Fishery Data Series No. 12-77

Anvik River Sonar Chum Salmon Escapement Study, 2011

Final for Project 08-202
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

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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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by

Malcolm S. McEwen

Alaska Department of Fish and Game, Division of Commercial Fisheries, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518

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Malcolm S. McEwen,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Road, Fairbanks, AK 99701, USA

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ABSTRACT

The 2011 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 642,528 fish (SE 6,638). The summer chum salmon passage was 8% below the upper end of the escapement goal range for the Anvik River (350,000 to 700,000 chum salmon). Based on 1979–1985 and 1987–2010 mean quartile passage dates, timing of the 2011 chum salmon run was average. A chum salmon diurnal migration pattern was observed with the highest passage (40%) occurring during the darkest part of the day (2100–0500 hours). Females comprised 52.5% of the catch in beach seines. Age-0.3and 0.4 fish comprised 98.9% of the chum salmon run in 2011.

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, 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]; Mauney 1977; Trasky 1974, 1976). 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, 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.

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 to 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 6.0 in) 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 (6.0 in 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 (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

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

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 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 162–210 chum salmon samples during each of three or four strata 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 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 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. Each DIDSON was mounted on an aluminum pod and manually aimed. A laptop computer running version 5.11 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 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. a Honda model EU-2000 generator provided power for all equipment.

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. 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 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 six 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 arcticus*, northern pike *Esox lucius*, longnose sucker *Catostomus catostomus*, and whitefish *Coregonus* spp.).

Sampling Procedures

Sonar project activities commenced on June 16 and ended on July 26, 2011. Hydroacoustic sampling began at 1200 hours on June 16 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, seven 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 0759, the second shift counted fish from 0800 to 1559, and the third shift counted fish from 1600 to 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 min 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 min intervals during the eight-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 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 two banks:

$$\hat{y}_d = \sum_z \hat{y}_{dz} \qquad (3)$$

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:

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

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:

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

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 four 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 four times per day (0730, 1300, 1700, and 2000) for 15 min, on each bank in order to determine numbers passing by species. On right bank a 15' 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 and count and identify by species salmon passing 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 by species salmon passing 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.

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:

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

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:

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

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:

$$\hat{V}ar\left(\hat{y}_{a}\right) = \sum_{d} \sum_{z} \hat{V}ar\left(\hat{y}_{dza}\right), \quad (13)$$

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

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

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 2011 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 2011, these strata were defined as: June 16–30, July 1–7, July 8–13 and July 14–26.

To meet regional 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, 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 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 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. The data was 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

Full sonar operations on both banks began at 1200 on June 16. Both transducers collected data through 2359 on July 26. The 2011 summer chum salmon passage estimate was 642,528 salmon. This includes estimates for missing sector or hourly counts and expansions for missing data. For the right bank a total of 510 minute sampling time (0.02%) was missed and on the left bank 646 min sampling time (0.03%) 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 intermittently throughout the season.

Summer chum salmon passage dates were within a day or two at each quartile when compared to the historic run timing, based on 1979–1985 and 1987–2010 runs (Table 1). The central half of the run passed between July 2 and July 14 and the duration of 13 days is longer than the historic mean of 10 days. The daily passage between the first and third quartile dates ranged from 16,344 (July 14) to 47,344 (July 3) with an estimated total of 360,816 summer chum salmon passing by the sonar site during this time (Table 2). The peak daily passage of 47,334 summer chum occurred on July 3 (Table 2). The 2011 chum salmon escapement estimate of 642,528 was greater than the average Anvik River escapement estimate of 605,292 fish, based on 1979–2010 data (Table 1). This year's escapement was within the BEG of 350,000 to 700,000 summer chum salmon.

SPATIAL AND TEMPORAL DISTRIBUTION

For 2011 season, there was no diurnal passage pattern and there is no change in passage between left and right bank (Figure 4). The right bank sonar detected 87% (562,062) of the chum salmon (Table 2; Figure 5).

SPECIES APPORTIONMENT

Tower counts were conducted and Chinook salmon were observed in low numbers. 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

From June 29 to July 20, 605 ASL samples from migrating chum salmon were obtained, and from these samples 509 scales were analyzed postseason. The scale sample analysis indicated that age-0.4 chum salmon accounted for 49.7% of the entire run and age-0.3 chum salmon accounted for 49.2% of the entire run, ranging from 37.5% to 54.3% throughout the run (Table 3; Figure 6). Age 0.2 and age 0.5 chum salmon accounted for 0.4% and 0.7% respectively of the entire run. Females accounted for 52.5% of the entire run (Table 3). Other species caught during ASL sampling were: Chinook salmon, sockeye salmon, whitefish, and grayling.

HYDROLOGIC AND CLIMATOLOGICAL CONDITIONS

The summer of 2011 saw cool temperatures and wet conditions on the Anvik River. Due to rain in the headwaters, the water level fluctuated at the sonar site; over an eight-day period (July 11 to July 19) the water rose 14 cm after which the water steadily decreased (Figure 7). The minimum air temperature was -1.3°C (July 4) and the maximum temperature was 26.4°C (June 17); the average air temperature was 12.1°C (Figure 8). The minimum water temperature was 8.4°C (July 19) and the maximum temperature was 13.7°C (July 23). The average water temperature over the operational period of the project was 10.8°C (Figure 9).

