Fishery Data Series No. 11-35

Anvik River Sonar Chum Salmon Escapement Study, 2010

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

by

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

The 2010 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 901,682 (SE 4,068), of which pink salmon comprised 56% (505,509) and summer chum salmon passage was 396,173. The summer chum salmon passage was 12% above the minimum escapement objective for the Anvik River biological escapement goal of 350,000 to 700,000 chum salmon. Based on 1979–1985 and 1987–2009 mean quartile passage dates, timing of the 2010 chum salmon run was 4 days later. 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 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[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.

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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 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 fish (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 (Schultz et al. 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 area (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 abundance in the Anvik River using DIDSON sonar from approximately June 16 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 Anvik 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 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 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 unit for left bank operated at 1.8 MHz, and the right bank sonar operated at 1.2 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. For right bank to the distance between the sonar and "topside box" (dependent on water level) a 33 m cable was attached to a booster and 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 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 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 1.2 and 1.8 MHz. DIDSON simultaneously transmits on, and then receives from sets of 12 beams. Images or frames are built in sequences of these sets of pings. At frequencies of 1.2 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 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 outward 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 16 and ended on July 26, 2010. Hydroacoustic sampling began at 1200 on June 16 on right and left bank and ran every day until 2359 on July 26. Passage estimates were available to fishery managers in Emmonak at 0810 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 to 1400, 1000 to 1800, and 1600 to 0100 hours. 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 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.

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-min count (i.e. 60 / 30 = 2). The daily passage for each bank is estimated by summing the 24 hourly samples:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \hat{y}_{dzp} \cdot \qquad (2)$$

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

$$\hat{y}_d = \sum_{z} \hat{y}_{dz} \quad . \qquad (3)$$

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:

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

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:

$$\hat{V}ar(\hat{y}) = \sum_{d} \sum_{z} \hat{V}ar(\hat{y}_{dz}). \qquad (5)$$

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:

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

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:

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

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) for 15 minutes, on each bank. To help with species identification, flash panels were deployed across the river bottom. The weir panels were positioned at either end to divert fish across the panels. 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. 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. 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. The number of salmon species for each bank and the visible range were entered into a Microsoft Excel spreadsheet; non-salmon species were not counted or recorded.

During the 2010 season at the Anvik sonar project, daily passage estimates were reported inseason for both chum and pink salmon.

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:

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

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

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

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

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

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

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

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

$$\hat{y}_a = \sum_{d} \sum_{z} \hat{y}_{dza} \quad , \tag{12}$$

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:

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

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

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

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 2010 sampling strata were determined postseason based on run timing data. They represent an attempt to sample the escapement for age, sex, and length

(ASL) information in relative proportion to the total run. In 2010, these strata were defined as: June 16–July 6, July 7–12, July 13–17 and July 18–26.

To meet region wide 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 $\alpha = 0.05$, assuming two major age classes, and two 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 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 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 0600 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 at 1200 on June 16. Both transducers collected data through 2359 on July 26. The 2010 passage estimate was 396,173 summer chum and 505,509 pink salmon. This includes estimates for missing sector or hourly counts and expansions for missing data. For the right bank a total of 11 hours of sampling time (2%) was missed and on the left bank 15 hours sampling time (3%) was missed. Most of the estimates for missing counts were due to high water and the moving of the weir panels and sonar, which occurred consistently throughout the season.

Summer chum salmon passage dates were 4 to 5 days late at each quartile when compared to the historic run timing, based on 1979–1985 and 1987–2009 runs. The central half of the run passed between July 8 and July 18 and the duration of 10 days is the same as the historic mean of 10 days. The daily passage between the first and third quartile dates ranged from 5,381 (July 15) to 46,462 (July 9) with an estimated 224,667 summer chum salmon passing by the sonar site during this time. The peak daily passage of 46,462 summer chum occurred on July 9. The 2010 chum salmon escapement estimate of 396,173 was 64.7% of the mean Anvik River escapement estimate of 612,263 fish, based on 1979–2009 data. This year's escapement was within the BEG of 350,000 to 700,000 summer chum salmon (Tables 1 and 2).

SPATIAL AND TEMPORAL DISTRIBUTION

There was a diurnal pattern to the passage in 2010 with 39% of the counts recorded between the hours of 2300 and 0500. Spatially, 76% of the salmon were detected by the right bank sonar (Figures 4 and 5).

SPECIES APPORTIONMENT

For tower counts, chum and pink salmon were the most prominent species on both banks. For the entire season, on right bank there were 3,381 (51.5%) chum salmon observed followed by 2,687 pink salmon (43.8%), and 19 Chinook salmon. On left bank there were 6,976 pink salmon (77.5%) observed followed by 1,993 chum salmon (22.1%), and 10 Chinook salmon.

AGE AND SEX COMPOSITION

Migrating chum salmon were sampled over 13 days from July 2 to July 21 and 620 ASL samples were obtained. Of those samples, 572 scales were analyzed postseason, of which, age-0.3 chum salmon accounted for 84.5% of the entire run. Age-0.4 chum salmon accounted for 8.2% of the entire run ranging from 11.2% to 6.5% throughout the run. Age-0.2 chum salmon accounted for 7.3% of the entire run ranging from 13.6% to 2.8% throughout the run. There were no age-0.5 chum salmon. Females accounted for 52.7% of the entire run (Table 3; Figure 6). Other species caught during ASL sampling were: Chinook salmon (16), pink salmon (653), whitefish (53), and grayling (8).

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The summer of 2010 saw warm temperatures and wet conditions on the Anvik River. Due to rain in the headwaters, the water level fluctuated greatly at the sonar site. During a 10-day period (June 30 to July 9) the water rose 25 cm and then steadily decreased, ending the season with the same water level as at the beginning. The minimum air temperature was 8.4°C (June 16) and a maximum high of 24.3°C (July 8) with an average air temperature of 15.9°C. The minimum water temperature was 7.3°C (June 28) and a maximum high of 16.7°C (July 13). The average water temperature over the operational period of the project was 12.2°C (Figures 7 and 8).

DISCUSSION

ESCAPEMENT ESTIMATION

The 2010 Anvik River summer chum salmon escapement estimate of 396,173 was 35% below the 1979–2009 average escapement of 612,263 but more than double last year's escapement estimate of 191,566 fish. This year's summer chum salmon escapement is about equal to the 10-year average of 365,923 fish. The timing of the summer chum salmon run into the Anvik River in 2010 was very similar to the pattern observed at Pilot Station. In addition, nearly a third of the summer chum salmon that were estimated to have passed Pilot Station were observed at the Anvik River sonar project. Historically, the contribution of the Anvik River has been greater than 40%, however, in recent years the relative contribution has been less than 25% and as low as 14%. In spite of the improvement in relative contribution of the Anvik River in 2010, the overall passage remains low at this site and does not yet indicate an overall improvement in production of summer chum salmon in the Anvik River (Figures 9 and 10). Although the exact reason for the low salmon runs in recent years is unknown, scientists speculate poor marine survival results from, or accentuated by, localized weather conditions in the Bering Sea (Kruse 1998).

