Fishery Data Series No. 10-78

Anvik River Sonar Chum Salmon Escapement Study, 2009

Report for Project 08-202
USFWS Office of Subsistence Management
Fisheries Information Services Division

by

Malcolm S. McEwen

November 2010

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

Symbols and Abbreviations

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

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

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

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

The 2009 Anvik River sonar project operated from late June until the end of July to estimate the passage of summer chum salmon *Oncorhynchus keta*. Data from each bank was collected using a high frequency imaging sonar (DIDSON) sampling 30 minutes of each hour, 24 hours per day, 7 days per week. The estimated salmon passage was 193,099 (SE 1,612). The summer chum salmon passage was 43% below the minimum escapement objective for the Anvik River biological escapement goal of 350,000 to 700,000 chum salmon. Based on the mean quartile passage dates of 1979 to 1985 and 1987 to 2008, timing of the 2009 chum salmon run was 2 to 3 days later for the first and third quartiles. A chum salmon diurnal migration pattern was observed with the highest passage (37%) occurring during the darkest part of the day (2300–0500 hours). Females comprised 54.7% of the catch in beach seines. Age-0.3 fish comprised 57.5% of the chum salmon run in 2009.

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, 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; Rodo River (rkm 719); Nulato River (rkm 777); Melozitna River (rkm 938); and Tozitna River (rkm 1,096). Spawning tributaries in the Koyukuk River (rkm 817) drainage are the Gisasa River (rkm 907) and Hogatza River (rkm 1,255); and in 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, 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.

Anvik River salmon escapements were partially estimated from visual counts made at counting towers above the confluence of the Anvik and Yellow Rivers, from 1972 to 1979 (Figure 2). A site 9 km above the Yellow River, on the mainstem Anvik River, was used from 1972 to 1975 (Lebida 1973[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 the Alaska Department of Fish and Game (ADF&G) for public purposes until 2023. Aerial survey data indicate chum salmon spawn primarily upstream of this sonar site.

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

Side-looking sonar, capable of detecting migrating salmon along the banks, has been in place in the Anvik River since 1980. The Electrodynamics Division of the Bendix Corporation[2] developed the side-looking sonar and conducted a pilot study using the side-looking sonar to estimate chum salmon escapement to the Anvik River in 1979. The results indicated sonar-based estimation of chum salmon escapement to the Anvik River was superior to the counting tower method used at that time (Mauney and Buklis 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 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 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.

BACKGROUND INFORMATION

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.

In the Lower Yukon Area, run timing of summer chum and Chinook salmon overlap, with runs beginning at river ice breakup in late May/early June and continuing through July. During this time commercial fisheries in the Lower Yukon Area have traditionally targeted Chinook salmon, while Subdistrict 4-A commercial fisheries have targeted summer chum salmon. In the Lower Yukon Area, large-mesh gillnets (stretch mesh greater than 15.2 cm) were employed to harvest Chinook salmon. Although these nets were efficient for Chinook salmon, the associated harvest of summer chum salmon through 1984 was minor in relation to the size of the chum salmon run. In order to allow directed harvests of summer chum salmon in the Lower Yukon, the Alaska Board of Fisheries (BOF), prior to the 1985 season, adopted regulations allowing fishing periods restricted to small-mesh gillnets (15.2 cm maximum stretch mesh) during the Chinook salmon season provided that (1) the summer chum salmon run was of sufficient size to support additional exploitation, and (2) incidental harvest of Chinook salmon during these small-mesh fishing periods did not adversely affect conservation of that species.

Increased market demand prompted allocation disputes between fishermen in different districts. In February of 1990, the 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 sub-district 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).

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

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 Reports for the Yukon Area published each year by the Alaska Department of Fish and Game (ADF&G).

OBJECTIVES

The objectives of the Anvik River sonar project are to:

1. Estimate chum salmon fish abundance in the Anvik River using DIDSON sonar from approximately June 20 through July 26.
2. Collect between 162 and 210 chum salmon samples during each of 3 to 4 stratum throughout the season to estimate the age, sex, and length (ASL) composition of the Aniak River chum salmon passage, such that simultaneous 95% confidence intervals of age composition in each sample are no wider than 0.20 (α=0.05 and d=0.10).
3. Monitor selected climatic and hydrological 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.

The Anvik river, at the sonar site, is characterized by broad meanders, with large gravel bars on the inside bends and cut banks with exposed soil, tree roots, and snags on the outside bends. As with past years, we were able to use the same location, due to the sites 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 25–35 m, while the left bank river bottom slopes steeply to the thalweg at about 10–15 m, depending on water level.

HYDROACOUSTIC DATA ACQUISITION

Equipment

Two DIDSON units were deployed at the Anvik sonar site, one for each bank. The sonar units operated at 1.1 MHz. Each DIDSON was mounted on an aluminum pod and manually aimed.

Each DIDSON was controlled by a laptop computer running version 5.11 of the DIDSON software. A 152.4 m cable transferred power and data between a "topside box" and the DIDSON unit in the water. For the right bank, a Honda model EU-2000 generator provided power for all equipment. An Ethernet cable routed data to a laptop computer. A RAID enclosure was connected to the laptop for storing of data (Figure 3). The enclosure was configured as RAID 1 allowing redundant copies of the data on two separate hard drives within the enclosure in the event one of the hard drives failed.

The left bank sonar electronic equipment was housed in a portable canvas wall tent and the equipment was powered by a single Honda model EU-1000 generator. A wireless Ethernet router (D-Link DWL-2100AP) transferred the data from the left bank DIDSON to the controlling laptop on the right bank where the data were saved to a RAID drive (Figure 3).

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 1.1 MHz. DIDSON simultaneously transmit on, and then receives from sets of 12 beams. Images or frames are built in sequences of these sets of pings. At frequencies of 1.1 MHz, 48 beams (4 sets of 12) 0.6° 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 4 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 4 to 10 m from the right bank, and 1 to 2 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 (66–85%, 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 thymallus,* northern pike *Esox lucius,* longnose sucker *Catostomus catostomus*, and whitefish *Coregonus*).

Sampling Procedures

Sonar project activities commenced on June 18 and ended on July 29, 2009. Hydroacoustic sampling began at 0001 hours on June 18 on right and left bank and ran every day until 1200 hours on July 29. 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 (one person per shift) occurring from 0600–1400, 1000–1800, and 1600–0100 hours. The technicians identified and tallied fish traces from the echogram recordings. The first shift counted fish from 0000 to 0800, the second shift counted fish from 0800 to 1600, and the third shift counted fish from 1600 to 0000. All fish were counted except for very small fish, 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 spreadsheet and checked over by the crew leader. All sonar data was saved to the RAID drive in 30 minute intervals during the 8 hour shift for later review as an echogram and/or video.

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: 1) read the log from the previous shift; 2) sign the log book, including date and time of arrival and departure; 3) record equipment problems, factors contributing to problems, and resolution of problems; 4) record equipment setting adjustments and their purpose; 5) record observations concerning weather, wildlife, boat traffic, etc.; and 6) 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, 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 is estimated by summing the 24 hourly samples:

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

Finally, the total daily passage $\hat{y}_d$ is 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 auto correlated (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:

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

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:

$$\hat{V}ar(\hat{y}) = \sum_d \sum_z \hat{V}ar(\hat{y}_{dz}). \tag{5}$$

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 one or more complete samples was missing, counts were interpolated by averaging counts from samples before and after the missing sample(s) as follows:

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

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:

$$\hat{y}_s = a + bx_s \quad (7)$$

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

During the 2009 season at the Anvik sonar project, daily passage estimates were reported inseason without any apportionment for species.