DISCUSSION

ESCAPEMENT ESTIMATION

The 2011 Anvik River summer chum salmon escapement estimate of 642,528 was 6% above the 1979–2010 average escapement of 605,292 and was the largest escapement since 1996 (933,240). The 2011 summer chum salmon escapement was also above the recent ten year average of 385,905. The timing of the summer chum salmon run into the Anvik River in 2011 was roughly similar to the pattern observed at Pilot Station (Figure 10). In addition, 36% of the summer chum salmon that were estimated to have passed Pilot Station were observed at the Anvik River sonar project (Figure 11). Historically the percentage of Yukon River summer chum salmon bound for the Anvik River has fluctuated. Although the overall contribution from 1995 to 2011 is 35.3%, this can be broken into two distinct periods. During the period from 1995 to 2002 the average contribution was 49.6%. From 2003 to present, the average contribution is 24.2%. Over the last two years the relative contribution has been above 30%. 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 production of summer chum salmon on the Anvik River. We will need a few more years of data to conclude if the productivity, relative to the rest of the Yukon River drainage, is improving in the Anvik 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 2006 chum salmon year class returned to spawn this year as age-0.4, accounting for 49.7% (319,304) of the total run. Age 0.3 fish accounted for 49.2% (316,060) and age-0.2 and 0.5 fish accounted for a combined total of 1.1% (7,163) of the total run. The average age of the 2011 run was 4.5 years which is above the long-term average of 4.4 years (Figure 12). The percentage of female chum salmon increased throughout the run from 43.8% at the beginning to 58.8% by the end of the run; overall there were 52.5% females which is below the long term average of 55.9%.

Age five and the age four summer chum salmon were the dominant age groups throughout the Yukon River drainage at 55.5% and 44.1% respectively. Age five summer chum salmon from the other escapement projects comprised 63.4% of the East Fork Andreafsky River, 53.4% of Henshaw Creek, 49.7% of Anvik River, and 43.7% of Gisasa River escapements. Age four summer chum salmon from these projects comprised 36.0% of the East Fork Andreafsky River, 44.2% of Henshaw Creek, 49.2% of Anvik River, and 54.8% of Gisasa River escapements (Larry Dubois, 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 three- to six-year-olds and occasionally as age seven. 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 the 20-year period 1987 to 2006 was 1.40 (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 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 over winter climatological data (water, air) 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 from October through April ranged from a low of -43.0 C to a high of 14.0 C with an average of -12.9 C in 2008–2009. For 2009–2010 air temperature ranged from a low of -42.1 C to a high of 13.8 C with an average of -

11.6 C. For 2010–2011 air temperature ranged from a low of -38.8 C to a high of 13.2 C with an average of -10.2 C.

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.

Spatial and Temporal Distribution

In 2011, chum salmon spatial migration followed historical trends with 87% of the fish passing on the right bank. Prior to 2006, passage has been associated with the right bank with the exception of three 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 2011 appeared to be about the same as in 2010.

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 from 1985 through 2008 and 2010 but not 2009. Distribution of sonar estimates in 2011 show a greater proportion of daily passage occurring at night. Additionally, chum salmon tended to move over to left bank at night and then back over to right bank during the day.

Conclusions

Over the past four years, chum salmon counts have increased overall from approximately 460,000 in 2007 and a low of 191,566 in 2009 to this year's count of 642,528 fish. During this same period, the proportion of chum salmon returning to the Anvik River versus the overall chum salmon run on the Yukon River increased from 26.5% in 2007 and a low of 14.1% in 2009 to 36.1% this past season. In 2008, a record breaking 734,837 pink salmon came back to spawn on the Anvik River. Due to the increase in pink salmon, the crew had difficulty in distinguishing between chum, Chinook, and pink salmon during the tower counts. In response to this, white Teflon-coated vinyl flash panels were deployed on the river bottom in 2010 to help distinguish species. Air and water temperatures are now being collected year round using HOBO temperature loggers at camp, for the Aquatic Restoration and Research Institute in Talkeetna Alaska.

Recommendations

With the recent increase in pink salmon in 2008 and 2010, an area for future observation will be to see whether these numbers stay the same and will they affect the chum salmon populations over the next two–four years. Another question to be resolved, given that the proportion of chum salmon in the Anvik River appears to be increasing, is what caused the decline in 2003? From 1995 to 2002, the average proportion of chum salmon going up the Anvik River was 49%, from 2003 to 2011 was 24%, and over the last two years the proportion has been above 30% (Figure 11).

ACKNOWLEDGEMENTS

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TABLES AND FIGURES

Table 1.–Annual passage estimates and passage timing for summer chum salmon runs, Anvik River sonar, 1979–2011.

						Days Between			
Year	Sonar passage	First Count	First	Median	Third	First count & first	First quartile &	Median &	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	8 Jul	12 Jul	18 Jul	22	4	6	10
2011	642,528	16 Jun	1 Jul	7 Jul	14 Jul	15	6	7	13
Average	605,292	22 Jun	3 Jul	8 Jul	13 Jul	11	5	5	10
Median	482,181	21 Jun	4 Jul	9 Jul	14 Jul	10	5	5	10
SD	340,365		3	3	3	3.9	1.5	1.4	2.1

Note: The mean, median and standard deviation of the timing statistics includes estimates from years 1979–1985 and 1987–2010. The 2011 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, 2011.