ASL Sampling

Age and sex composition of chum salmon passing the sonar site changes throughout 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 2006 chum salmon year class returned to spawn this year as age-0.3, accounting for 84.5% (334,766) of the total run. Age-0.4 fish accounted for 8.2% (32,486) and age-0.2 accounted for 7.3% (28,921) of the total run, there were no age-0.5 fish.

The average age of the 2010 run was 3.7 years which is below the long-term average of 4.3 years. For the overall run 52.7% were females, which is below the long-term average of 55.9% (Figure 11).

Age-0.3 summer chum salmon were the dominant age group throughout the Yukon River drainage at 70.1%. The age-0.3 summer chum salmon ranged from the Andreafsky River East Fork weir at 90.9% of the overall run to the Salcha River carcass survey at 46.9% (Larry Dubois Commercial Fisheries Biologist, ADF&G, Anchorage; personal communication).

Return for each brood year was determined by summing the return for appropriate age groups in subsequent years. 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, the average over a 30-year period from 1972 to 2002 was 1.73 (Table 4).

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: 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). Climatological data for the Anvik River, while not available for all years, show that the river freezes in mid-October and thaws in mid-May. Air temperature from October through April, in 2008 and 2009 ranged from a low of -43.0°C to a high of 14.0°C with an average of -12.9°C. Air temperature in 2009 and 2010 ranged from a low of -42.1°C to a high of 13.8°C with an average of -11.6°C.

High water levels during spawning period may result in chum salmon spawning in less than ideal habitat away from the main channel. A subsequent drop in water levels in the autumn may result in desiccation of redd sites and extensive egg mortality. Spawning is confined to the main channel in years of low water.

SPATIAL AND TEMPORAL DISTRIBUTION

In 2010, chum salmon spatial migration followed historical trends with 76% 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%, respectively, of the adjusted passage occurred on the right bank (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 2010 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 2010 indicates a distinct diurnal pattern (Figure 4). Between the hours of 2300 and 1000 chum salmon travel on the right bank and then switch to the left bank where the water is deeper. This trend was observed in 2008 but not 2009. The fish 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, 1979–2010.

Year	Sonar passage estimate	Day of first salmon count	First quartile day	Median day	Third quartile day	Days Between Quartiles: 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	191,566	18 Jun	4 Jul	9 Jul	15 Jul	16	5	6	11
2010	396,173	16 Jun	6 Jul	12 Jul	18 Jul	22	4	6	10
Average	612,263	22 Jun	3 Jul	8 Jul	13 Jul	11	5	5	10
Median	484,741	21 Jun	4 Jul	8 Jul	13 Jul	10	5	5	10
SD	343,925		3	3	3	3.4	1.5	1.4	2.1

Note: The mean, median and standard deviation of the timing statistics include estimates from years 1979–1985 and 1987–2009. The 2010 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 and pink salmon daily and cumulative counts, Anvik River sonar, 2010.

	Right Bank		Left Bank		Daily Totals		
Date	Chum Salmon	Pink Salmon	Chum Salmon	Pink Salmon	Chum Salmon	Pink Salmon	Cumulative
16 Jun	10	0	24	0	34	0	34
17 Jun	30	0	47	0	77	0	111
18 Jun	45	0	58	0	103	0	214
19 Jun	66	0	80	0	146	0	360
20 Jun	62	0	98	0	160	0	520
21 Jun	78	0	62	0	140	0	660
22 Jun	112	0	114	0	226	0	886
23 Jun	112	0	80	0	192	0	1,078
24 Jun	146	0	100	0	246	0	1,324
25 Jun	140	0	268	0	408	0	1,732
26 Jun	490	0	118	0	608	0	2,340
27 Jun	1,068	0	46	0	1,114	0	3,454
28 Jun	748	0	46	0	794	0	4,248
29 Jun	5,768	0	60	0	5,828	0	10,076
30 Jun	14,487	237	978	0	15,465	237	25,778
1 Jul	14,740	360	1,808	0	16,548	360	42,686
2 Jul	16,311	1,425	1,800	343	18,111	1,768	62,565
3 Jul	7,910	1,708	4,388	1,502	12,298	3,210	78,073
4 Jul	13,175	1,550	7,003	3,367	20,178	4,917	103,168
5 Jul	3,977	663	3,434	2,318	7,411	2,981	113,559
6 Jul	16,374	1,643	2,890	8,730	19,264	10,373	143,196
7 Jul	16,708	2,566	5,569	9,429	22,277	11,995	177,468
8 Jul	31,926	3,390	12,039	12,343	43,965	15,733	237,166
9 Jul	32,274	8,698	14,188	29,893	46,462	38,591	322,220
10 Jul	20,766	12,978	10,016	27,392	30,781	40,371	393,372
11 Jul	15,889	6,337	5,793	15,109	21,683	21,445	436,500
12 Jul	8,370	14,546	3,577	21,971	11,947	36,517	484,964
13 Jul	7,335	10,973	2,670	19,980	10,005	30,953	525,922
14 Jul	5,477	11,497	959	9,873	6,436	21,370	553,728
15 Jul	4,106	6,392	1,275	6,695	5,381	13,087	572,196
16 Jul	15,952	7,680	4,041	12,553	19,993	20,233	612,422
17 Jul	14,558	11,761	3,759	14,153	18,317	25,914	656,653
18 Jul	7,832	17,042	1,864	13,626	9,696	30,668	697,017
19 Jul	4,007	13,179	1,307	9,066	5,314	22,245	724,575
20 Jul	3,801	9,869	943	9,659	4,744	19,528	748,847
21 Jul	3,658	9,482	1,884	12,988	5,542	22,470	776,859
22 Jul	5,480	12,038	845	14,373	6,325	26,411	809,595
23 Jul	2,151	14,257	363	9,759	2,513	24,017	836,125
24 Jul	1,250	9,586	175	9,037	1,426	18,622	856,173
25 Jul	2,083	12,916	363	9,349	2,446	22,265	880,884
26 Jul	1,522	10,652	48	8,576	1,570	19,228	901,682
Season Totals	300,991	213,429	95,182	292,080	396,173	505,509	

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

Table 3.–Age and sex composition of chum salmon, Anvik River sonar, 2010.