Daily 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:

$$\hat{y}_{dza} = \hat{y}_{dz} \cdot \hat{p}_{dza} \quad (8)$$

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

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

and the variance of the species passage estimate was calculated as:

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

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

$$\hat{y}_{da} = \sum_z \hat{y}_{dza}, \quad (11)$$

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

$$\hat{y}_a = \sum_d \sum_z \hat{y}_{dza} \quad (12)$$

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:

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

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

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

Tower counts were attempted 4 times per day (0730, 1300, 1700, 2000) for 15 minutes on each bank. On right bank a 15' tower was erected, and anchored in the river just upstream of the sonar. A crew member would stand on top with polarized sunglasses and count and identify the number of salmon going by the sonar. On left bank the crew member would stand on the bank just upriver of the sonar and with polarized sunglasses count and identify the number of salmon going by the sonar. 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. Data would be entered into a *Microsoft Excel* spreadsheet as to the number of each species for each bank, and how far out you could see.

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. The 2009 sampling strata were determined postseason based on run timing data. They represent an attempt to sample the escapement for age, sex, and length information in relative proportion to the total run. In 2009, these strata were defined as: June 18 to July 7, July 8–16, and July 17–29 (Table 1).

To meet regionwide standards for the sample size needed to describe a salmon population, the initial seasonal ASL sample goal was 608 chum salmon, with a minimum of 162 chum salmon samples collected 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 to sample all fish captured while pursuing the chum salmon sampling goal.

A beach seine (31 m long, 66 meshes deep, 6.35-cm mesh) was drifted, beginning approximately 10 m downstream of the sonar site, to capture chum salmon to 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 5 mm from mideye to tail fork, and one 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 three 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 temperature was measured using a HOBO® water temp logger, which electronically recorded the temperature 4 times per day starting at 0115 and again every 6 hours. The data was downloaded to a computer at the end of the season. Daily maximum and minimum air temperatures were recorded in degrees C. Subjective notes on wind speed and direction, cloud cover, and precipitation were recorded.

RESULTS

ESCAPEMENT ESTIMATES AND RUN TIMING

Full sonar operations on both banks began on June 18. Both transducers collected data through 1200 on July 29. The 2009 summer chum salmon passage estimate was 193,099 (SE 1,612) fish. This includes estimates for missing sector or hourly counts and expansions for missing data. For the right bank a total of 15 hour sampling time (2%) was missed and on the left bank 105 hour sampling time (21%) was missed. The left bank sonar was not operating due to equipment failure for 8 days, 22–29 June (96 hour sampling time). No pink salmon were observed while conducting visual counts in 2009; therefore, all counts were attributed to summer chum salmon.

Summer chum salmon passage dates were 1–2 days late at each quartile when compared to the historic run timing, based on 1979–1985 and 1987–2008 runs. The summer chum passage quartiles were close to their historic median dates. The central half of the run passed between July 4 and July 15 and the duration of 11 days is near the historic mean of 10 days (Table 1). The daily passage between the first and third quartile dates ranged from 3,478 (July 15) to 14,952 (July 7) with an estimated 100,321 summer chum salmon passing by the sonar site during this time. The peak daily passage of 14,952 summer chum occurred on July 7 (Table 2). The 2009 chum salmon escapement estimate of 193,099 was 30.5% of the mean Anvik River escapement estimate of 626,770 fish, based on 1979–2008 data (Table 1). This year's escapement was below the BEG of 350,000 to 700,000 summer chum salmon.

SPATIAL AND TEMPORAL DISTRIBUTION

There was a diurnal pattern to the passage in 2009 with 37% of the counts recorded between the hours of 2300 and 0500 (Figure 4). Spatially, 60% of the chum salmon were detected by the right bank sonar (Figure 5).

AGE AND SEX COMPOSITION

From July 2 to July 21, a total of 13 days of sampling and, from these, 583 ASL samples from migrating chum salmon were obtained. Of those samples 338 scales were analyzed post season of which age-0.3 and 0.4 chum salmon accounted for 93.6% of the entire run (Table 3; Figure 6). The age-0.3 chum salmon accounted for 57.5% of the entire run ranging from 48.3% to 70.1% throughout the run. The age-0.4 chum salmon accounted for 36.1% of the entire run. The age-0.5 and age-0.2 chum salmon comprised 4.0% and 2.4% respectively of the overall run. Females accounted for 54.7% of the entire run (Table 3).

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The summer of 2009 saw warm temperatures and wet conditions on the Anvik River. Due to rain in the headwaters, the water level fluctuated little at the sonar site and we ended up with the same water level at the end of the season as at the beginning (Figure 7). The minimum air temperature was 9.5°C (June 27) and a maximum high of 20.8°C (July 12) with an average high and low of 19°C and 8°C respectively (Figure 8). Water temperatures were measured 4 times per day (0115, 0715, 1315, and 1915 hours). The lowest temperature by time was 7.3°C at 0715 and the highest temperature was 18.6°C at 1915 (Figure 9). The average water temperature over the operational period of the project was 13.1°C. The temperature averaged 12.7°C between the hours of 0115 and 0715 and 13.4°C from 1315 to 1915.

DISCUSSION

ESCAPEMENT ESTIMATION

The 2009 Anvik River summer chum salmon escapement estimate of 193,099 was 70% below the 1979–2008 average escapement of 626,770 and 49% below last year's escapement estimate (374,928). This is the lowest escapement estimate since the projects inception in 1979. Although the exact reason for the low salmon runs in past years is unknown, scientists speculate poor marine survival results from, or are accentuated by, localized weather conditions in the Bering Sea (Kruse 1998).

Due to the large number of pink salmon returning in 2008, we are developing methods to accurately apportion species in season. The ADF&G Division of Sport Fish in Fairbanks uses flash panels to apportion salmon counts in season on some projects in the region (Chena River Counting Tower, Gulkana River Counting Tower) (J. Savereide, Sport Fishery Biologist, ADF&G Fairbanks; personal communication). This year we deployed flash panels part way across the river bottom, just downstream of the weir panels, on the right bank. Due to high water levels at the beginning of the season we were not able to pull the cable across the river. The flash panels were made of white Teflon-coated vinyl. Each flash panel was 6.1 m across at the top, 7.3 m across at the bottom, and 2.4–3.0 m wide (Figure 10). Two 3.0 m PVC pipes were inserted in each of the 2.7 m sleeves at the top of the panel. Locking carabineers were attached at each end of the PVC pipes which were then attached to the steel cable. When standing on top of the counting tower fish were easily identified as they swim across the white fabric stand. The flash panels were deployed for a couple of weeks until the water level receded and the rest of the equipment (sonar, weir) were moved out beyond the end of the flash panels. In 2010 flash panels will be deployed across the width of the river.

ASL Sampling

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 2005 chum salmon year class returned to spawn this year as age-0.3, accounting for 57.5% (110,243) of the total run. Age 0.4 fish accounted for 36.1% (69,150) and age-0.5 accounted for 4.0% (7,601) of the total run.

