3 Jul	10 Jul	9	5	7	12
1998	487,301	22 Jun	5 Jul	10 Jul	14 Jul	13	5	4	9
1999	437,356	27 Jun	6 Jul	10 Jul	16 Jul	9	4	6	10
2000	196,349	21 Jun	8 Jul	11 Jul	13 Jul	17	3	2	5
2001	224,058	26 Jun	6 Jul	10 Jul	15 Jul	10	4	5	9
2002	459,058	22 Jun	3 Jul	7 Jul	12 Jul	11	4	5	9
2003	256,920	21 Jun	5 Jul	10 Jul	15 Jul	14	5	5	10
2004	365,353	22 Jun	29 Jun	5 Jul	9 Jul	7	6	4	10
2005	525,391	26 Jun	4 Jul	10 Jul	15 Jul	8	6	5	11
2006	605,485	28 Jun	3 Jul	6 Jul	12 Jul	5	3	6	9
2007	460,121	26 Jun	5 Jul	10 Jul	17 Jul	9	5	7	12
2008	374,928	18 Jun	5 Jul	8 Jul	16 Jul	17	3	8	11
2009	191,566	18 Jun	4 Jul	9 Jul	15 Jul	16	5	6	11
2010	396,173	16 Jun	8 Jul	12 Jul	18 Jul	22	4	6	10
2011	642,527	16 Jun	2 Jul	7 Jul	14 Jul	16	5	7	12
2012	484,090	18 Jun	9 Jul	14 Jul	18 Jul	21	5	4	9
2013	577,877	17 Jun	2 Jul	8 Jul	11 Jul	15	6	3	9
Average	587,826	21 Jun	3 Jul	8 Jul	13 Jul	11	5	5	10
Median	483,136	21 Jun	4 Jul	8 Jul	14 Jul	11	5	5	10
SD	318,992	3 Jan	3 Jan	3 Jan	3 Jan	4.1	1.4	1.3	1.9

Note: The mean, median and standard deviation (SD) of the timing statistics include estimates from years 1979–1984 and 1987–2012. The 2013 data is not included so that the current year can be compared to the historical averages. In 1985 sonar counting operations began late and in 1986, sonar counting operations were terminated early, probably resulting in the incorrect calculation of the quartile statistics. Therefore, the 1985 and 1986 run timing statistics were excluded from the calculation of the overall mean and timing statistic and associated standard deviation.

Table 2.–Summer chum salmon daily and cumulative counts, Anvik River sonar, 2013.

Date	Left Bank	Right Bank	Daily Total	Cumulative
17 Jun	129	204	333	333
18 Jun	345	284	629	962
19 Jun	178	328	506	1,468
20 Jun	54	146	200	1,668
21 Jun	114	102	216	1,884
22 Jun	46	54	100	1,984
23 Jun	30	40	70	2,054
24 Jun	38	60	98	2,152
25 Jun	48	64	112	2,264
26 Jun	292	318	610	2,874
27 Jun	3,414	5,328	8,742	11,616
28 Jun	4,454	12,664	17,118	28,734
29 Jun	1,166	20,926	22,092	50,826
30 Jun	436	28,774	29,210	80,036
1 Jul	4,354	31,122	35,476	115,512
2 Jul	2,840	32,643	35,483	150,995
3 Jul	3,498	17,280	20,778	171,773
4 Jul	3,958	15,889	19,847	191,620
5 Jul	4,555	23,642	28,197	219,817
6 Jul	4,154	24,688	28,842	248,659
7 Jul	4,244	32,002	36,246	284,905
8 Jul	4,844	28,434	33,278	318,183
9 Jul	7,545	30,774	38,319	356,502
10 Jul	11,100	36,886	47,986	404,488
11 Jul	8,809	28,323	37,132	441,620
12 Jul	5,302	14,604	19,906	461,526
13 Jul	5,542	16,373	21,915	483,441
14 Jul	2,810	21,170	23,980	507,421
15 Jul	1,120	8,046	9,166	516,587
16 Jul	928	5,914	6,842	523,429
17 Jul	1,256	4,334	5,590	529,019
18 Jul	1,668	7,388	9,056	538,075
19 Jul	2,209	6,007	8,215	546,291
20 Jul	1,706	4,705	6,411	552,702
21 Jul	2,623	3,483	6,106	558,808
22 Jul	3,844	3,048	6,892	565,700
23 Jul	2,856	2,036	4,892	570,592
24 Jul	1,488	1,753	3,241	573,833
25 Jul	862	1,282	2,144	575,977
26 Jul	748	1,152	1,900	577,877
Season Total	105,607	472,270	577,877	

Note: The large box indicates the central 50% of the chum salmon run (second and third quartiles).

Table 3.–Number of minutes by bank and day that were adjusted to calculate the hourly or daily salmon passage, and the resulting number of fish added to estimate, Anvik River sonar, 2013.

	Left Bank		Right Bank	
Date	Minutes	Fish	Minutes	Fish
17 Jun	330.0	48	0.0	0
18 Jun	60.0	55	0.0	0
19 Jun	0.0	0	0.0	0
20 Jun	0.0	0	0.0	0
21 Jun	90.0	3	0.0	0
22 Jun	0.0	0	0.0	0
23 Jun	0.0	0	0.0	0
24 Jun	0.0	0	0.0	0
25 Jun	0.0	0	0.0	0
26 Jun	0.0	0	0.0	0
27 Jun	0.0	0	0.0	0
28 Jun	0.0	0	0.0	0
29 Jun	330.0	1,942	240.0	4,688
30 Jun	0.0	0	0.0	0
1 Jul	0.0	0	0.0	0
2 Jul	0.0	0	30.0	1,595
3 Jul	0.0	0	0.0	0
4 Jul	270.0	1,356	270.0	5,881
5 Jul	30.0	151	150.0	4,428
6 Jul	0.0	0	0.0	0
7 Jul	0.0	0	0.0	0
8 Jul	0.0	0	0.0	0
9 Jul	300.0	2,716	390.0	16,196
10 Jul	90.0	1,508	180.0	9,250
11 Jul	60.0	725	60.0	2,201
12 Jul	0.0	0	30.0	494
13 Jul	0.0	0	30.0	453
14 Jul	0.0	0	150.0	4,426
15 Jul	0.0	0	150.0	1,514
16 Jul	0.0	0	0.0	0
17 Jul	90.0	198	120.0	850
18 Jul	0.0	0	30.0	212
19 Jul	180.0	445	150.0	1,077
20 Jul	0.0	0	570.0	3,440
21 Jul	90.0	284	150.0	753
22 Jul	0.0	0	0.0	0
23 Jul	0.0	0	150.0	486
24 Jul	0.0	0	180.0	545
25 Jul	0.0	0	0.0	0
26 Jul	0.0	0	0.0	0
Total	1,590.0	9,383	3,030.0	58,489

Table 4.–Age and sex composition of summer chum salmon, Anvik River sonar, 2013.