2010 Sample Dates (Strata)	Sample Size	Sex	Age (0.2) Number Fish	(0.2) %	(0.3) Number Fish	(0.3) %	(0.4) Number Fish	(0.4) %	Total Number Fish	Total %
07/04 - 07/05	143	Male	0	0.0	65,101	63.4	10,850	81.2	75,951	63.6
(6/16- 7/6)		Female	3,338	100	37,558	46.6	2,504	18.8	43,400	36.4
		Subtotal	3,338	2.8	102,659	86.0	13,354	11.2	119,351	100.0
07/09 - 07/10	128	Male	6,919	50.0	62,267	41.3	11,070	88.8	80,255	45.3
(7/7- 12)		Female	6,919	50.0	88,558	58.7	1,384	11.2	96,860	54.7
		Subtotal	13,837	7.8	150,824	85.2	12,453	7.0	177,115	100.0
07/14 - 07/16	154	Male	1,562	23.5	17,571	35.4	781	20.0	19,914	33.1
(7/13- 17)		Female	5,076	76.5	32,018	64.6	3,124	80.0	40,218	66.9
		Subtotal	6,638	11.0	49,589	82.5	3,905	6.5	60,132	100.0
07/18 - 07/19	147	Male	1,346	25.0	8,865	28.2	554	20.0	10,764	27.2
(7/18- 26)		Female	4,037	75.0	22,637	71.8	2,137	80.0	28,811	72.8
		Subtotal	5,382	13.6	31,502	79.6	2,691	6.8	39,575	100.0
Season Total	572	Male	9,904	52.9	154,111	46.0	23,374	71.8	187,390	47.3
		Female	19,016	47.1	180,655	54.0	9,112	28.2	208,783	52.7
		Total	28,921	7.3	334,766	84.5	32,486	8.2	396,173	100.0

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

Table 4.–Anvik River summer chum salmon brood table with return per spawner 1981 to present, with average 1972–2002.

		Number of Fish							
Brood Year	Escapement	Age 0.2	Age 0.3	Age 0.4	Age 0.5	Age 0.6	Total Return	Spawners	R/S
1981	1,479,582	25,347	1,028,684	1,131,492	36,613	0	2,222,135	742,553	1.50
1982	444,581	25,717	489,890	227,736	15,193	0	758,537	313,956	1.71
1983	362,912	5,295	460,582	356,962	4,197	0	827,037	464,125	2.28
1984	891,028	8,424	1,354,563	762,877	12,465	0	2,138,329	1,247,301	2.40
1985	1,080,243	65,276	446,452	255,665	4,925	0	772,318	-307,925	0.71
1986	1,189,602	8,530	338,004	604,033	41,841	0	992,407	-197,195	0.83
1987	455,876	13,501	480,033	697,632	15,804	22	1,206,993	751,117	2.65
1988	1,125,449	840	267,719	214,012	16,142	0	498,714	-626,735	0.44
1989	636,906	2,520	374,740	780,541	73,620	238	1,231,658	594,752	1.93
1990	403,627	3,379	441,397	676,695	26,148	23	1,147,643	744,016	2.84
1991	847,772	22	844,961	534,460	14,516	0	1,393,960	546,188	1.64
1992	775,626	39,076	630,294	404,043	7,591	7	1,081,012	305,386	1.39
1993	517,409	5,312	292,425	103,577	5,632	0	406,946	-110,463	0.79
1994	1,147,262	3,269	424,089	301,083	4,487	0	732,928	-414,334	0.64
1995	1,394,162	129	172,419	62,925	5,397	0	240,870	-1,153,292	0.17
1996	1,017,873	92	158,411	210,835	8,832	0	378,170	-639,703	0.37
1997	619,300	1,767	33,796	104,646	4,378	0	144,587	-474,713	0.23
1998	487,301	0	369,562	73,361	1,928	0	444,852	-42,450	0.91
1999	437,356	8,894	205,099	226,119	3,467	0	443,579	6,223	1.01
2000	196,349	3,147	164,193	165,669	172	81	333,262	136,913	1.70
2001	224,058	10,106	547,217	630,393	59,203	82	1,247,002	1,022,943	5.57
2002	459,058	179	406,635	197,735	21,304	156	626,009	166,951	1.36
2003	256,920	12,951	314,732	237,209	10,008	0	574,901		
2004	365,353	5,049	197,539	57,959	0	0	260,548		
2005	525,391	6,081	61,348	0	0	0	67,429		
2006	992,378	5,890	0	0	0	0	5,890		
2007	459,038	0							
2008	374,928								
2009	193,099								
Average	(1972-2002)						875,861	139,801	1.50
							Contrast	7.54	