The average age of the 2009 run was 4.4 years which is the same as the long-term average of 4.4 years (Figure 11). For the overall run there were 54.7% females which is below the long-term average of 55.9%.

SPATIAL AND TEMPORAL DISTRIBUTION

In 2009, chum salmon spatial migration followed historical trends with 60% passing on the right bank. Prior to 2006, 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 in 2009 appeared to be higher than last year.

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 day. Similar diurnal patterns were reported from 1985 through 2008. Temporal distribution of sonar estimates in 2009 indicates a distinct diurnal pattern (Figure 4). The chum salmon could be migrating in greater numbers at night due to the fact that the water is slightly cooler (0.7°C) or to escape predation from various birds and mammals.

ACKNOWLEDGEMENTS

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TABLES AND FIGURES

Table 1.–Annual passage estimates and associated passage timing statistics for summer chum salmon runs, Anvik River sonar, 1979–2009.

						Days Between Quartiles			
Year	Sonar passage estimate	Day of first Salmon Count	First Quartile day	Median day	Third Quartile day	First count & first quartile	First & median	Median & third	First & third
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	193,099	18 Jun	4 Jul	9 Jul	15 Jul	16	5	6	11
Mean	626,770	22 Jun	3 Jul	8 Jul	13 Jul	10	5	5	10
Median	487,301	22 Jun	4 Jul	8 Jul	13 Jul	10	5	5	10
SD	340,544		3	3	3	3	1	1	2

Note: The mean, median and standard deviation of the timing statistics includes estimates from years 1979–1985 and 1987–2008. The 2009 data is not included so that the current year can be compared to the historical averages. In 1986, sonar counting operations were terminated early, probably resulting in the incorrect calculation of the quartile statistics. Therefore, the 1986 run timing statistics were excluded from the calculation of the overall mean and timing statistic and associated standard deviation (SD).

Table 2.–Summer chum salmon daily and cumulative counts, Anvik River sonar, 2009.

Date	Right Bank	Left Bank	Daily Total	Cumulative Total	Cumulative percent passage
18 Jun	14	63	77	77	0.0%
19 Jun	140	466	606	683	0.4%
20 Jun	220	300	520	1,203	0.6%
21 Jun	100	162	262	1,464	0.8%
22 Jun	110	435[a]	545	2,010	1.0%
23 Jun	256	708[a]	965	2,975	1.5%
24 Jun	456	982[a]	1,438	4,413	2.3%
25 Jun	630	1255[a]	1,886	6,298	3.3%
26 Jun	1,034	1529[a]	2,563	8,861	4.6%
27 Jun	1,710	1802[a]	3,512	12,374	6.4%
28 Jun	1,368	2075[a]	3,444	15,818	8.2%
29 Jun	1,610	2349[a]	3,959	19,777	10.2%
30 Jun	2,542	2,623	5,165	24,942	12.9%
1 Jul	3,088	3,314	6,402	31,344	16.2%
2 Jul	2,294	4,996	7,290	38,634	20.0%
3 Jul	2,836	4,836	7,672	46,306	24.0%
4 Jul	2,684	3,088	5,772	52,078	27.0%
5 Jul	2,302	1,956	4,258	56,336	29.2%
6 Jul	4,092	7,994	12,086	68,422	35.4%
7 Jul	4,558	10,394	14,952	83,374	43.2%
8 Jul	6,504	3,920	10,424	93,798	48.6%
9 Jul	4,521	2,073	6,594	100,393	52.0%
10 Jul	5,712	890	6,602	106,995	55.4%
11 Jul	7,952	3,698	11,650	118,645	61.4%
12 Jul	5,878	3,976	9,854	128,499	66.5%
13 Jul	5,730	3,802	9,532	138,031	71.5%
14 Jul	4,294	824	5,118	143,149	74.1%
15 Jul	3,022	456	3,478	146,627	75.9%
16 Jul	4,466	1,042	5,508	152,135	78.8%
17 Jul	5,410	1,978	7,388	159,523	82.6%
18 Jul	3,460	436	3,896	163,419	84.6%
19 Jul	2,308	210	2,518	165,937	85.9%
20 Jul	3,300	344	3,644	169,581	87.8%
21 Jul	3,393	422	3,815	173,396	89.8%
22 Jul	4,992	888	5,880	179,276	92.8%
23 Jul	2,986	652	3,638	182,914	94.7%
24 Jul	1,626	318	1,944	184,858	95.7%
25 Jul	1,396	206	1,602	186,460	96.6%
26 Jul	952	100	1,052	187,512	97.1%
27 Jul	1,360	140	1,500	189,012	97.9%
28 Jul	1,800	230	2,030	191,042	98.9%
29 Jul	1,795[b]	261[b]	2,057	193,099	100.0%
Season Totals	114,901	78,198	193,099		

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

[a] DIDSON inoperable due to mechanical trouble, counts extrapolated postseason.

[b] End of season sonar's turned off 1200 extrapolated postseason for complete daily counts.

Table 3.–Age and sex composition of chum salmon, Anvik River sonar, 2009.

			AGE									
			(0.2)		(0.3)		(0.4)		(0.5)		Total	
2009 Sample Date (Strata)	Sample Size	Sex	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%
7/2-4, 6 (6/18-7/7)	87	Males	0	0.0	21,094	52.4	19,176	48.8	1,918	66.7	42,187	50.6
		Females	959	100.0	19,176	47.6	20,093	51.2	959	33.3	41,187	49.4
		Subtotal	959	1.1	40,270	48.3	39,269	47.1	2,877	3.4	83,374	100.0
7/9, 11, 12, 14, 15 (7/8-16)	144	Males	955	33.3	16,713	39.8	11,938	56.8	1,910	66.7	31,515	45.8
		Females	1,910	66.7	25,308	60.2	9,073	43.2	955	33.3	37,245	54.2
		Subtotal	2865	4.2	42,020	61.1	21,010	30.6	2,865	4.2	68,760	100.0
7/18-21 (7/17-29)	107	Males	0	0.0	8,805	30.7	4,211	44.0	766	40.0	13,782	33.6
		Females	766	100.0	19,908	69.3	5,360	56.0	1,149	60.0	27,182	66.4
		Subtotal	766	1.9	28,713	70.1	9,571	23.4	1,914	4.7	40,964	100.0
Season Total	338	Males	965	20.8	46,537	41.9	35,337	50.7	4,634	60.0	87,474	45.3
		Females	3,669	79.2	64,495	58.1	34,372	49.3	3,090	40.0	105,625	54.7
		Total	4,634	2.4	111,032	57.5	69,709	36.1	7,724	4.0	193,099	100.0

Note: Number fish is based on the sonar estimate divided by percent of fish in age class and stratum.