			Age									
			(0.2)		(0.3)		(0.4)		(0.5)		Total	
2013 Sample Dates (Strata)	Ageable scales	Sex	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%
6/27-29	200	Male	0	0.0	6,353	61.1	60,066	58.1	1,733	100.0	68,152	59.0
(6/18-7/1)		Female	0	0.0	4,043	38.9	43,317	41.9	0	0.0	47,360	41.0
		Subtotal	0	0.0	10,396	9.0	103,383	89.5	1,733	1.5	115,512	100.0
7/3, 6	128	Male	0	0.0	17,417	47.8	76,002	46.6	1,583	50.0	95,002	46.9
(7/2-8)		Female	0	0.0	19,000	52.2	87,085	53.4	1,583	50.0	107,669	53.1
		Subtotal	0	0.0	36,417	18.0	163,087	80.5	3,167	1.6	202,671	100.0
7/12, 13	134	Male	0	0.0	44,419	53.6	47,380	42.7	1,481	33.3	93,279	47.0
(7/9-15)		Female	0	0.0	38,496	46.4	63,667	57.3	2,961	66.7	105,125	53.0
		Subtotal	0	0.0	82,915	41.8	111,047	56.0	4,442	2.2	198,404	100.0
7/17, 19, 20	120	Male	0	0.0	9,704	29.7	14,301	50.0	0	0.0	24,005	39.2
(7/16-26)		Female	0	0.0	22,984	70.3	14,301	50.0	0	0.0	37,285	60.8
		Subtotal	0	0.0	32,688	53.3	28,602	46.7	0	0.0	61,290	100.0
Season	582	Male	0	0.0	77,893	48.0	197,749	48.7	4,797	51.3	280,439	48.5
		Female	0	0.0	84,523	52.0	208,370	51.3	4,545	48.7	297,438	51.5
		Total	0	0.0	162,417	28.1	406,119	70.3	9,341	1.6	577,877	100.0

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

Table 5.–Anvik River summer chum salmon brood table with return per spawner 1987 to present.

Brood Year	Escapement	Number of Fish by Age Class[a] 0.2	0.3	0.4	0.5	0.6	Total Return	R/S
1987	455,876	13,501	480,033	697,632	15,804	22	1,206,993	2.65
1988	1,125,449	840	267,719	214,012	16,142	0	498,714	0.44
1989	636,906	2,520	374,740	780,541	73,620	238	1,231,658	1.93
1990	403,627	3,379	441,397	676,695	26,148	23	1,147,643	2.84
1991	847,772	22	844,961	534,460	14,516	0	1,393,960	1.64
1992	775,626	39,076	630,294	404,043	7,591	7	1,081,012	1.39
1993	517,409	5,312	292,425	103,577	5,632	0	406,946	0.79
1994	1,147,262	3,269	424,089	301,083	4,487	0	732,928	0.64
1995	1,394,162	129	172,419	62,925	5,397	0	240,870	0.17
1996	1,017,873	92	158,411	210,835	8,828	0	378,166	0.37
1997	619,300	1,767	33,796	104,599	4,284	0	144,446	0.23
1998	487,301	0	369,505	72,451	1,928	0	443,884	0.91
1999	437,356	8,894	203,268	226,119	3,467	0	441,748	1.01
2000	196,349	3,141	164,193	165,669	172	81	333,257	1.70
2001	224,058	10,106	547,217	630,375	59,123	88	1,246,909	5.57
2002	459,058	179	406,630	197,377	21,692	156	626,034	1.36
2003	256,920	12,951	315,016	240,519	10,003	0	578,490	2.25
2004	365,353	5,061	199,985	120,668	1,290	0	327,004	0.90
2005	525,391	6,087	161,296	63,681	6,130	0	237,193	0.45
2006	992,378	5,915	420,978	394,426	8,207	0	829,526	0.84
2007	460,121	35,346	402,640	177,568	4,821	0	620,375	1.35
2008	374,928	2,733	441,160	534,181			978,075	2.61
2009	191,566	3,511	270,512				274,023	1.43
2010	396,173	0						
2011	642,528							
2012	484,090							
2013	577,877							

[a] Includes a proportion of the commercial catch from Districts 1, 2, 3, and 4 destined for Anvik River.