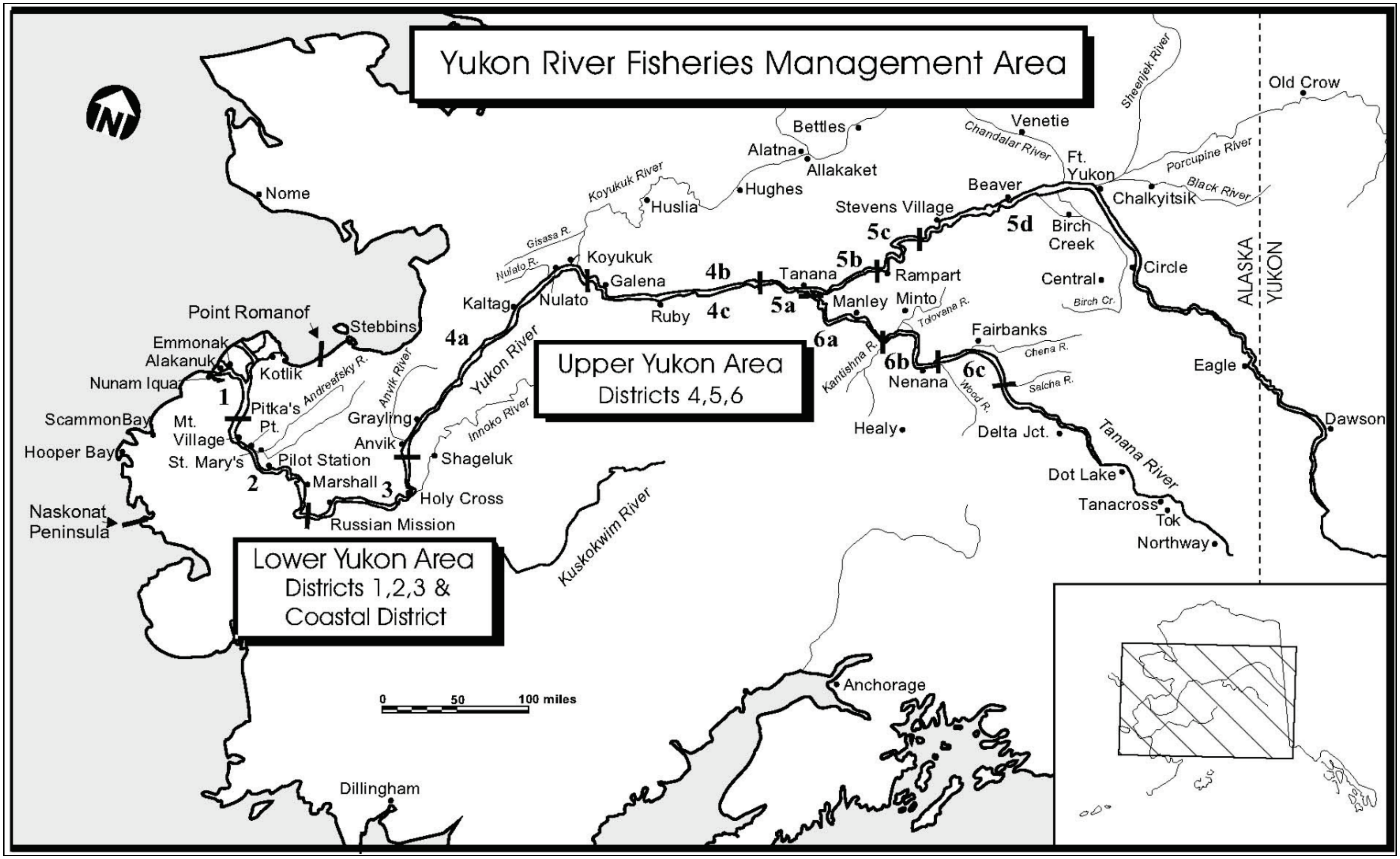


Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

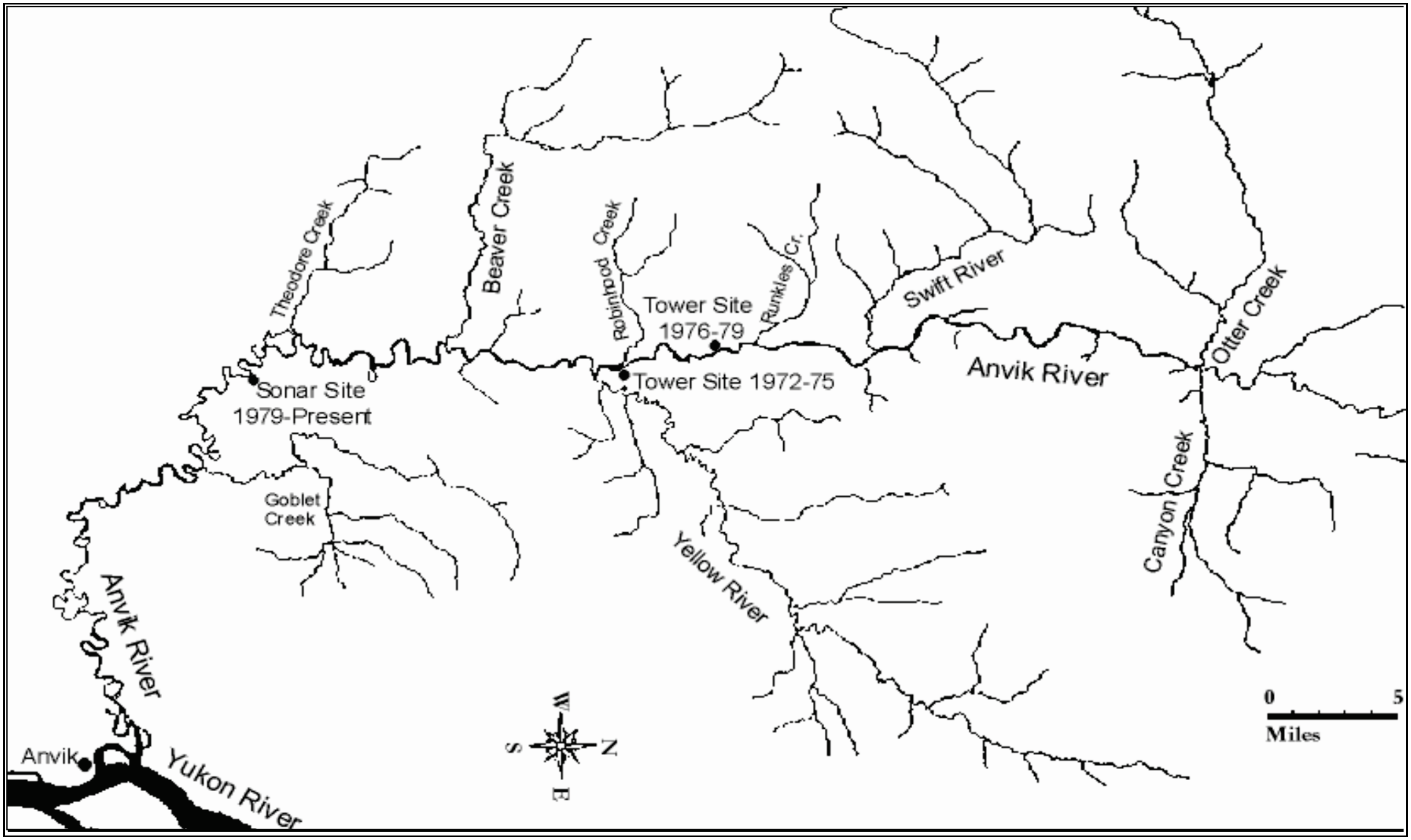


Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

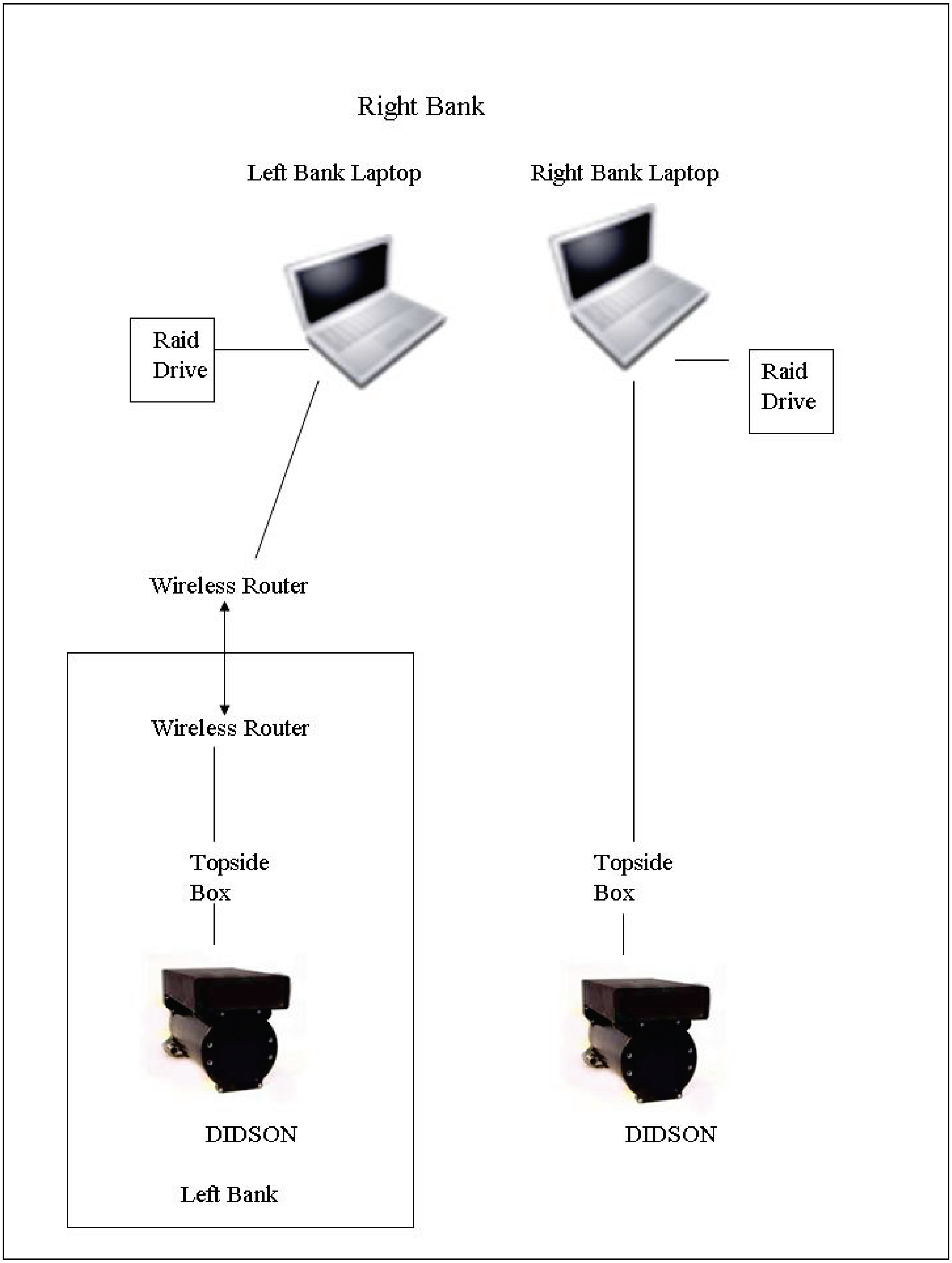


Figure 3.–DIDSON Sonar equipment schematic, Anvik River sonar, 2010.