Date	Right Bank	Left Bank	Daily Total	Cumulative	Percent Passage
16 Jun	42	154	196	196	0%
17 Jun	192	683	875	1,072	0%
18 Jun	159	566	725	1,797	0%
19 Jun	696	736	1,432	3,229	1%
20 Jun	1,782	696	2,478	5,707	1%
21 Jun	2,691	338	3,029	8,735	1%
22 Jun	580	129	709	9,445	1%
23 Jun	1,216	252	1,468	10,913	2%
24 Jun	1,730	1,136	2,866	13,779	2%
25 Jun	5,220	1,090	6,310	20,089	3%
26 Jun	6,400	414	6,814	26,903	4%
27 Jun	16,965	2,678	19,642	46,545	7%
28 Jun	14,134	1,780	15,914	62,459	10%
29 Jun	15,598	2,378	17,976	80,435	13%
30 Jun	19,614	1,562	21,176	101,611	16%
1 Jul	26,622	1,637	28,259	129,870	20%
2 Jul	32,984	4,968	37,952	167,822	26%
3 Jul	44,176	3,158	47,334	215,156	33%
4 Jul	15,688	756	16,444	231,600	36%
5 Jul	24,142	1,306	25,448	257,048	40%
6 Jul	28,978	1,904	30,882	287,930	45%
7 Jul	28,306	2,552	30,858	318,788	50%
8 Jul	29,710	3,630	33,340	352,128	55%
9 Jul	22,112	1,682	23,794	375,922	59%
10 Jul	21,572	2,072	23,644	399,566	62%
11 Jul	25,562	2,770	28,332	427,898	67%
12 Jul	22,642	3,580	26,222	454,120	71%
13 Jul	16,890	3,332	20,222	474,342	74%
14 Jul	14,606	1,738	16,344	490,686	76%
15 Jul	25,996	2,340	28,336	519,022	81%
16 Jul	25,477	3,010	28,487	547,508	85%
17 Jul	13,153	3,116	16,269	563,777	88%
18 Jul	11,750	1,812	13,562	577,339	90%
19 Jul	6,112	2,606	8,718	586,057	91%
20 Jul	9,966	4,820	14,786	600,843	94%
21 Jul	12,758	5,200	17,958	618,801	96%
22 Jul	5,320	3,602	8,922	627,723	98%
23 Jul	4,678	1,870	6,548	634,270	99%
24 Jul	2,040	634	2,674	636,944	99%
25 Jul	1,320	637	1,957	638,901	99%
26 Jul	2,484	1,143	3,627	642,528	100%
Season Totals	562,062	80,466	642,528		

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, 2011.

			Age									
			(0.2)		(0.3)		(0.4)		(0.5)		Total	
2011 Sample Dates (Strata)	Sample Size	Sex	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%	Number Fish	%
6/29-30	144	Male	0	0.0	19,052	50.0	36,693	59.1	1,411	100.0	57,156	56.3
(6/16-30)		Female	0	0.0	19,052	50.0	25,403	40.9	0	0.0	44,455	43.8
		Subtotal	0	0.0	38,104	37.5	62,096	61.1	1,411	1.4	101,611	100.0
7/5-6	140	Male	0	0.0	54,294	46.6	54,294	54.7	0	0.0	108,589	50.0
(7/1-7)		Female	1,551	100.0	62,051	53.3	44,987	45.3	0	0.0	108,589	50.0
		Subtotal	1,551	0.7	116,345	53.6	99,281	45.7	0	0.0	217,177	100.0
7/11, 13	140	Male	0	0.0	34,444	40.7	34,444	50.0	1,111	100.0	69,999	45.0
(7/8-13)		Female	1,111	100.0	50,000	59.3	34,444	50.0	0	0.0	85,555	55.0
		Subtotal	1,111	0.7	84,444	54.3	68,888	44.3	1,111	0.7	155,554	100.0
7/17, 19-20	85	Male	0	0.0	27,701	35.9	39,573	44.4	1,979	100.0	69,253	41.2
(7/14-26)		Female	0	0.0	49,466	64.1	49,466	55.6	0	0.0	98,933	58.8
		Subtotal	0	0.0	77,168	45.9	89,040	52.9	1,979	1.2	168,186	100.0
Season	509	Male	0	0.0	135,492	42.9	165,004	51.7	4,501	100.0	304,997	47.5
		Female	2,662	100.0	180,569	57.1	154,300	48.3	0	0.0	337,531	52.5
		Total	2,662	0.4	316,060	49.2	319,304	49.7	4,501	0.7	642,528	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 4.–Anvik River summer chum salmon brood table with return per spawner 1987 to present.

		Number of Fish by Age Class						
Brood Year	Escapement	0.2[a]	0.3[a]	0.4[a]	0.5[a]	0.6[a]	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	6,114	0	237,177	0.45
2006	992,378	5,915	420,978	393,691	0	0	820,584	0.83
2007	460,121	35,346	401,793					
2008	374,928	2,732						
2009	193,099							
2010	396,173							
2011	642,528							

[a] Includes a proportion of the commercial catch from Districts 1–4 destined for Anvik River.