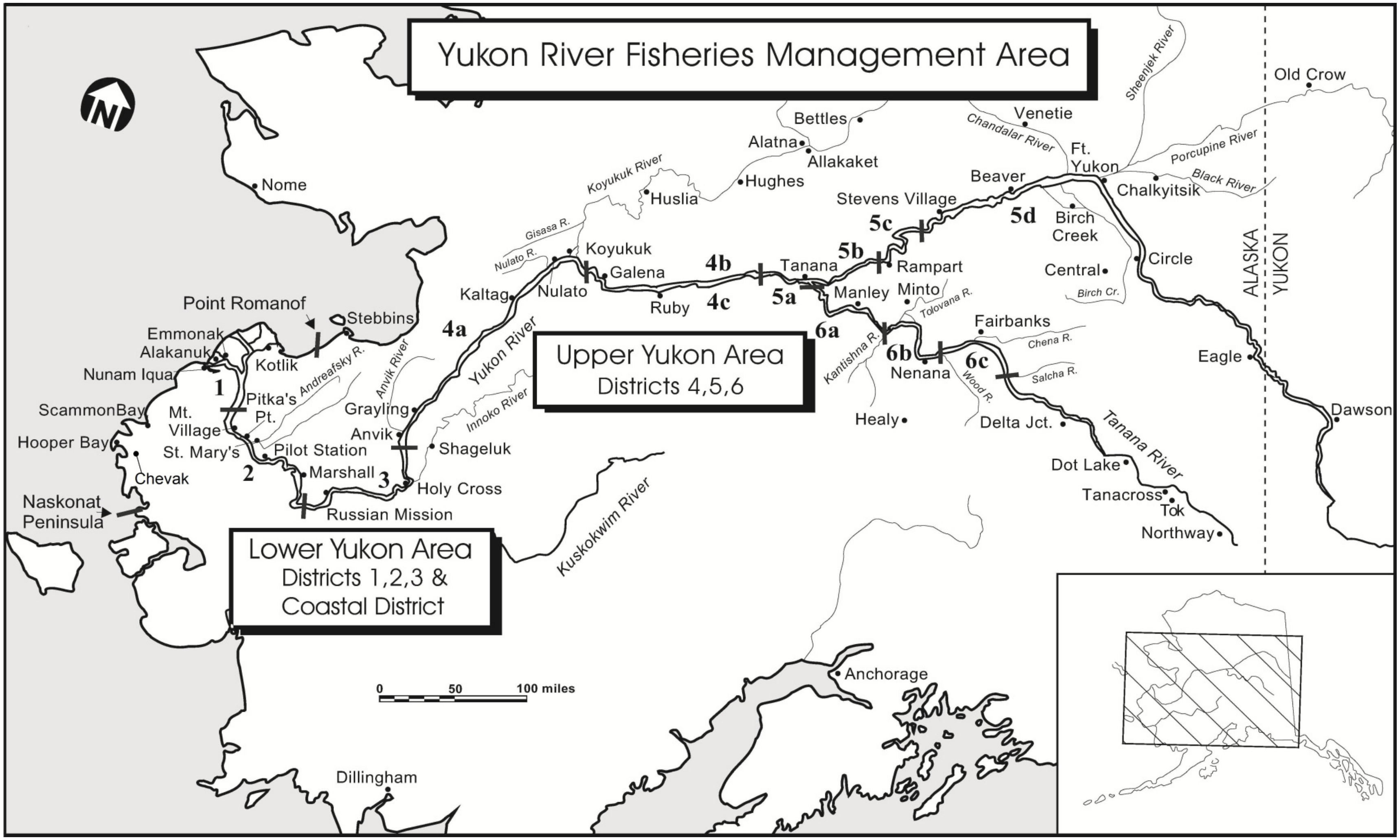

Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

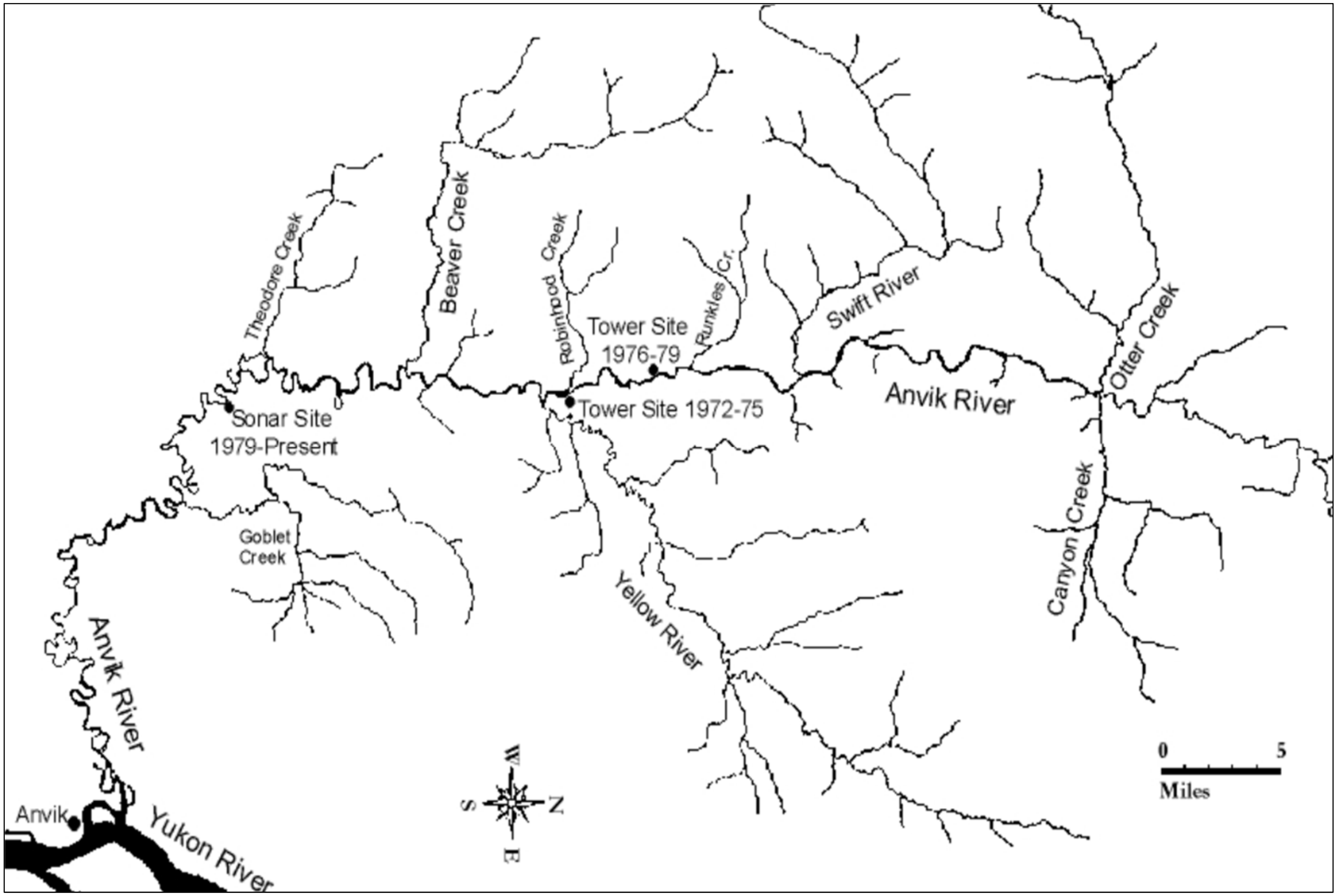

Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

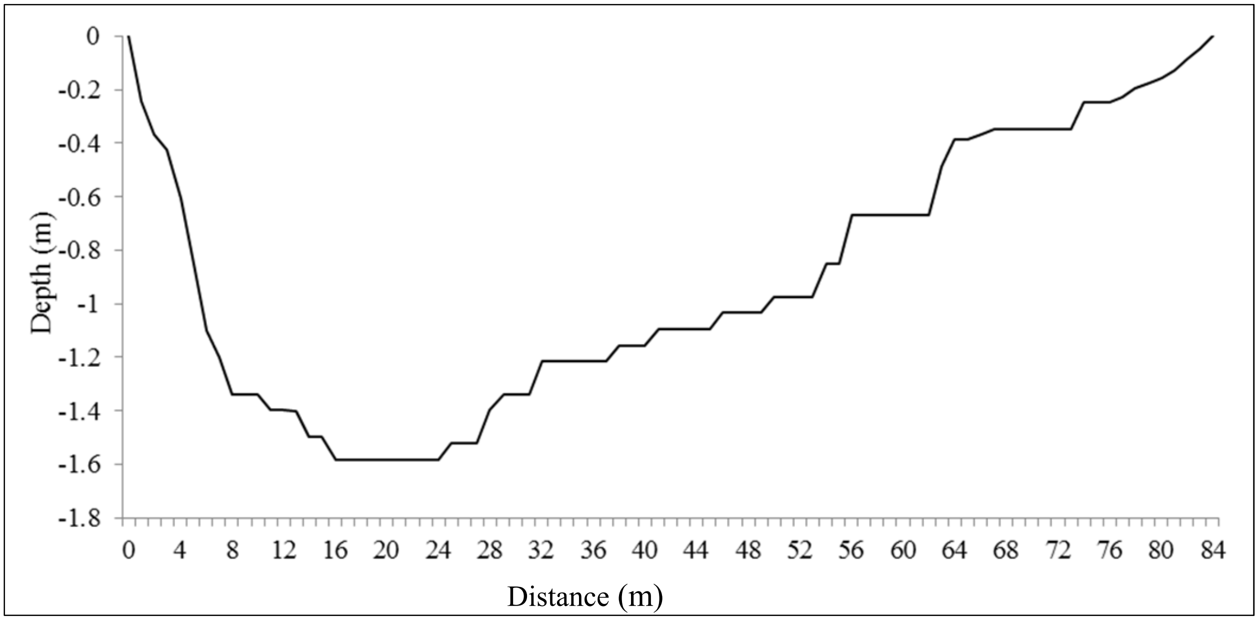

Figure 3.–Anvik River depth profile (downstream view) made June 26, 2013.