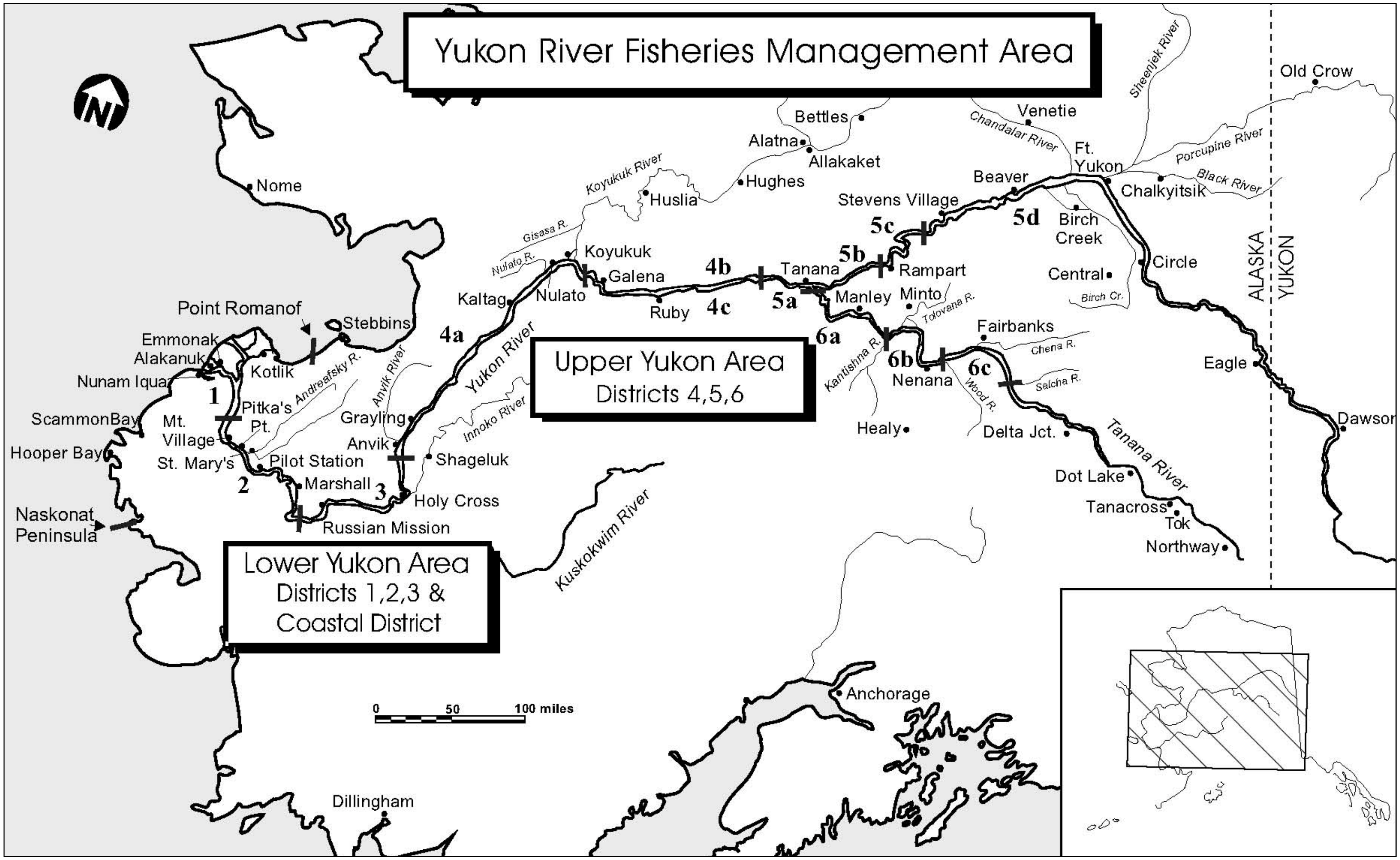


Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

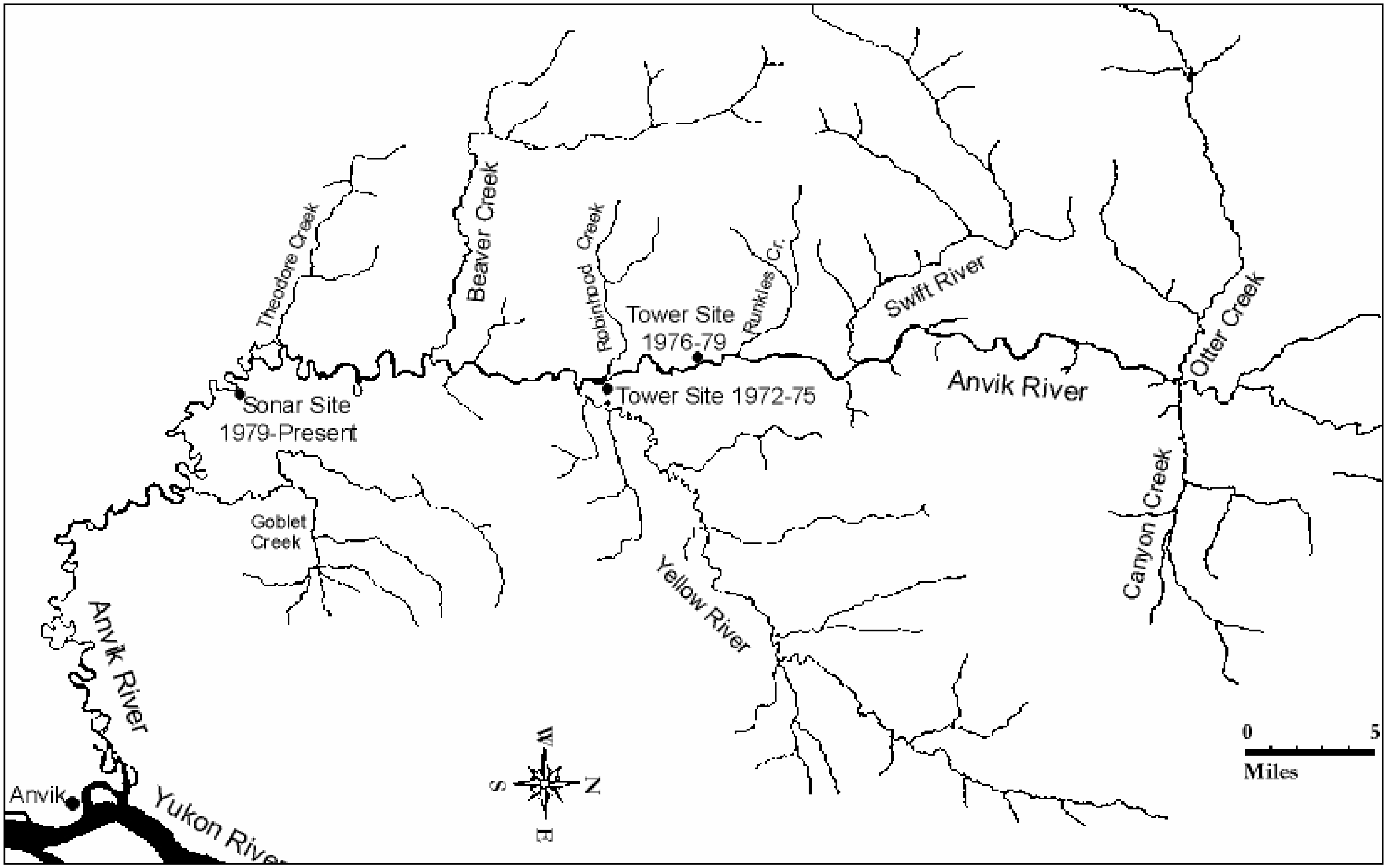


Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

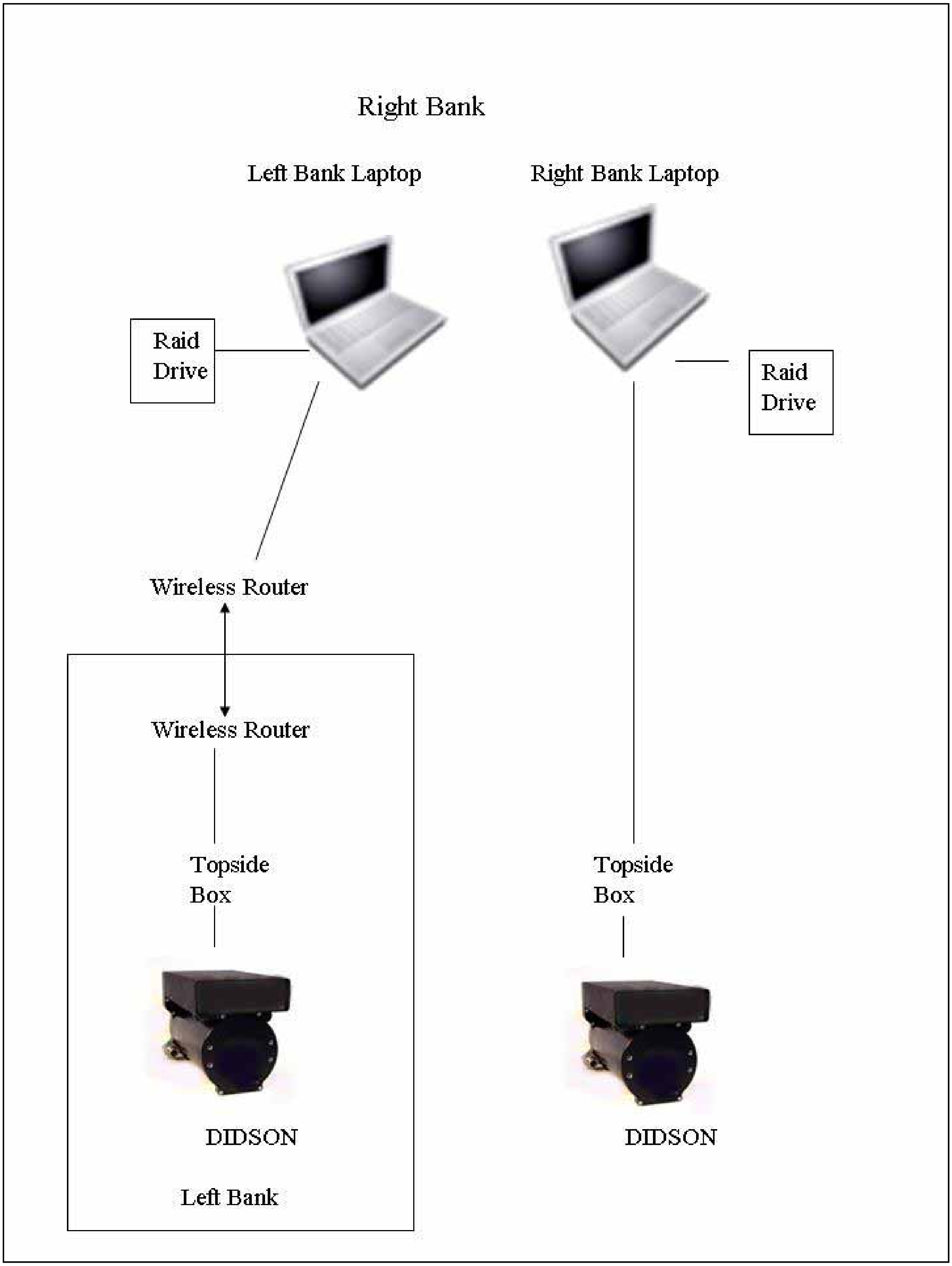