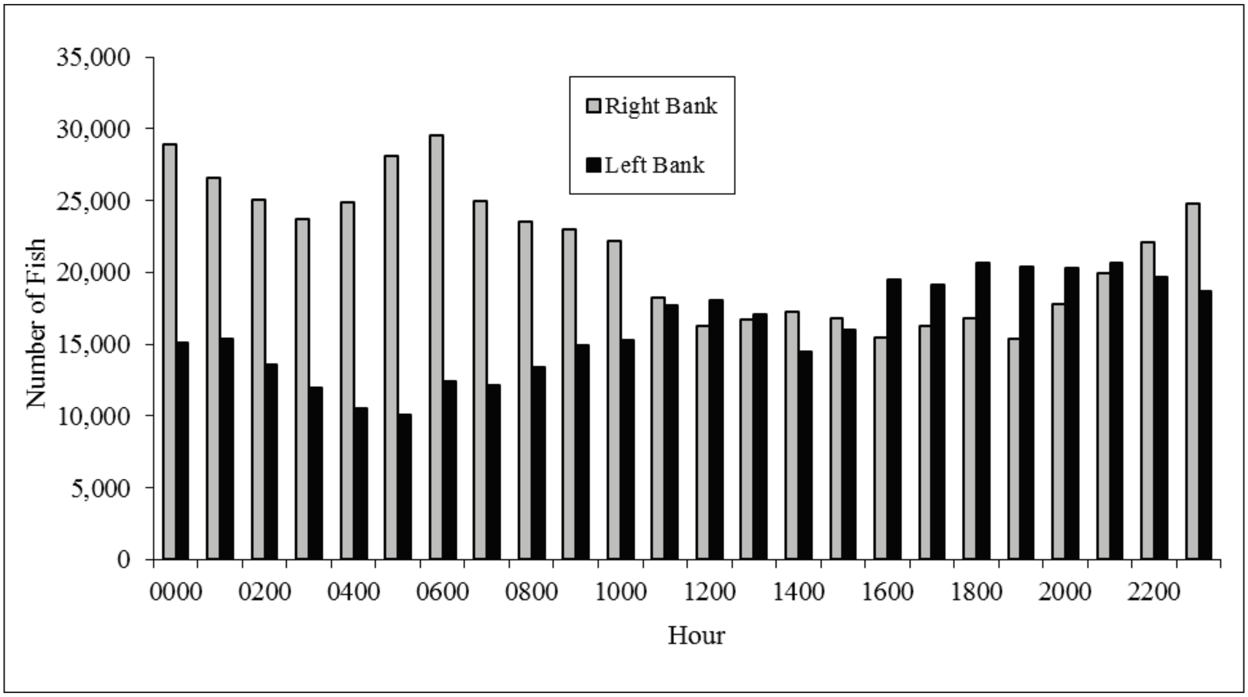


Figure 4.–Estimated passage of chum salmon by hour for each bank, Anvik River sonar 2010.

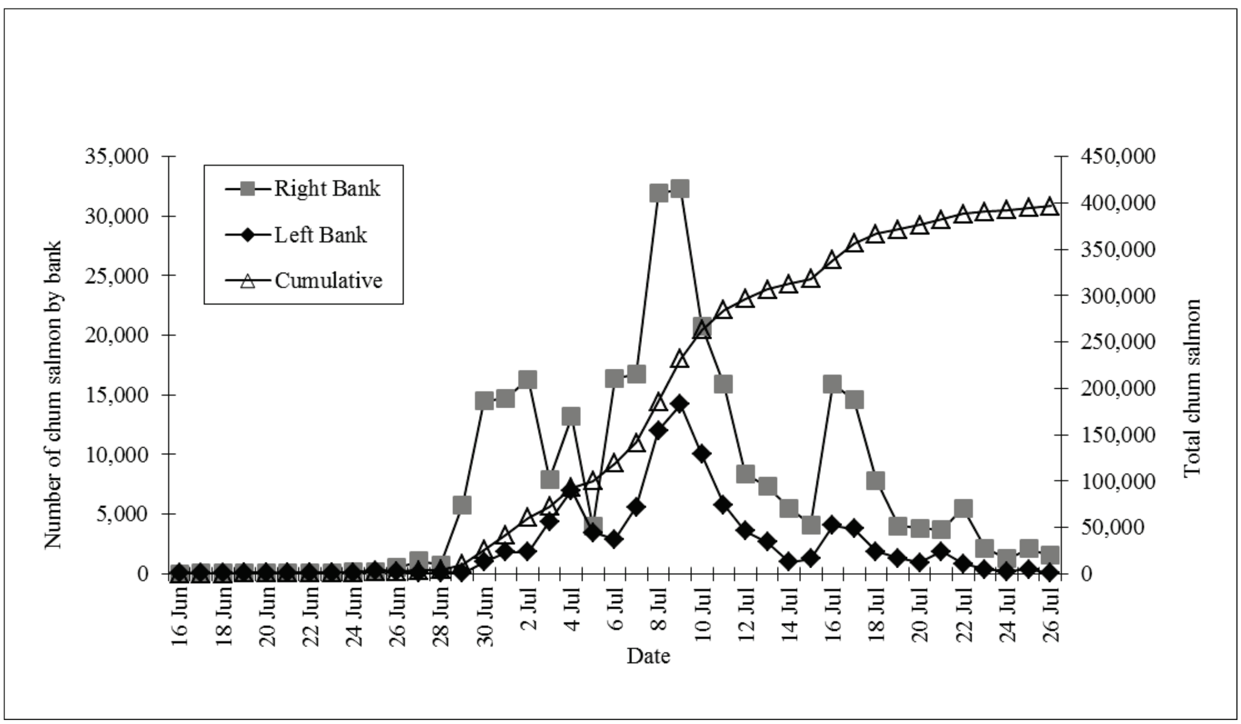


Figure 5.–Chum salmon daily and cumulative counts, Anvik River sonar 2010.