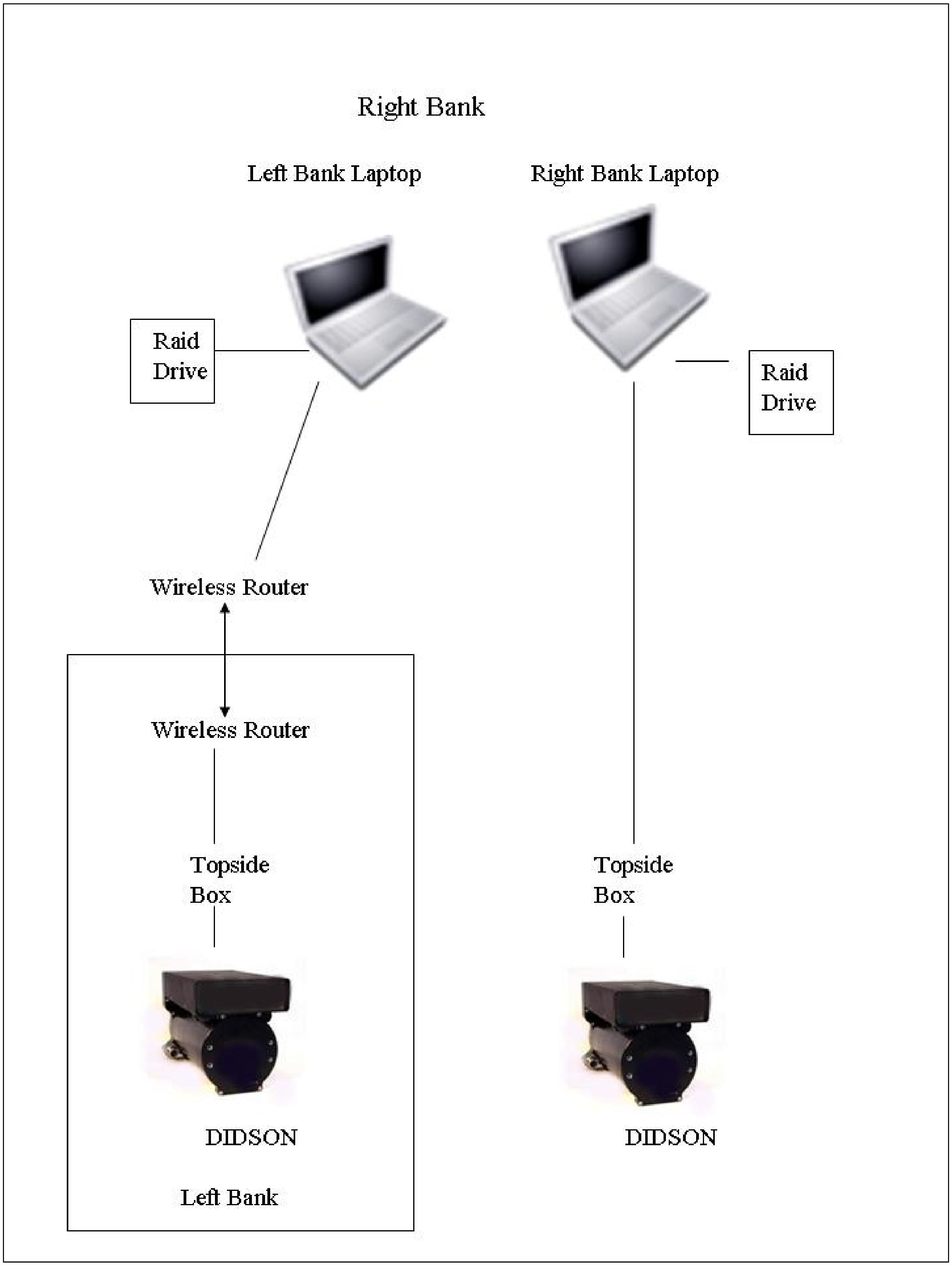

Figure 4.–DIDSON sonar equipment schematic, Anvik River sonar, 2013.

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

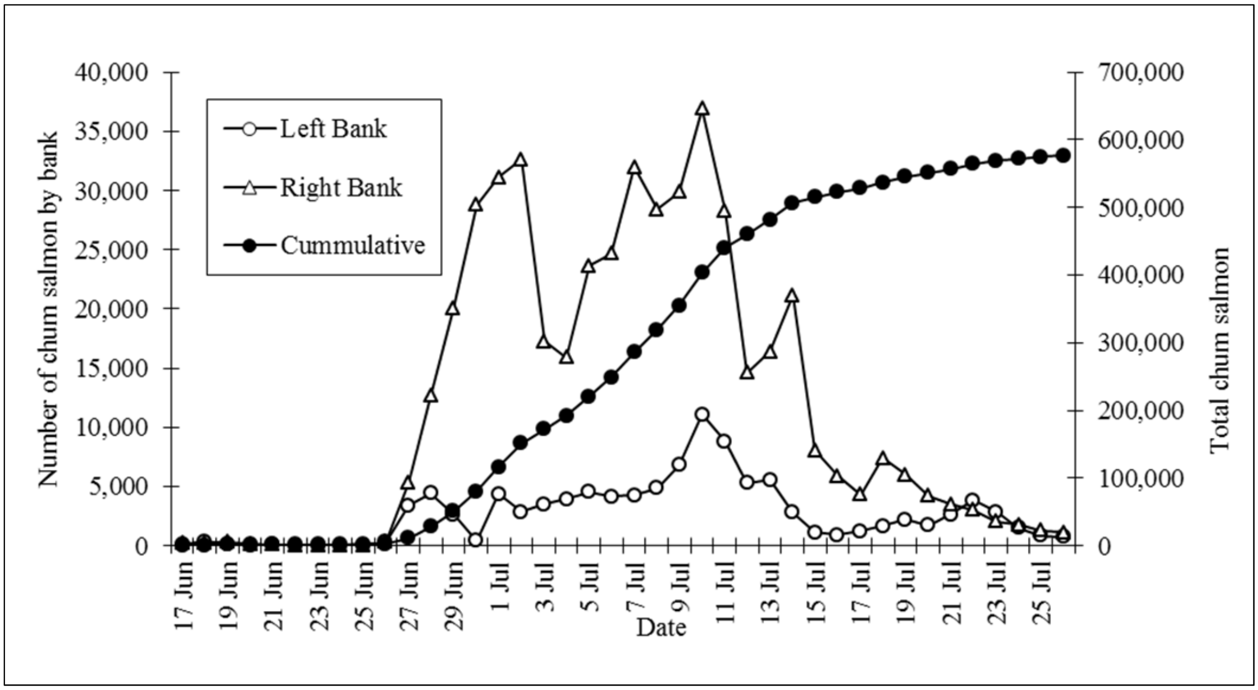

Figure 5.–Summer chum salmon daily and cumulative counts, Anvik River sonar, 2013.