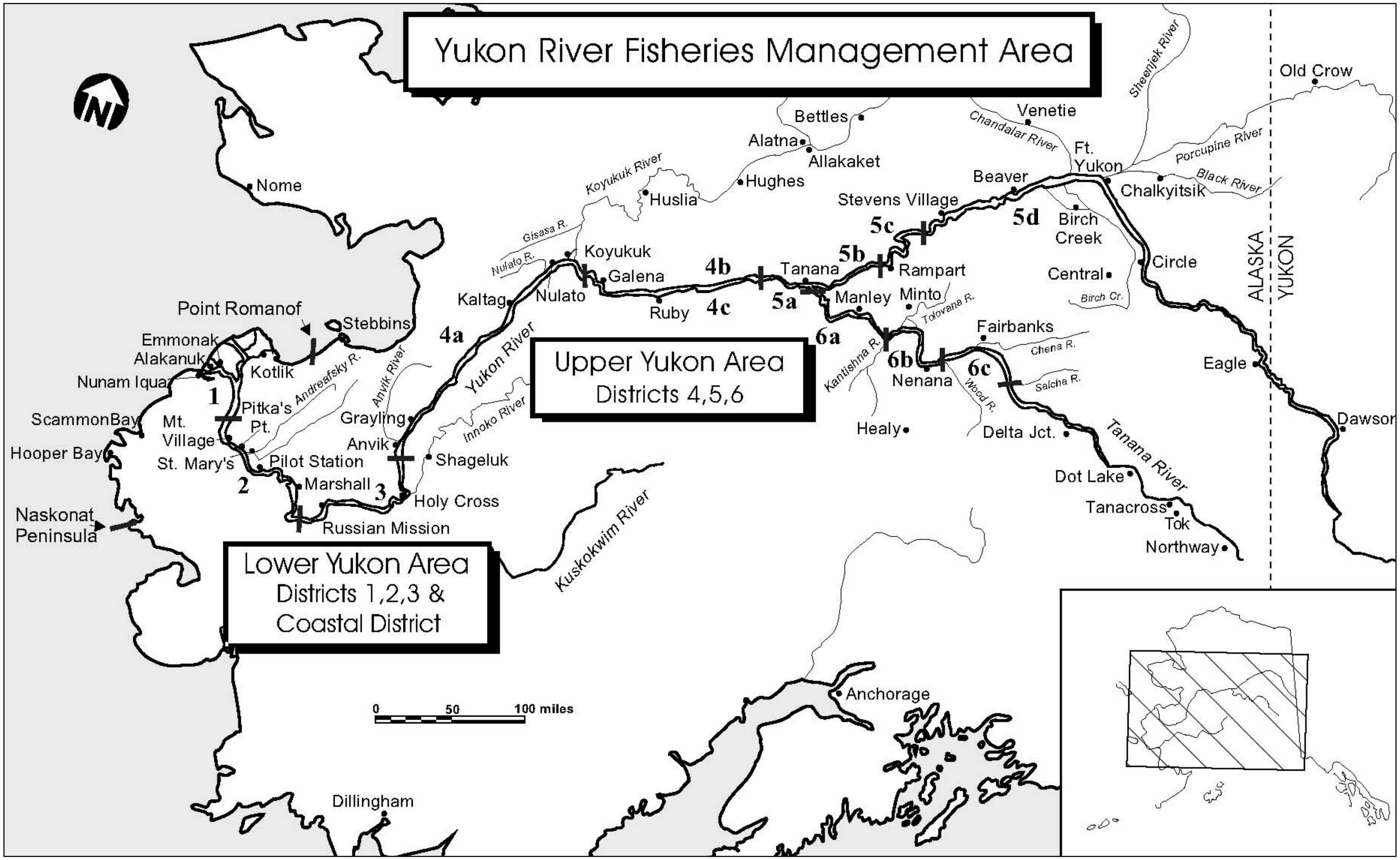


Figure 1.–Alaska portion of the Yukon River drainage showing communities and fishing districts.

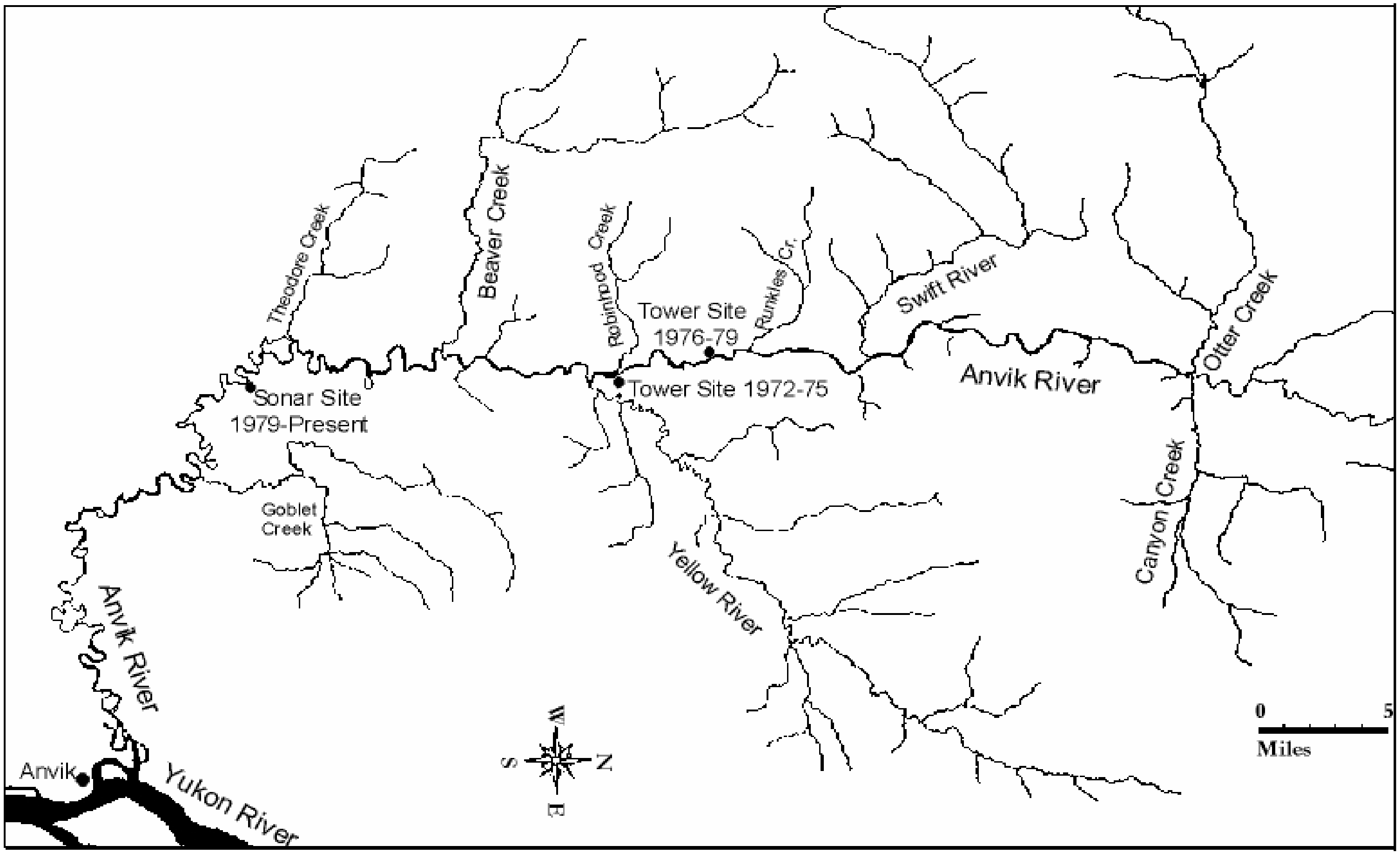


Figure 2.–Anvik River drainage with historical chum salmon escapement project locations.