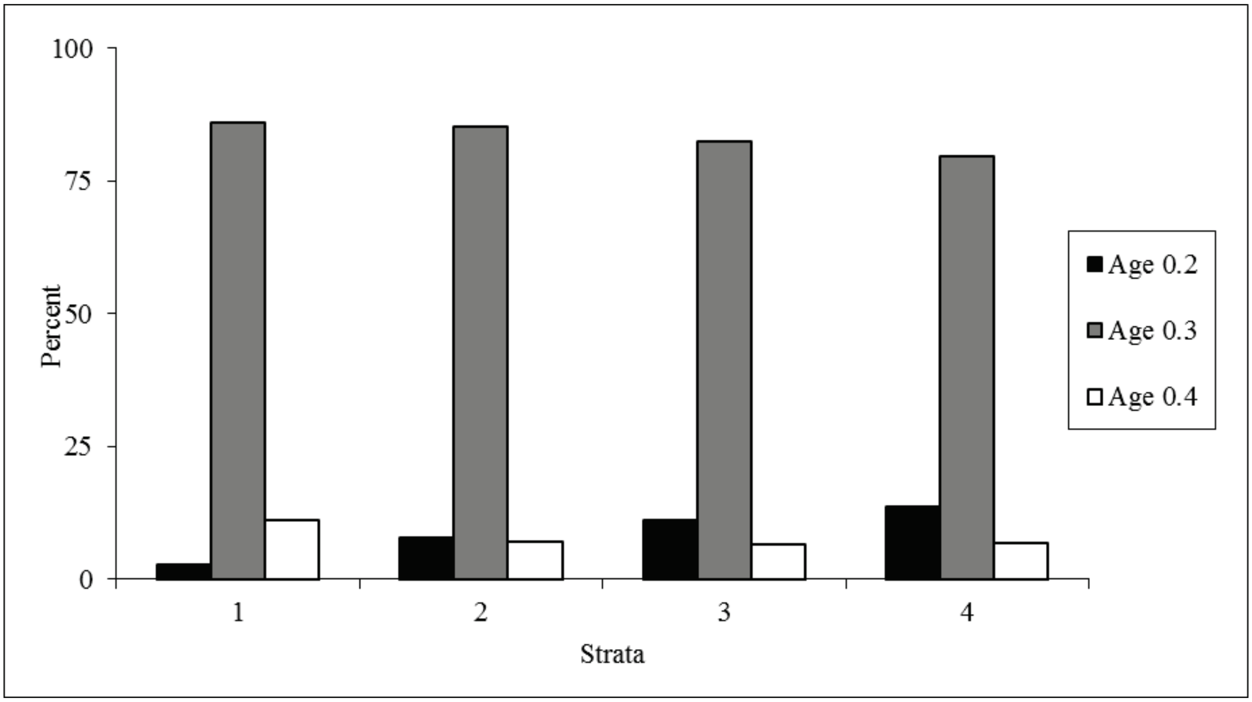


Figure 6.–Chum salmon age composition, Anvik River sonar, 2010.

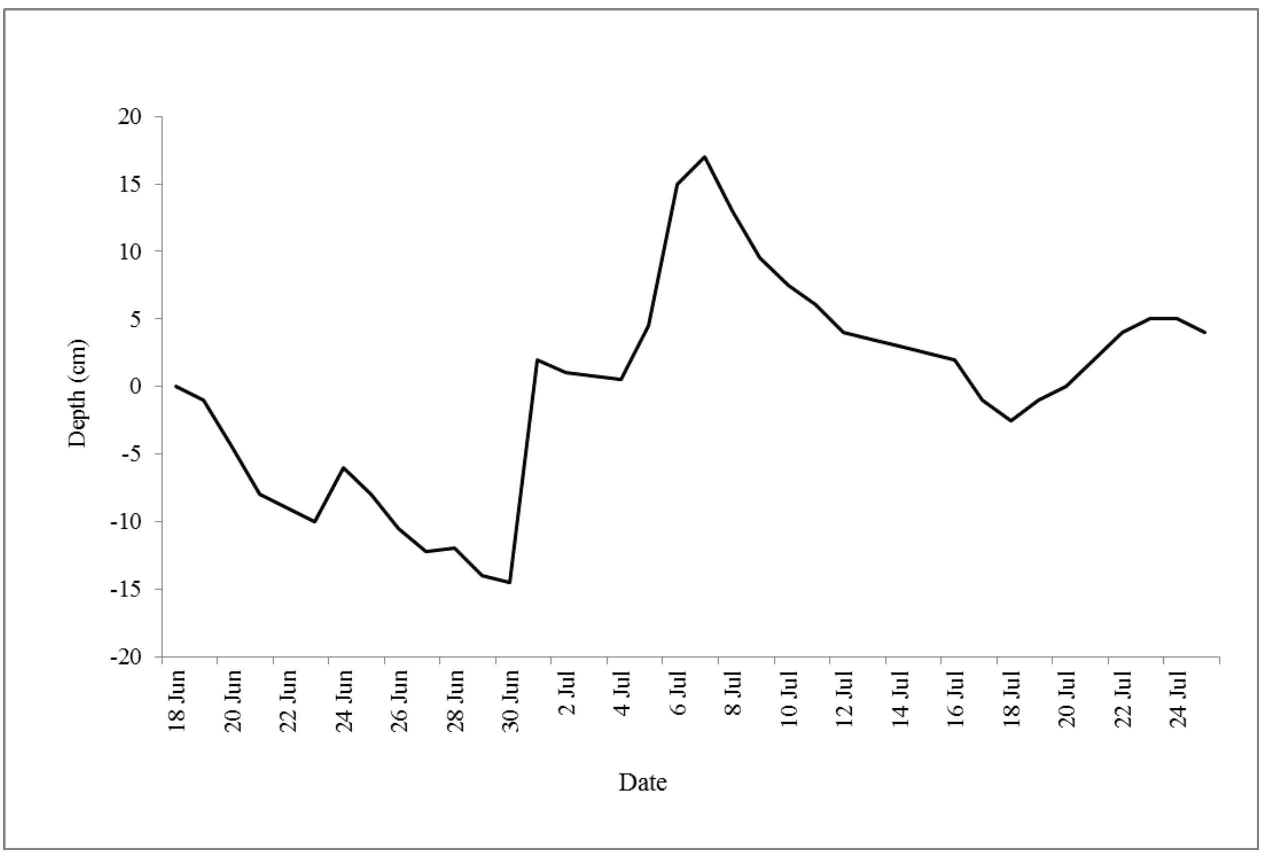


Figure 7.–Water depth at Anvik River sonar, 2010.