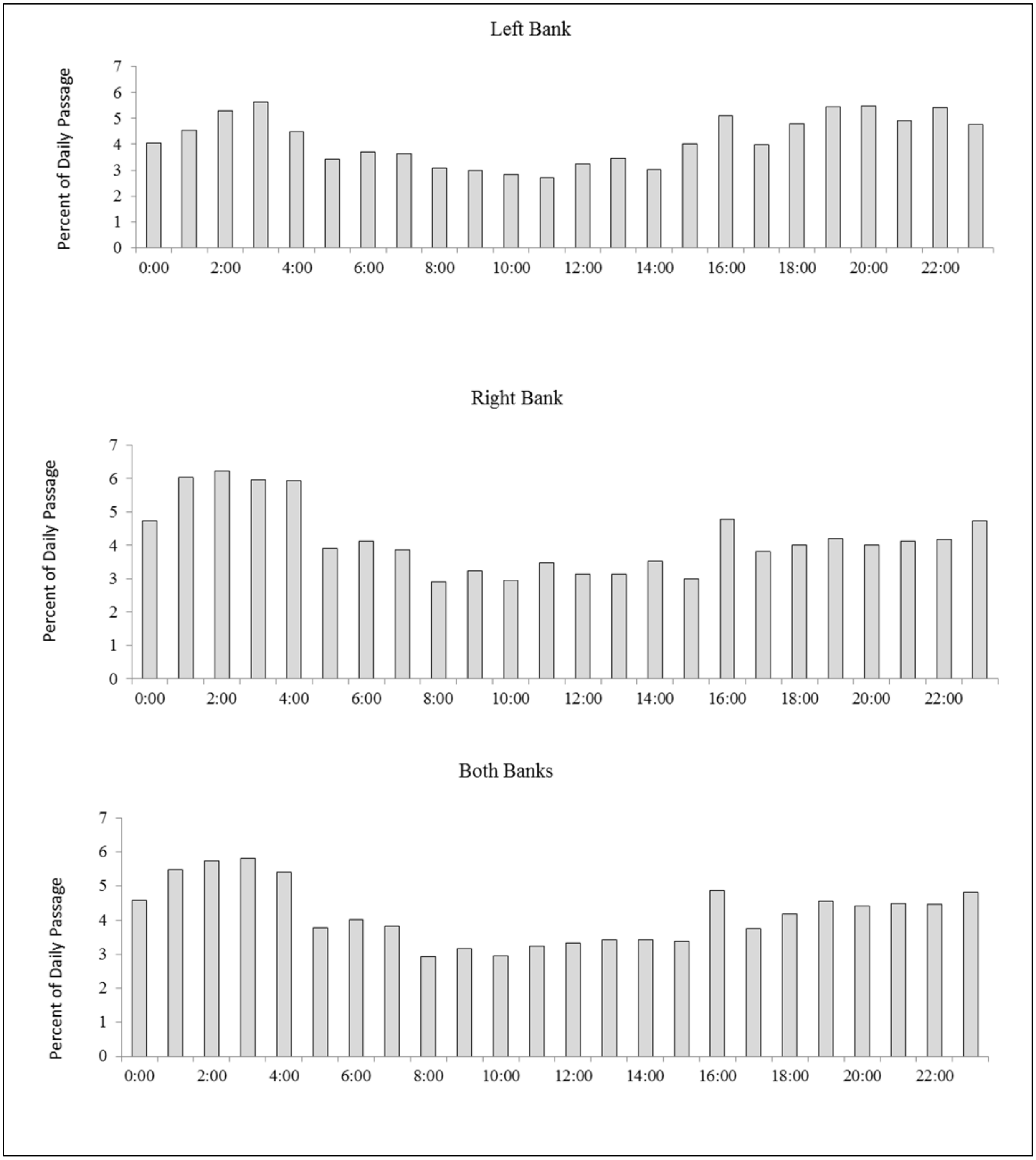

Figure 6.–Diel migration pattern of salmon on the left bank (top), right bank (middle), and both banks combined (bottom) of the Anvik River, 2013.

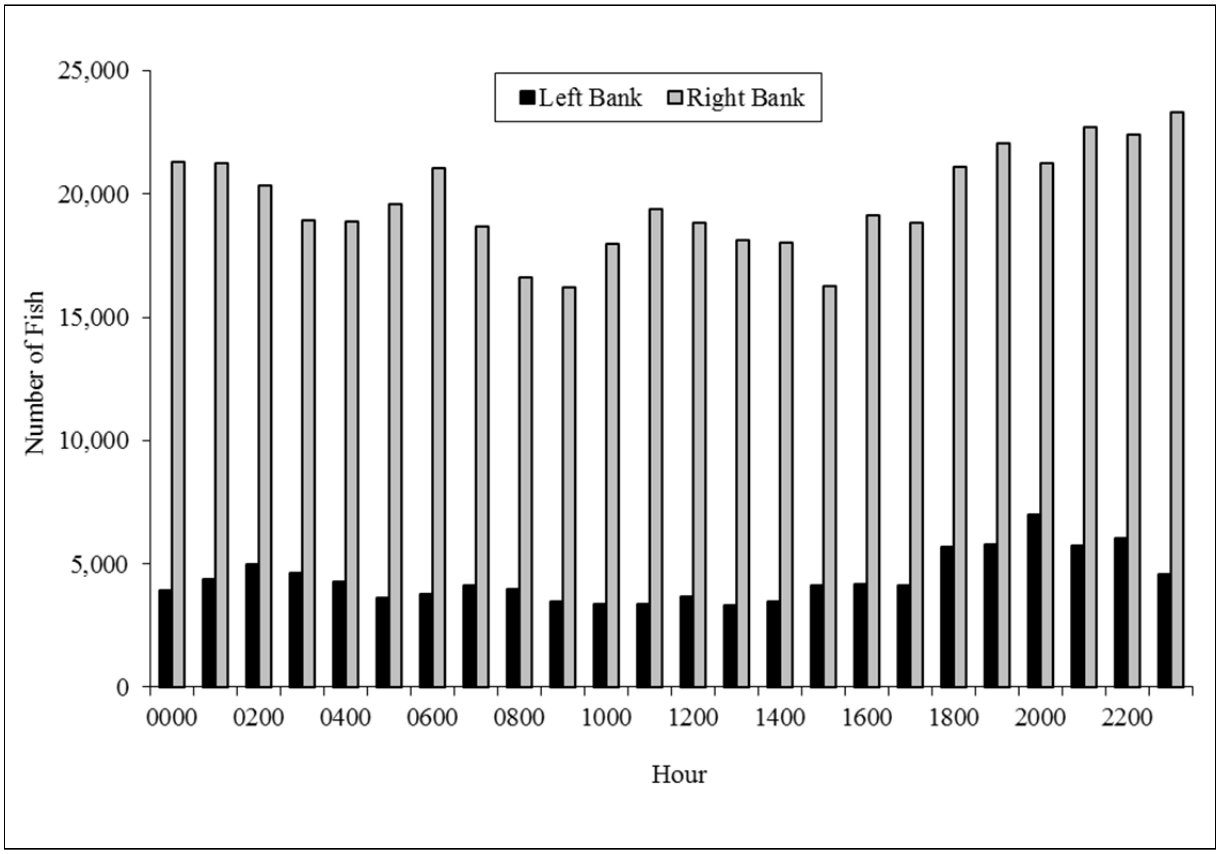

Figure 7.–Estimated total passage of salmon by hour for each bank, Anvik River sonar, 2013.

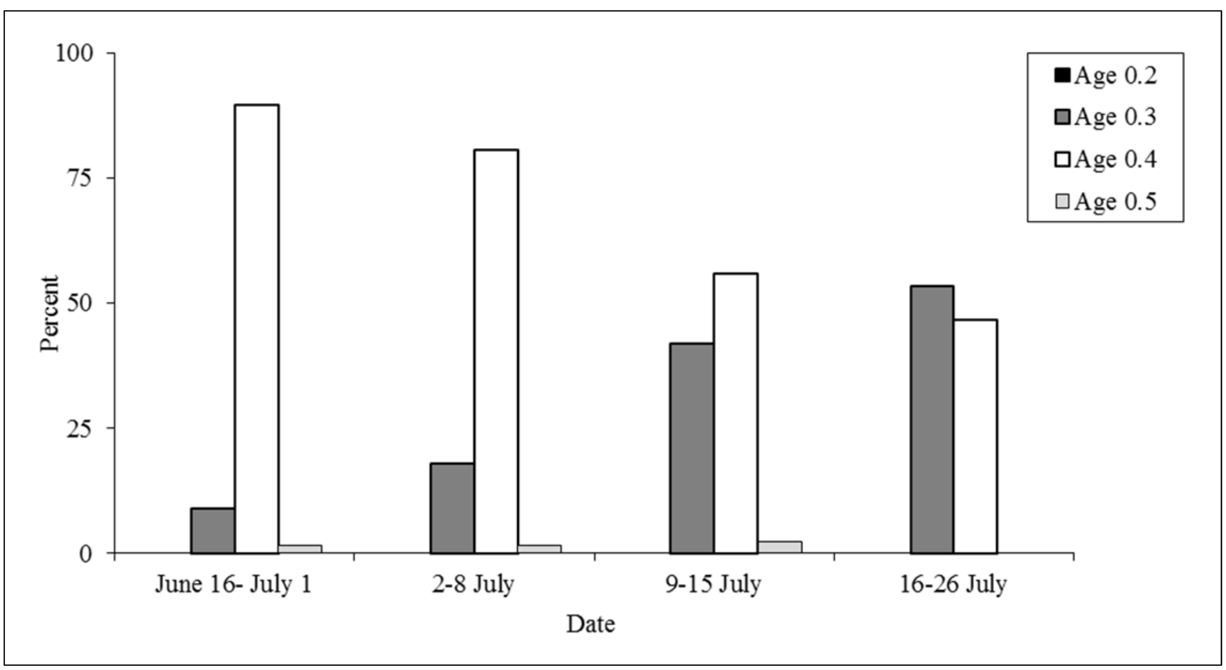

Figure 8.–Summer chum salmon age composition, Anvik River sonar, 2013.