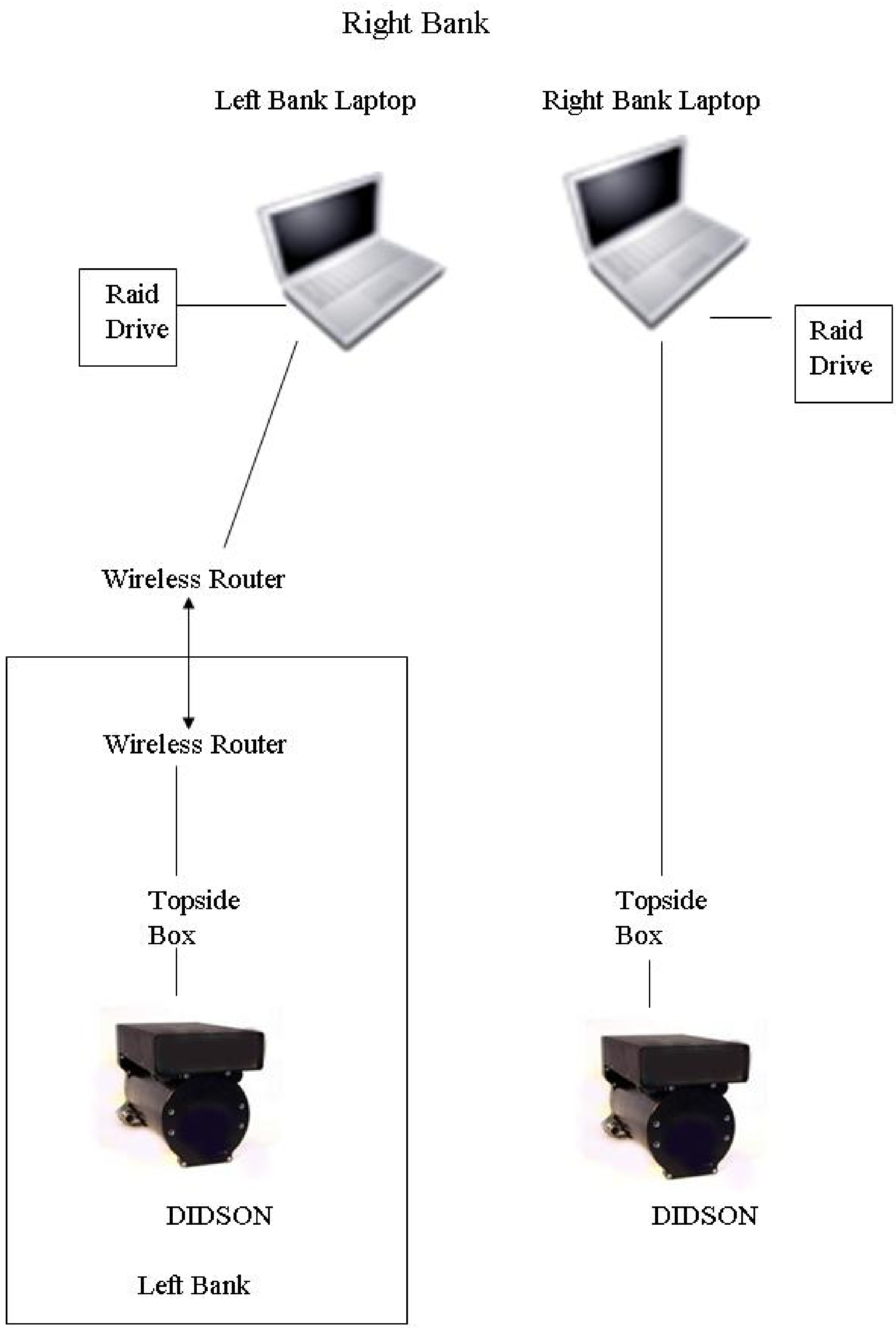


Figure 3.–DIDSON Sonar equipment schematic, Anvik River sonar, 2011.