Figure 3.–DIDSON Sonar equipment schematic, Anvik River Sonar, 2009.

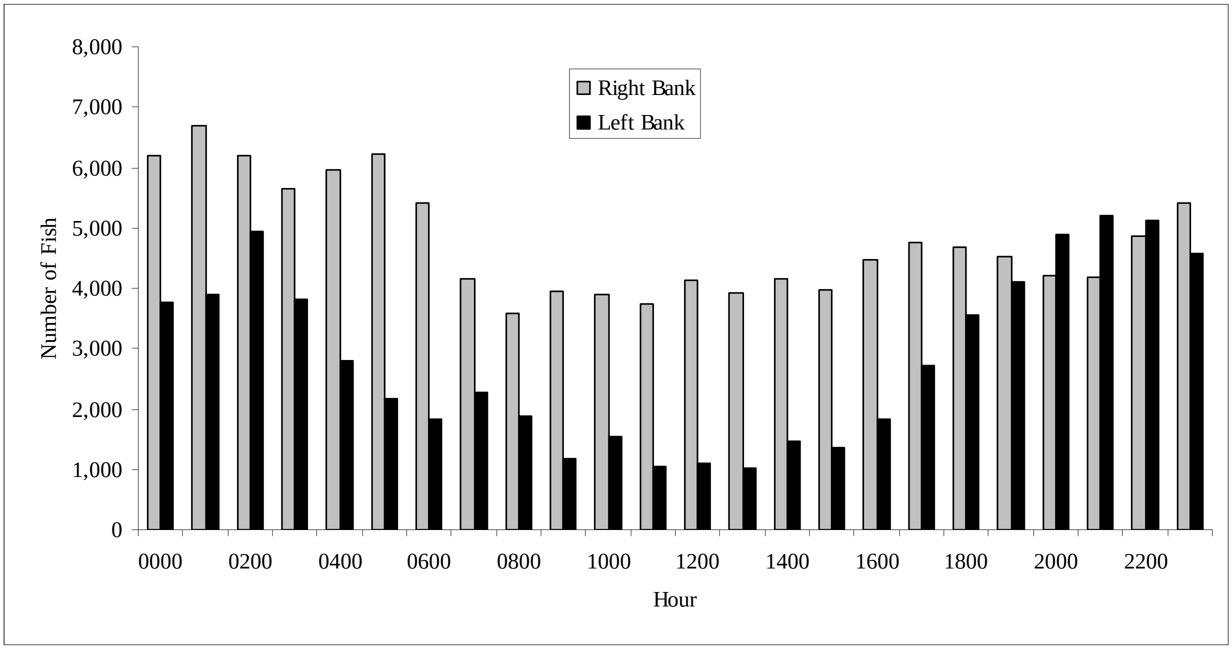


Figure 4.–Estimated passage of chum salmon by hour for each bank, Anvik River sonar 2009.