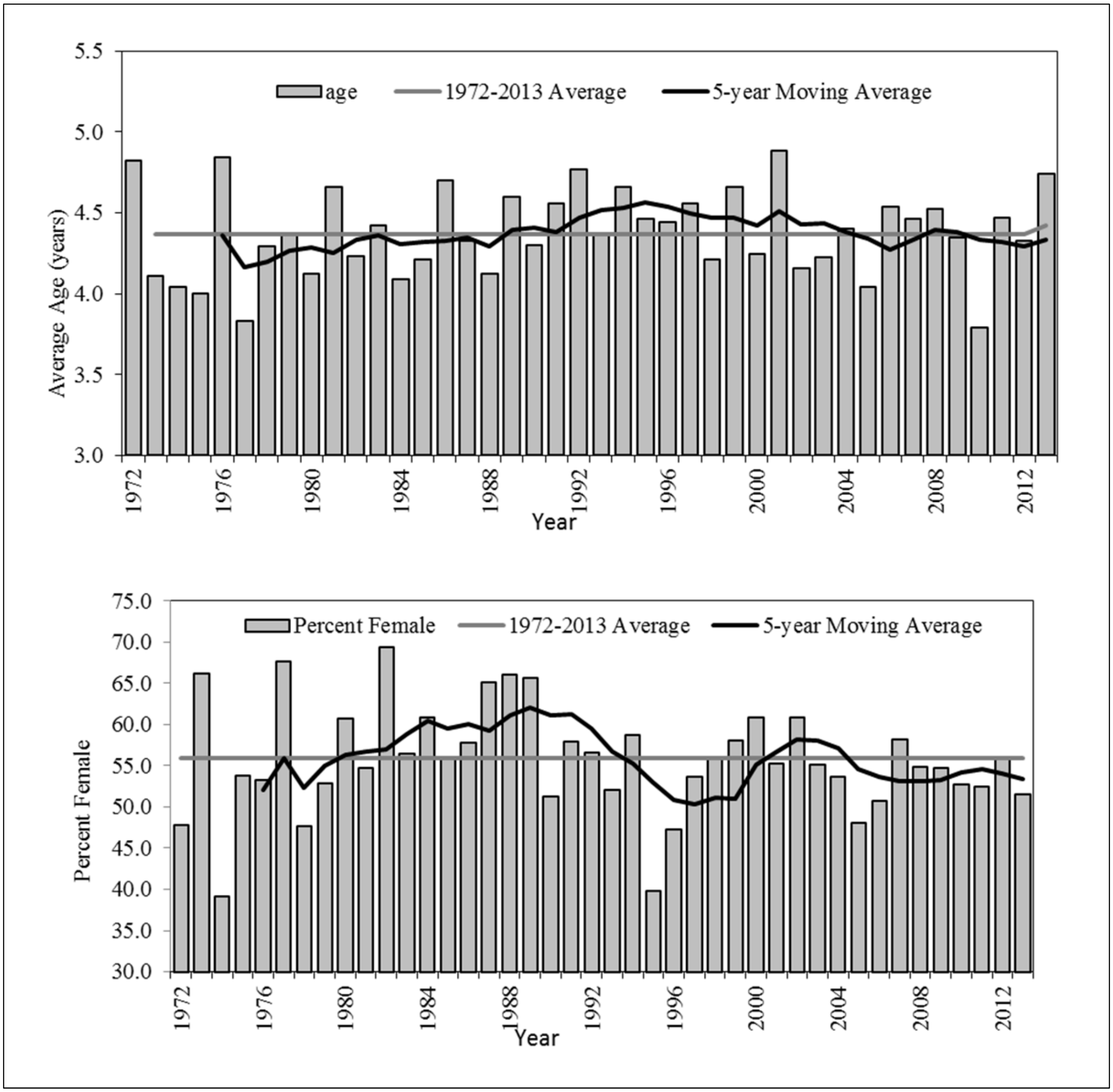

Figure 9.–Annual age at maturity (top) and percentage of females (bottom) of the Anvik River summer chum salmon escapement, 1972–2013.

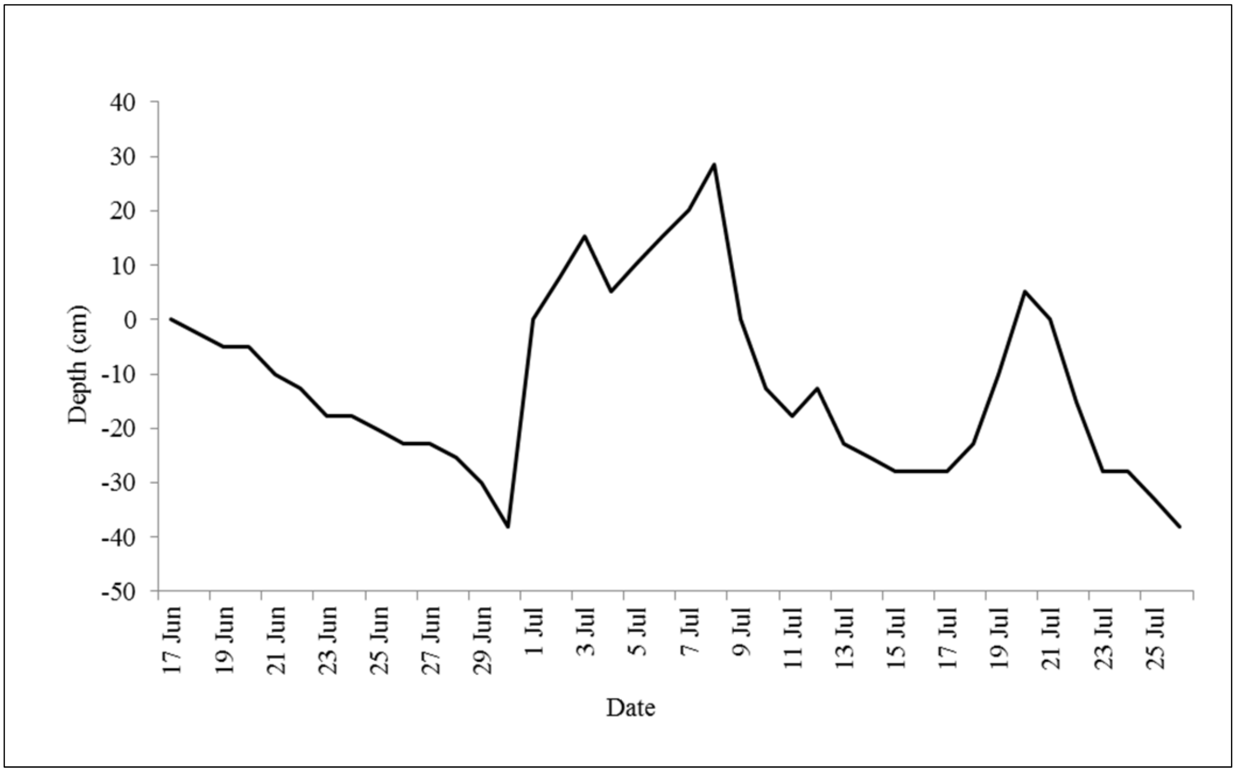

Figure 10.–Water depth at Anvik River sonar, 2013.