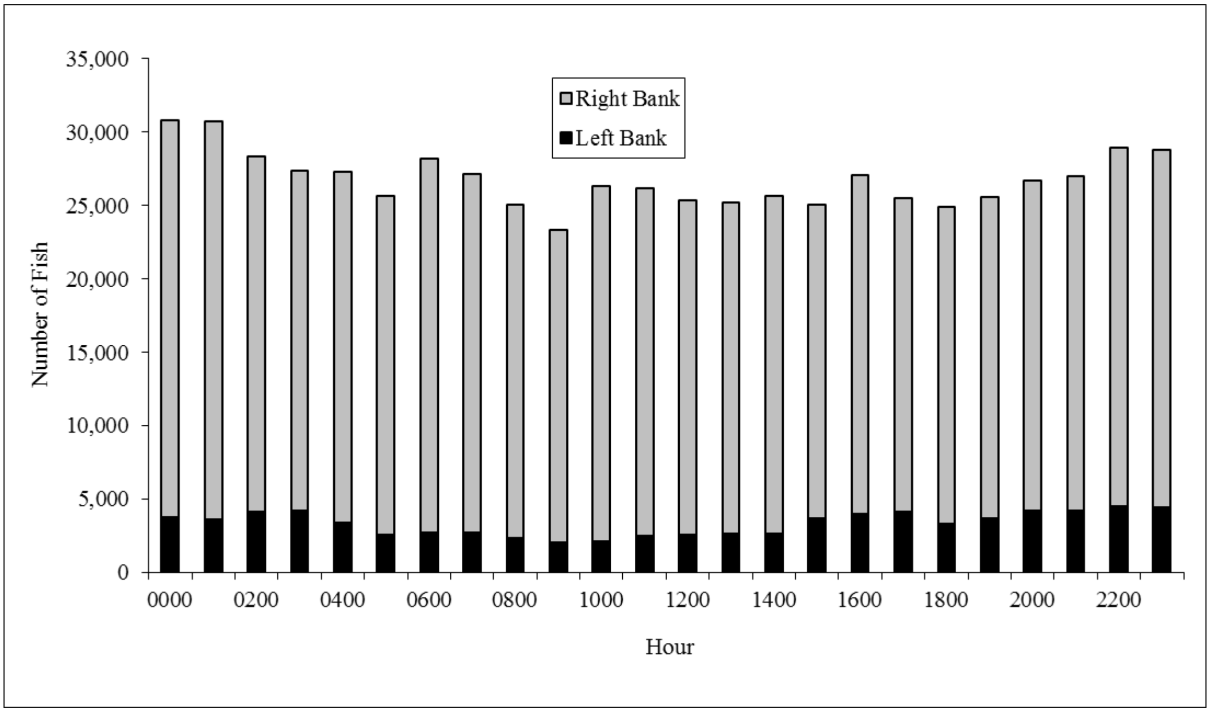


Figure 4.–Estimated cumulative passage of chum salmon by hour for each bank, Anvik River sonar 2011.

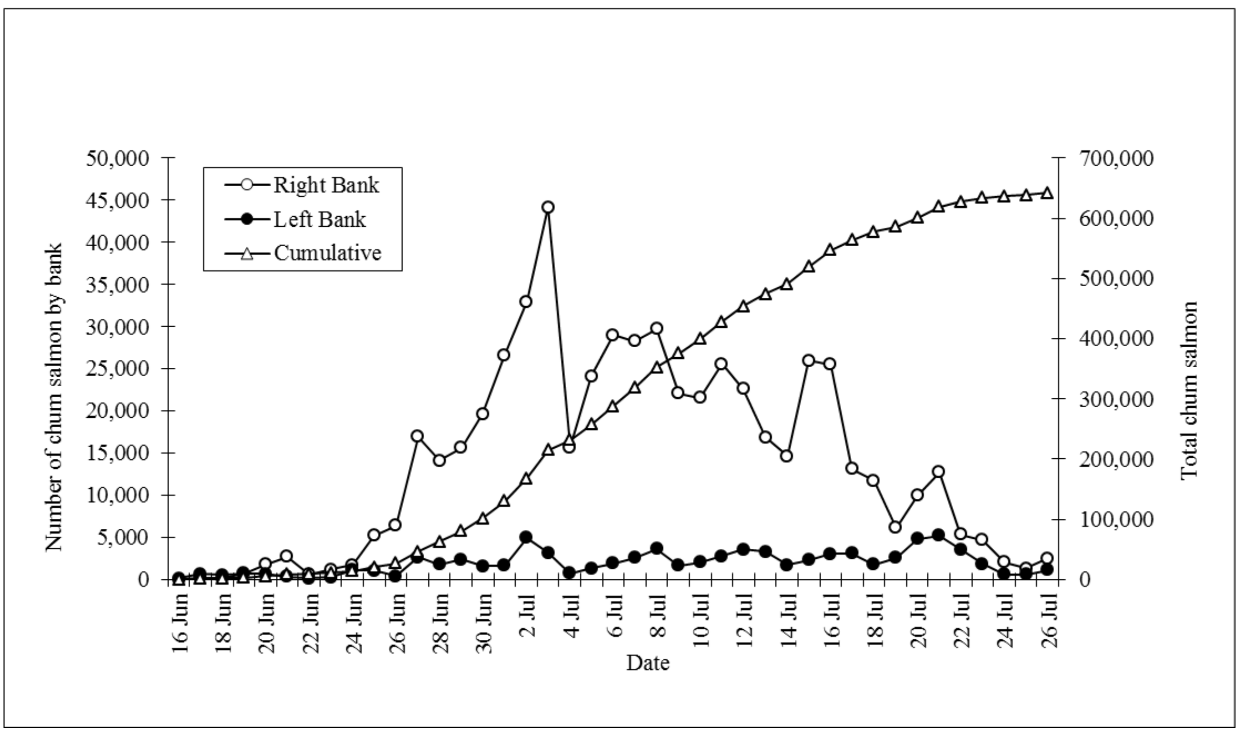


Figure 5.–Chum salmon daily and cumulative counts, Anvik River sonar 2011.