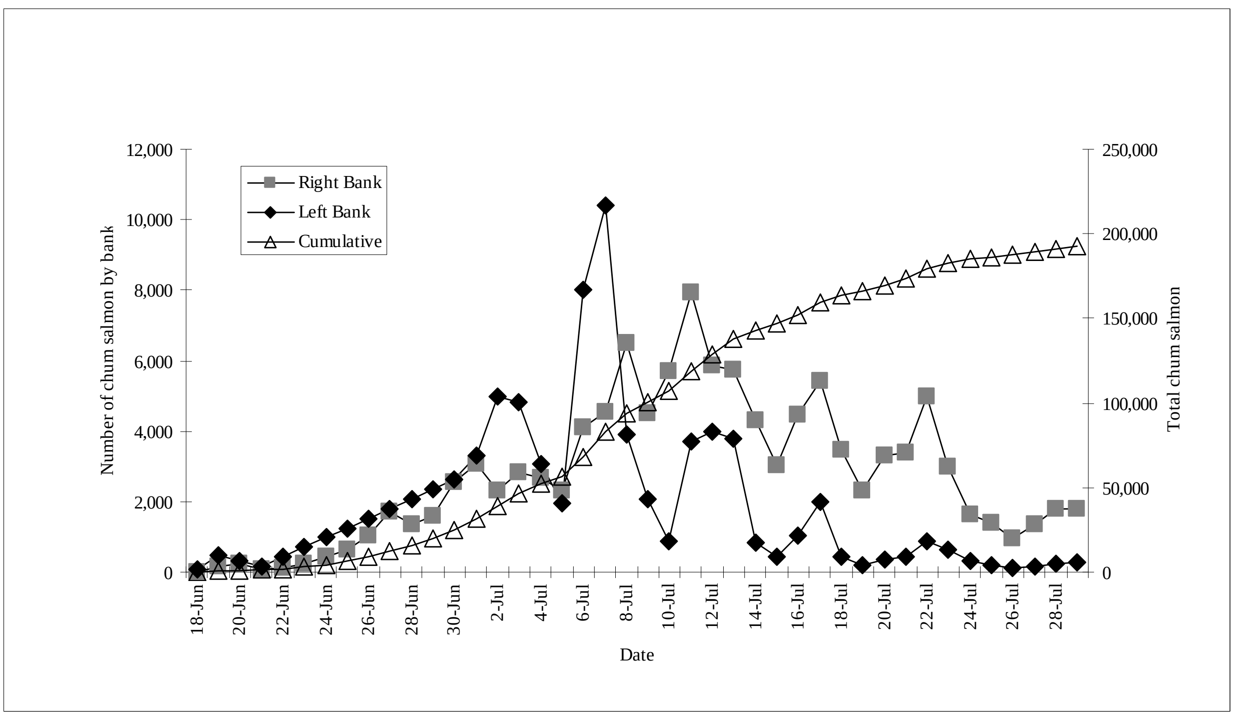


Figure 5.–Chum salmon daily and cumulative counts, Anvik River sonar 2009.

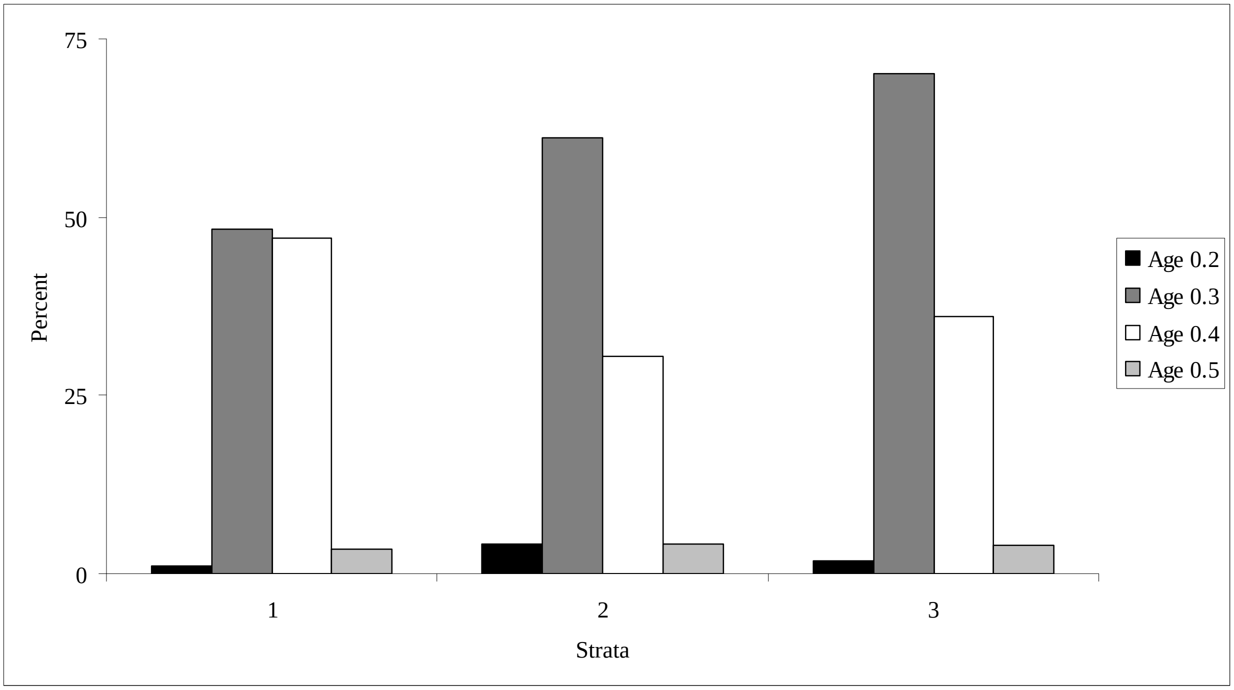


Figure 6.–Chum salmon age composition, Anvik River sonar, 2009.

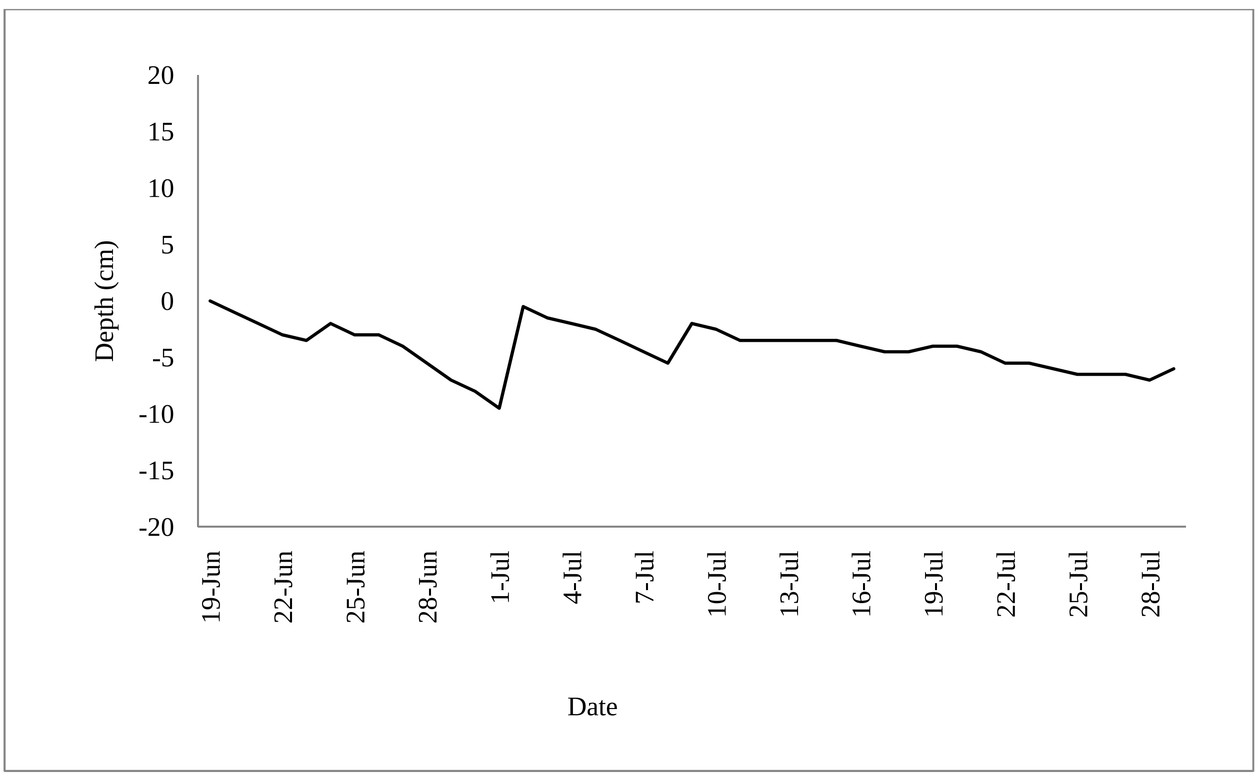


Figure 7.–Water depth at Anvik River sonar, 2009.