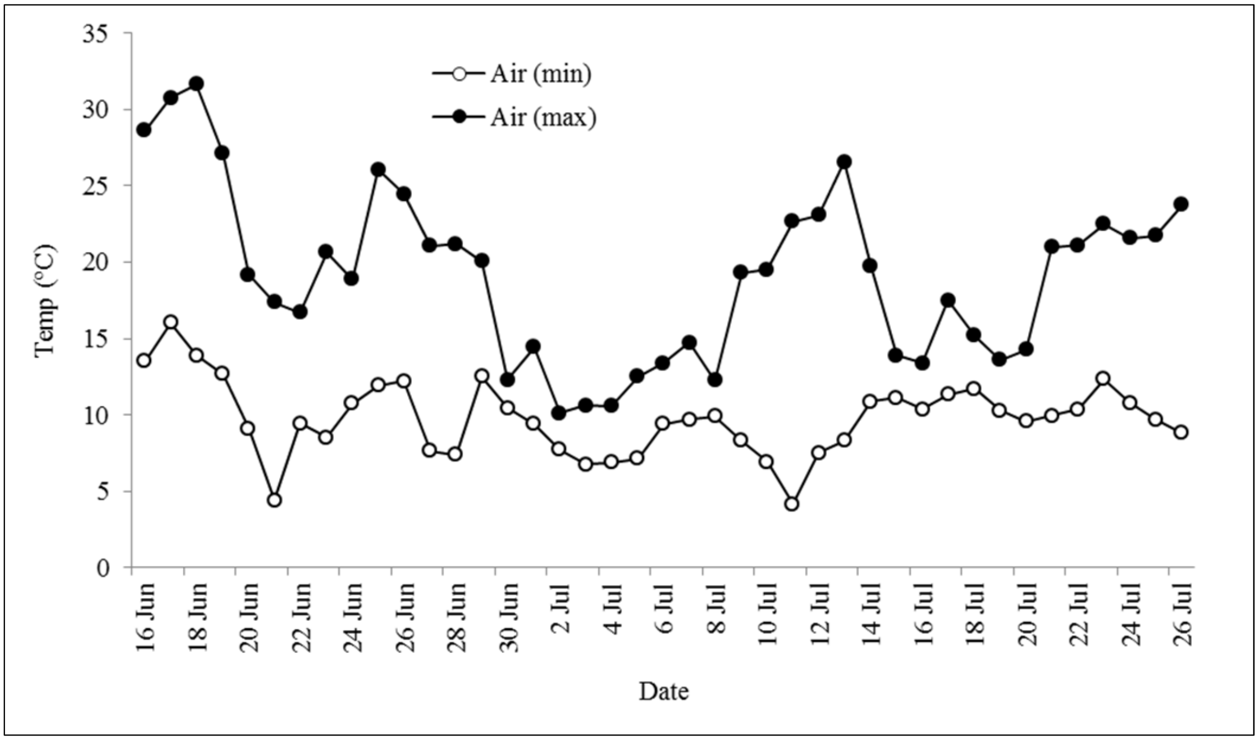

Figure 11.–Air temperature, Anvik River sonar, 2013.

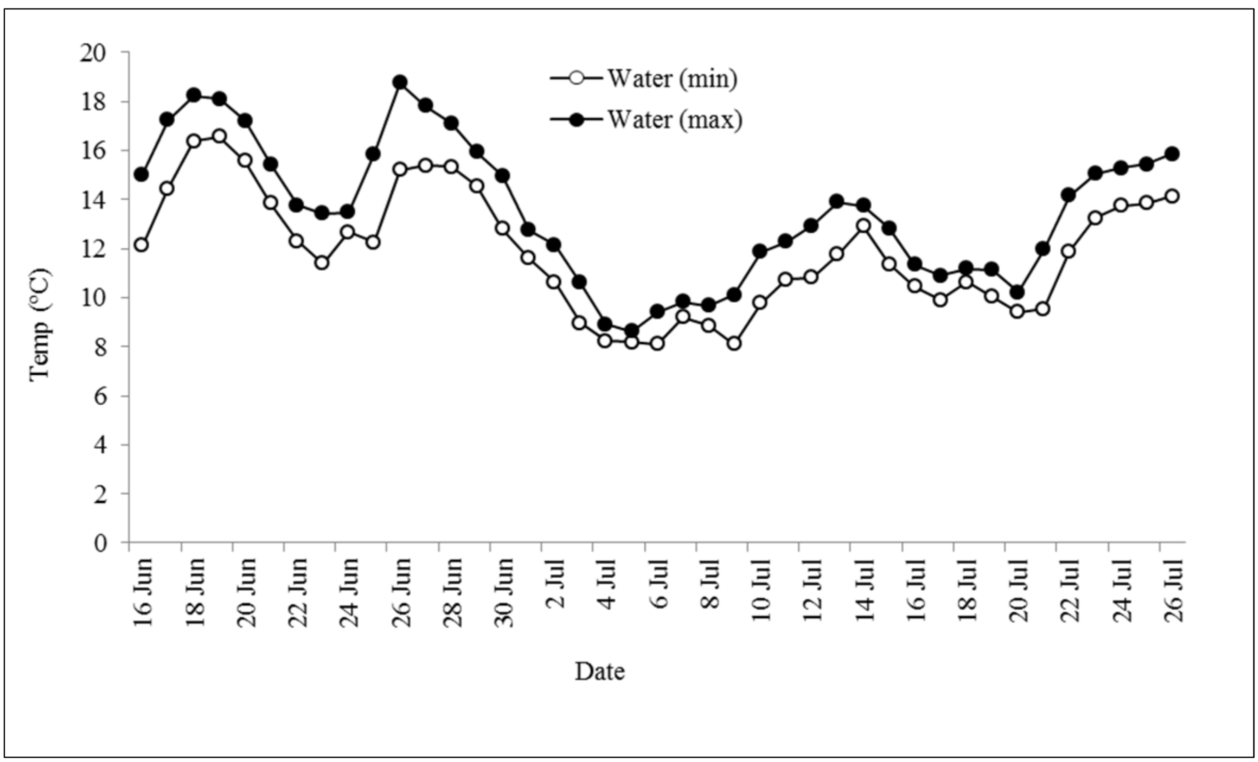

Figure 12.–Water temperature, Anvik River sonar, 2013.