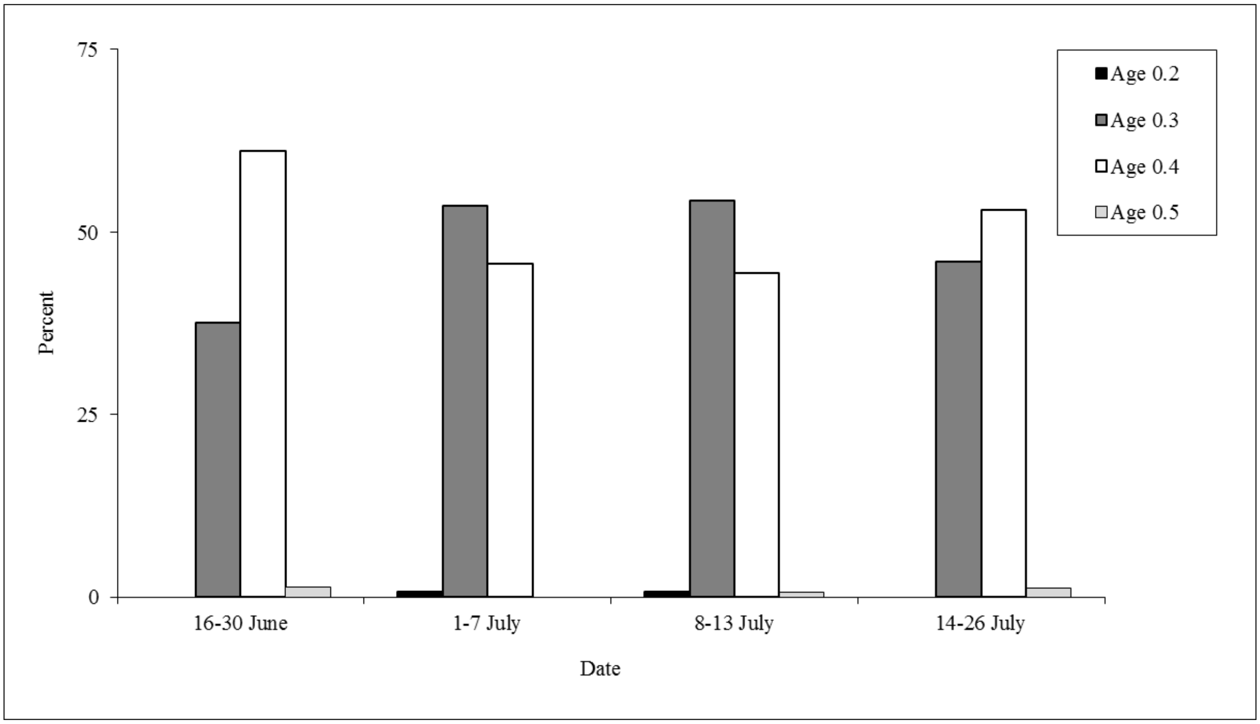


Figure 6.–Chum salmon age composition, Anvik River sonar, 2011.

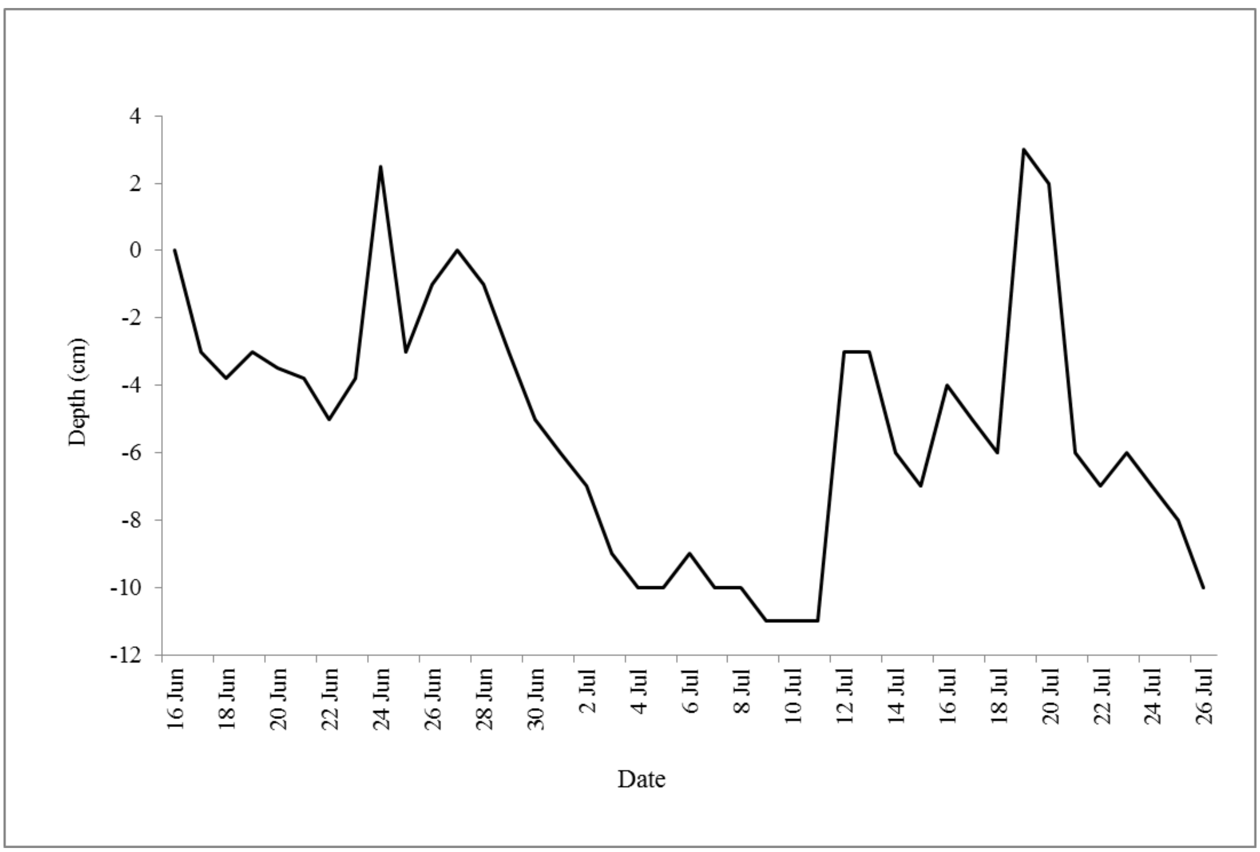


Figure 7.–Water depth at Anvik River sonar, 2011.