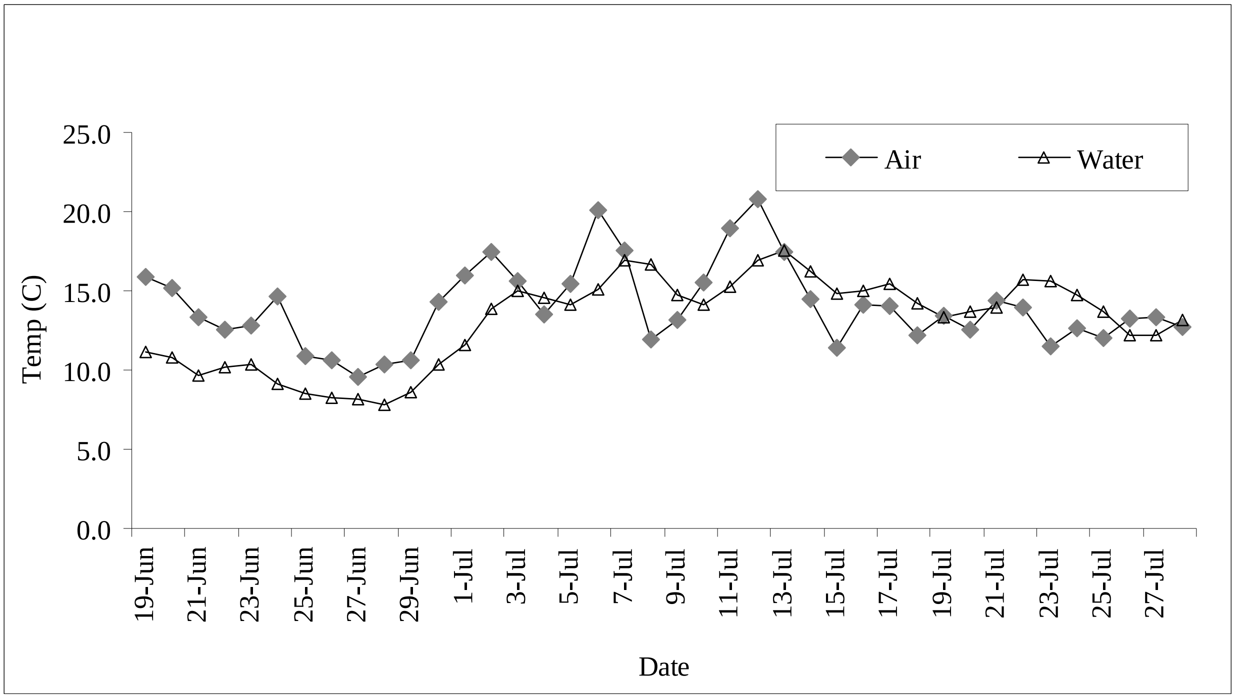


Figure 8.–Air and water temperature, Anvik River sonar, 2009.

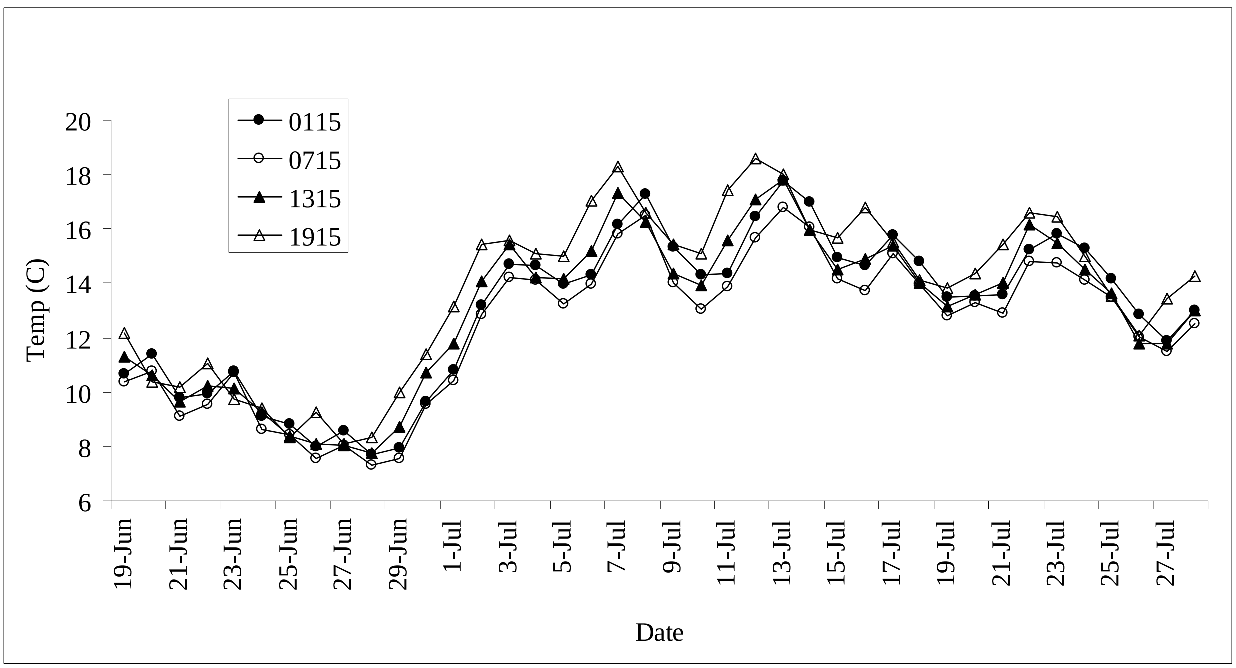
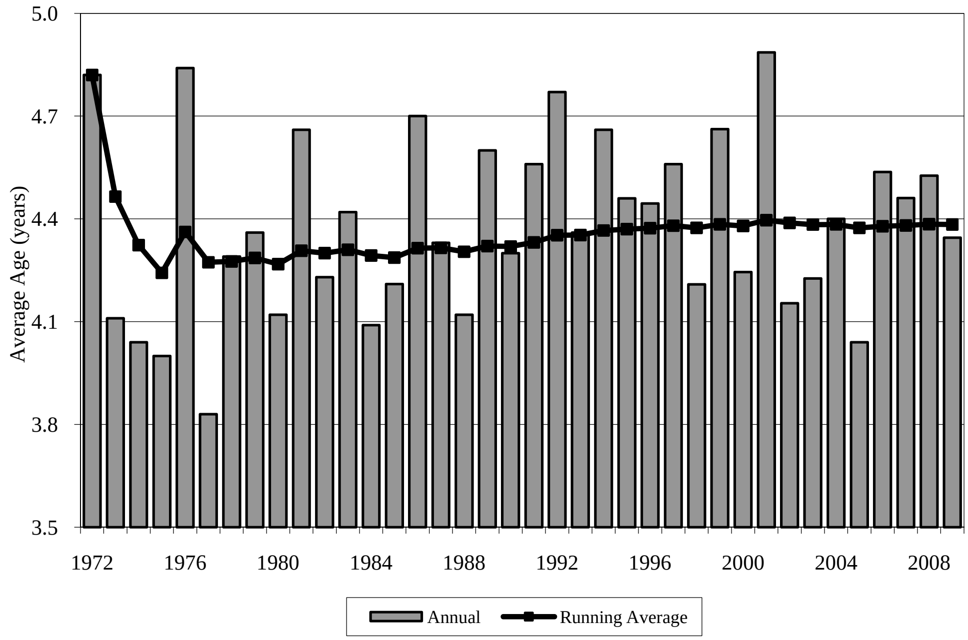


Figure 9.–Daily water temperature by time, Anvik River Sonar, 2009.