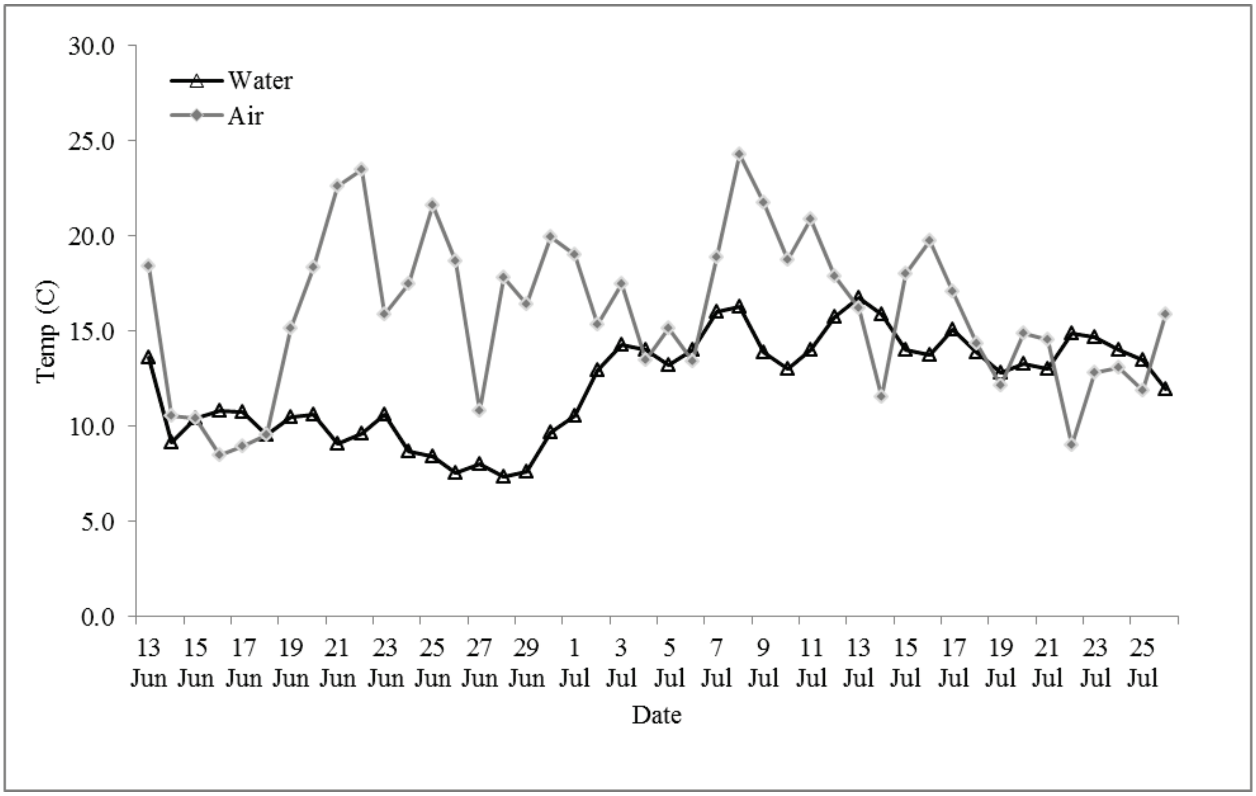
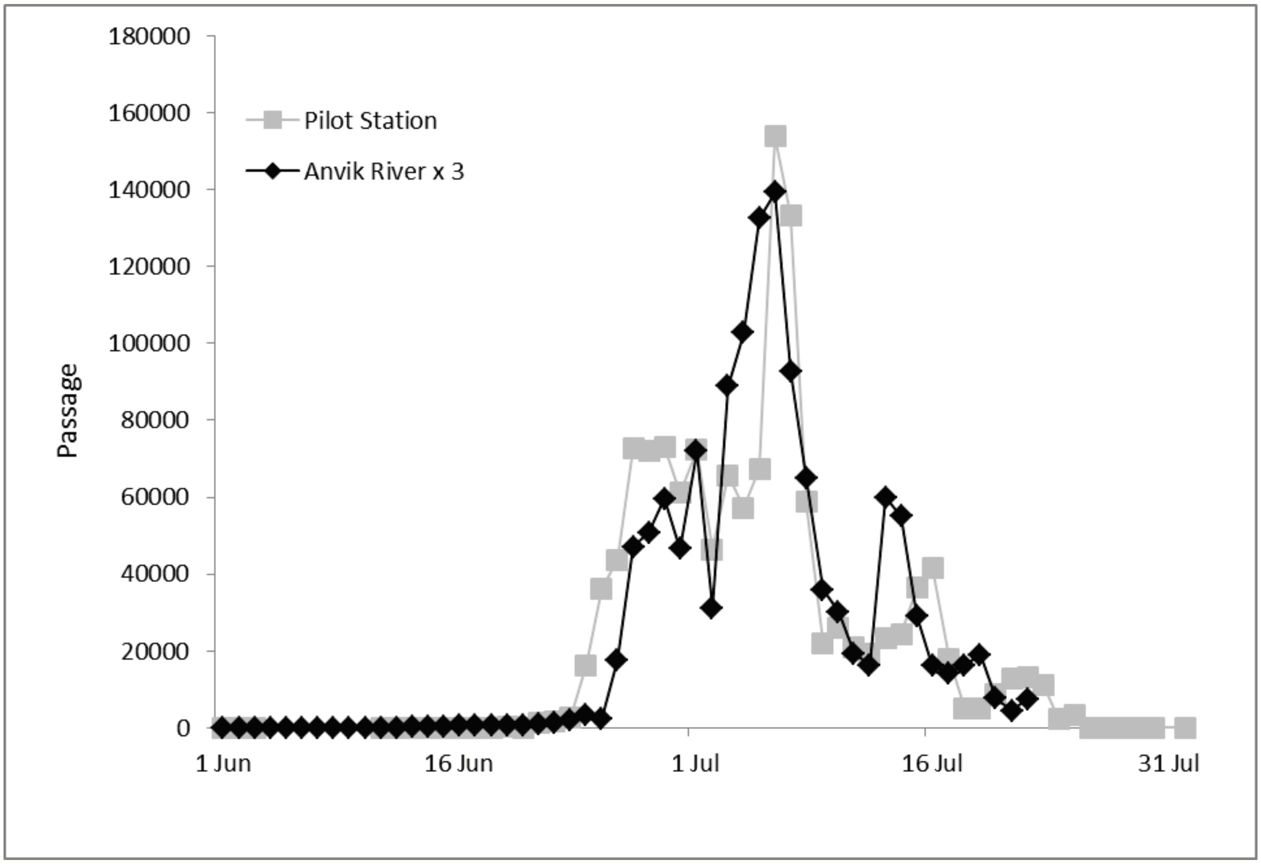


Figure 8.–Air and water temperature, Anvik River sonar, 2010.



Note: Pilot Station shifted forward 10 days to align with Anvik.

Figure 9.–Comparison of daily summer chum salmon passage at Pilot Station sonar and Anvik River sonar, 2010.