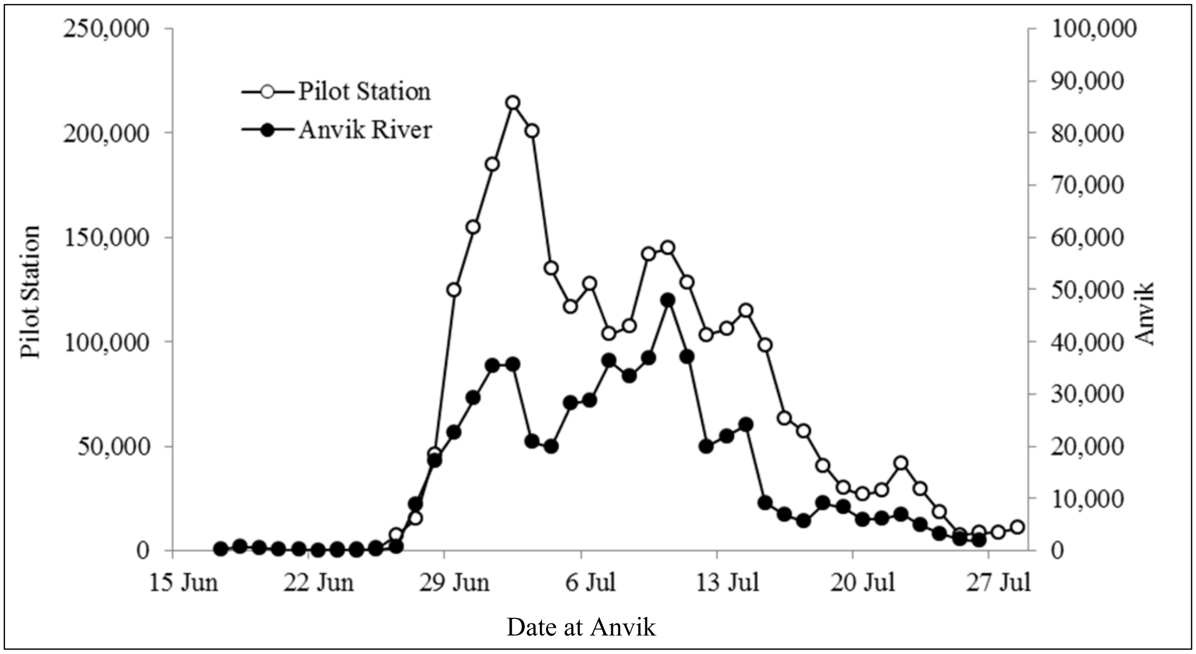

Figure 13.–Comparison of daily summer chum salmon passage at Pilot Station sonar and Anvik River sonar, 2013.

Note: Pilot Station lagged forward 9 days to align with Anvik.

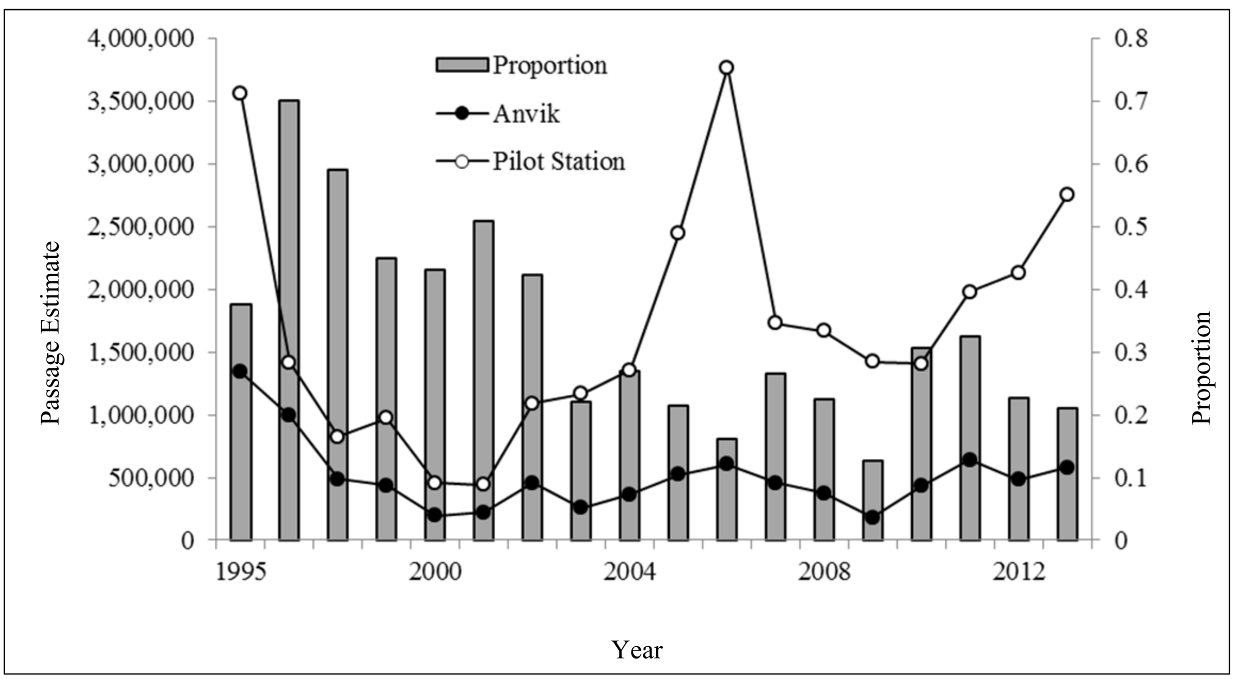

Figure 14.–Summer chum salmon passage estimate comparison between Pilot Station sonar project and Anvik River sonar project with the proportion of the Pilot Station estimate observed at the Anvik River in each year.

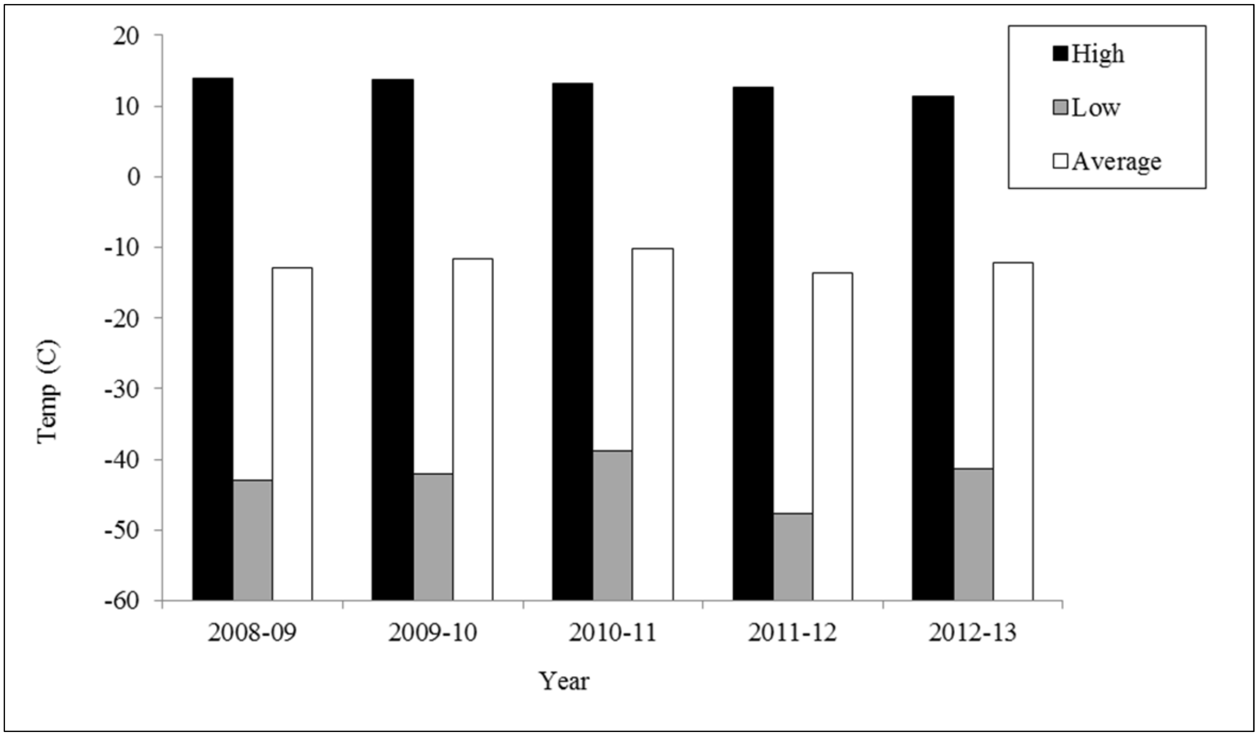

Figure 15.–Overwintering air temperatures Anvik River sonar 2008–2013.