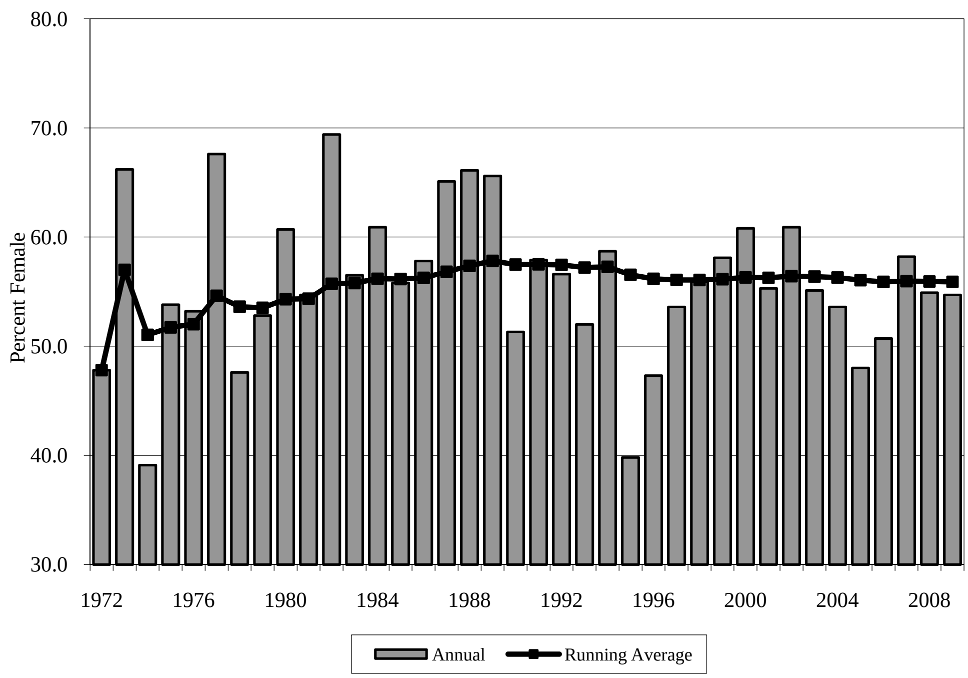


Figure 10.–Annual age at maturity (top) and percentage of females (bottom) of the Anvik River chum salmon escapement, 1972–2009.

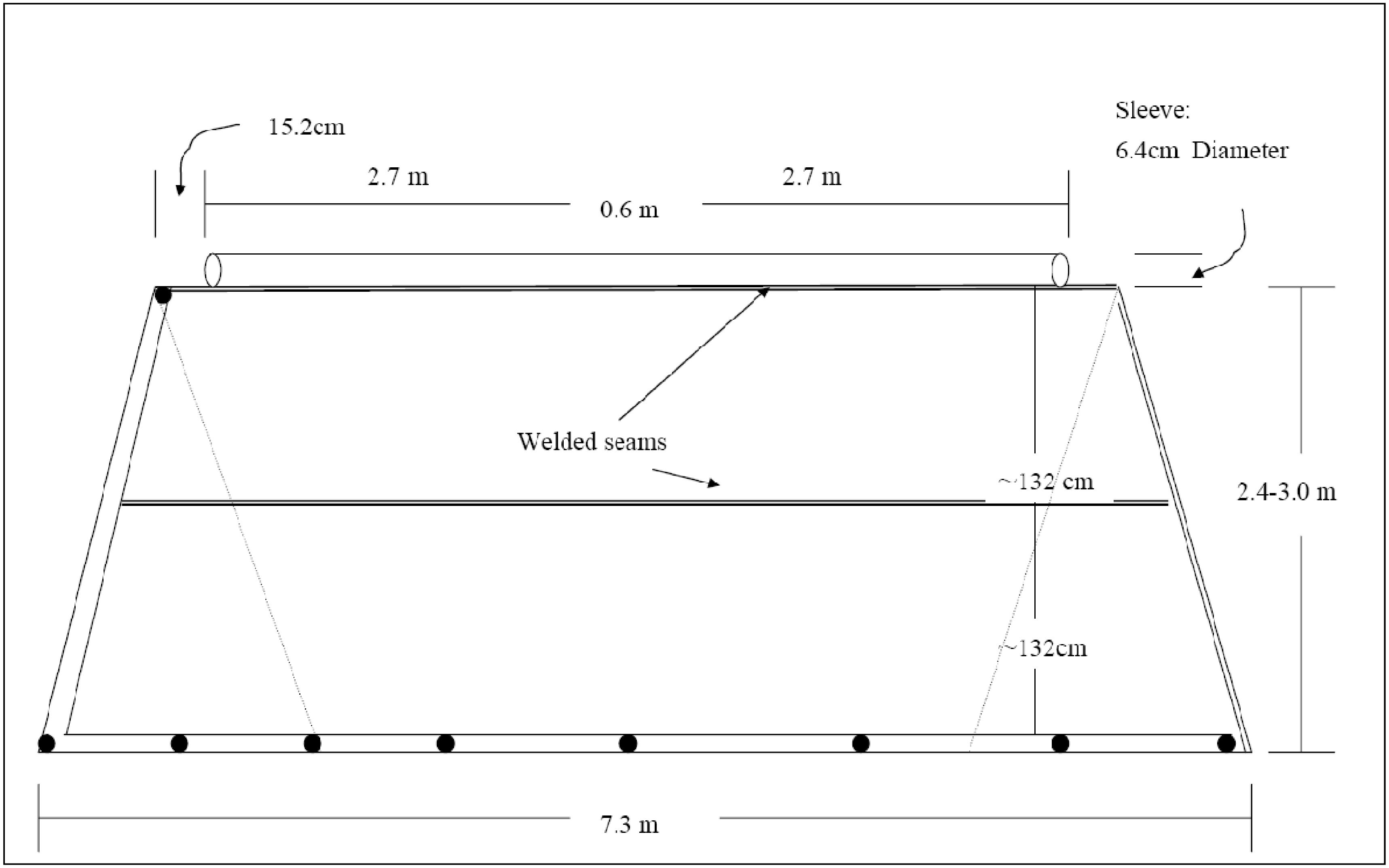


Figure 11.–Schematic drawing of flash panels used at Anvik River Sonar 2009.