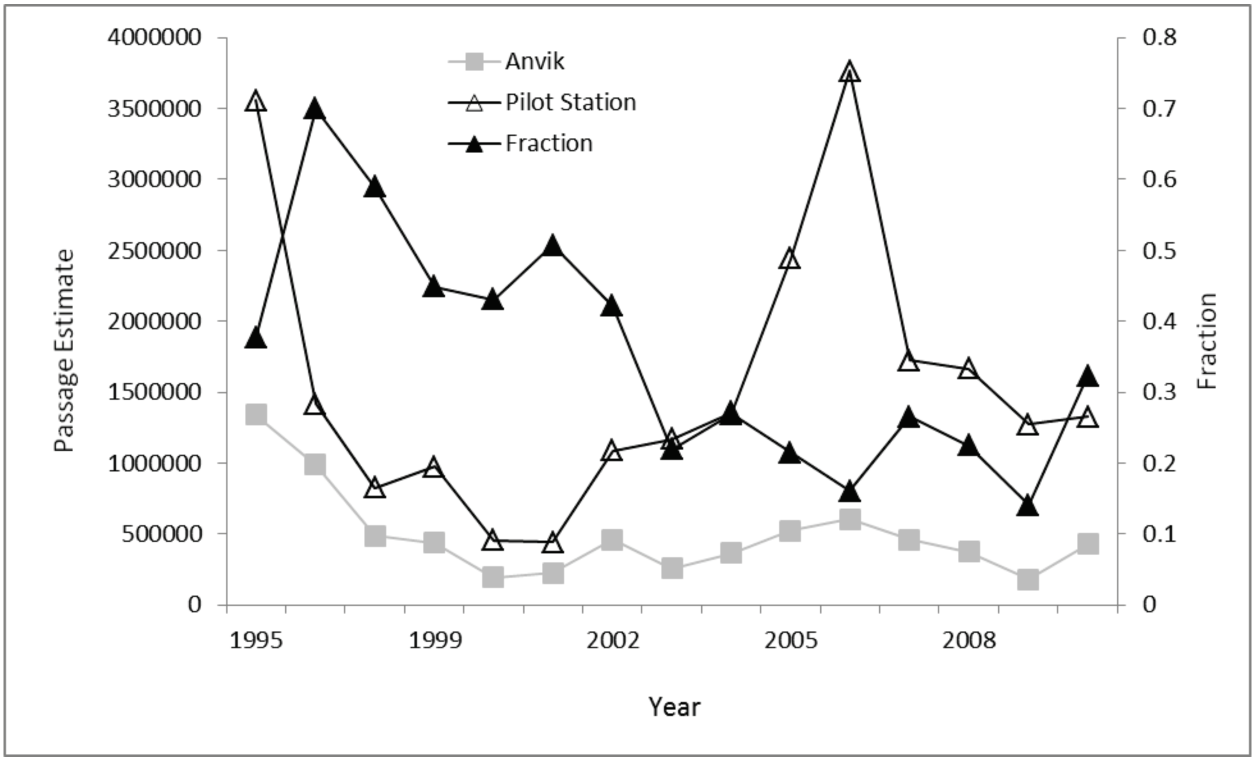


Figure 10.–Yearly passage estimate comparison between Pilot Station sonar project and Anvik River sonar project with the fraction of the Pilot Station estimate that was observed at the Anvik River in each year.

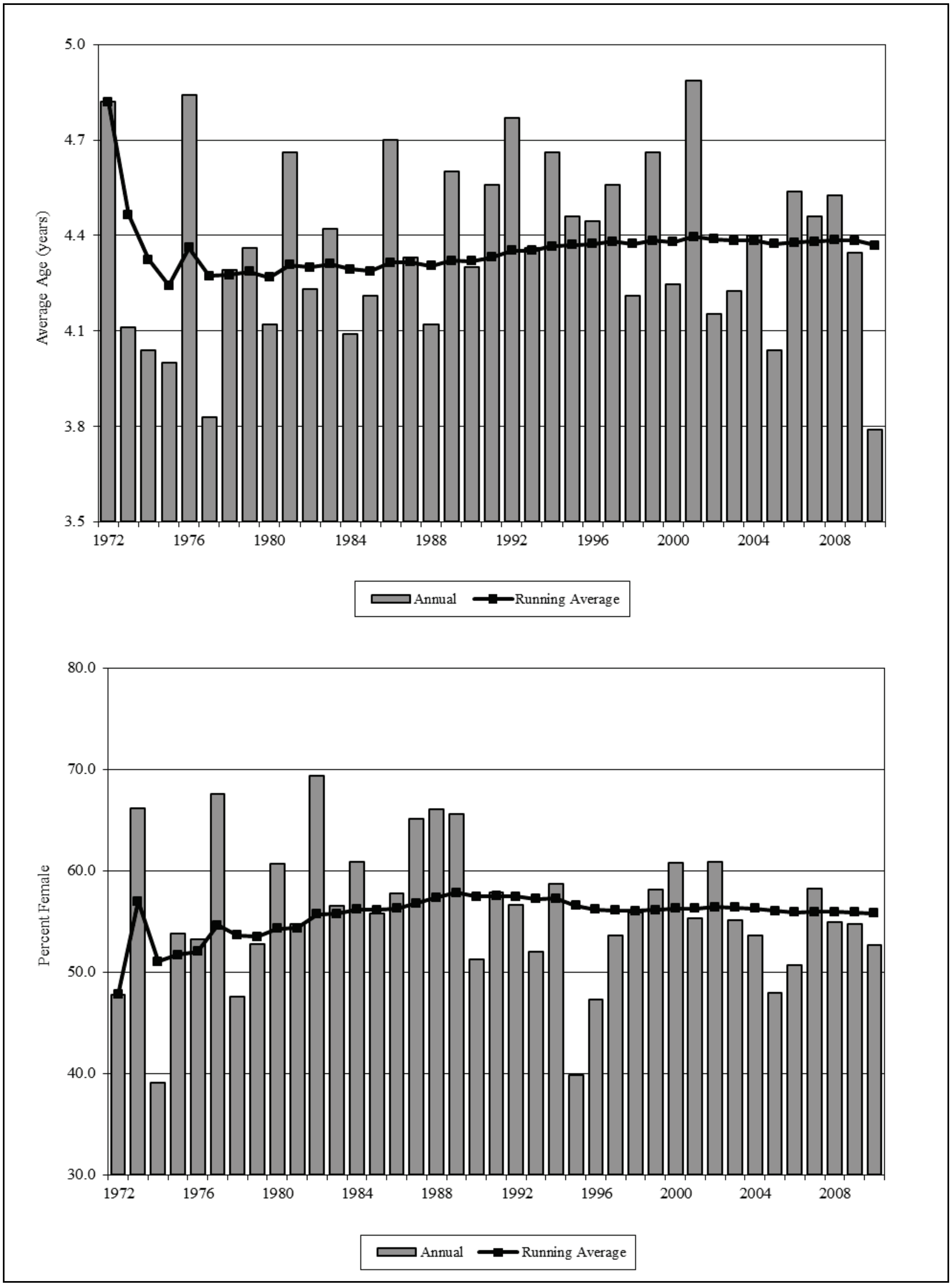


Figure 11.–Annual age at maturity (top) and percentage of females (bottom) of the Anvik River chum salmon escapement, 1972–2010.