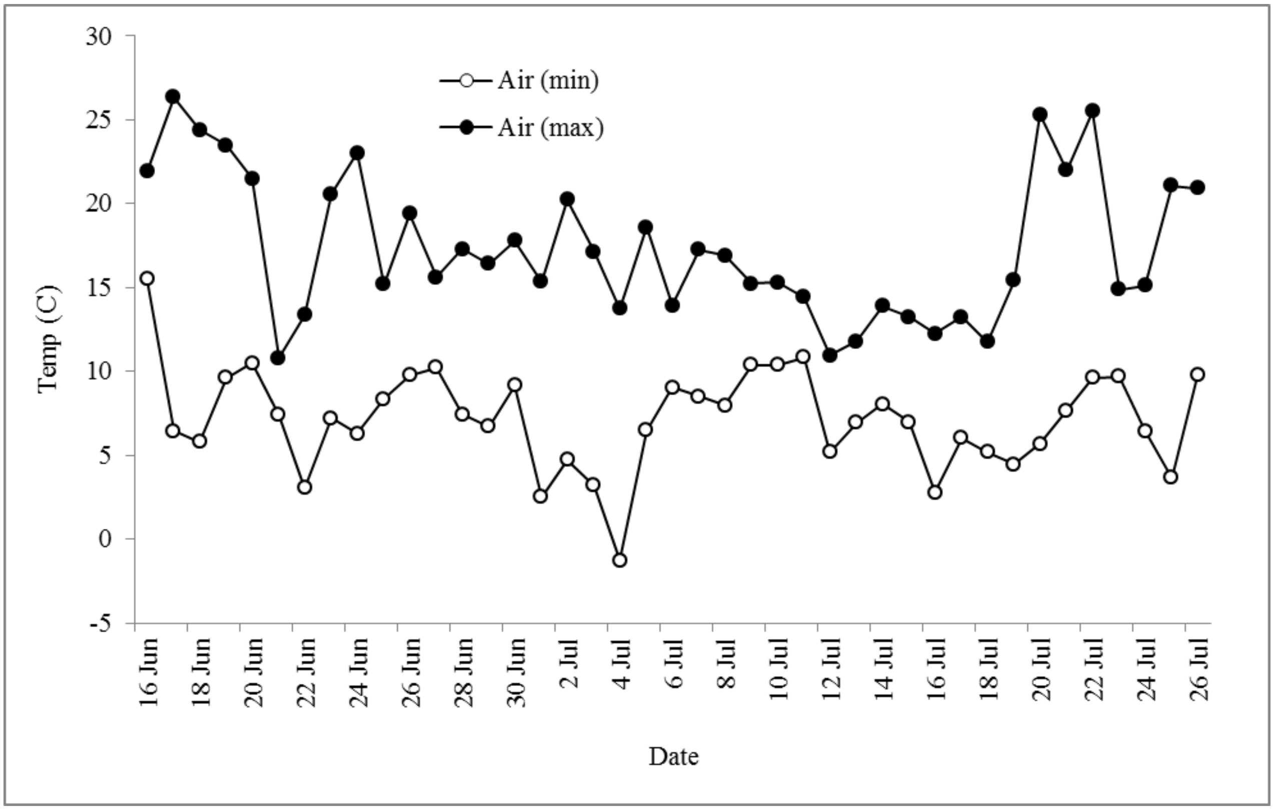


Figure 8.–Air temperature, Anvik River sonar, 2011.

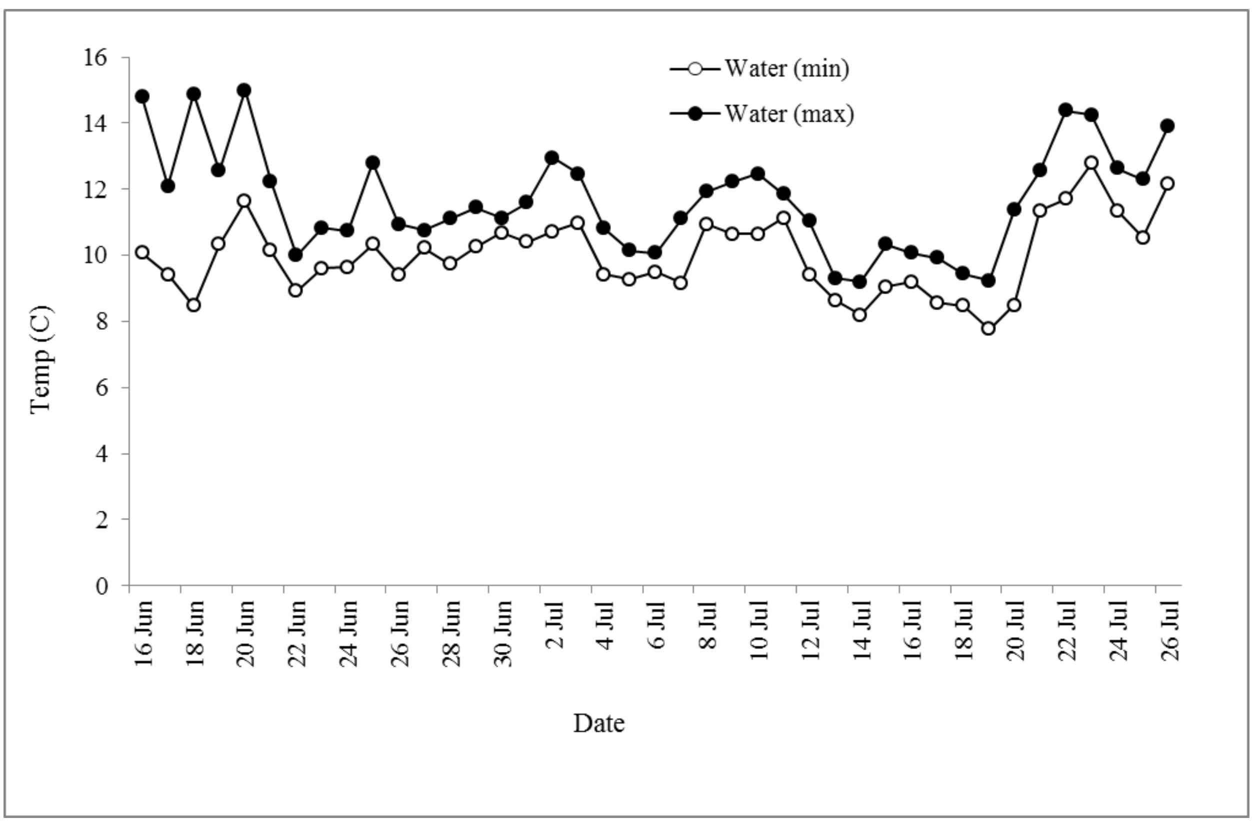
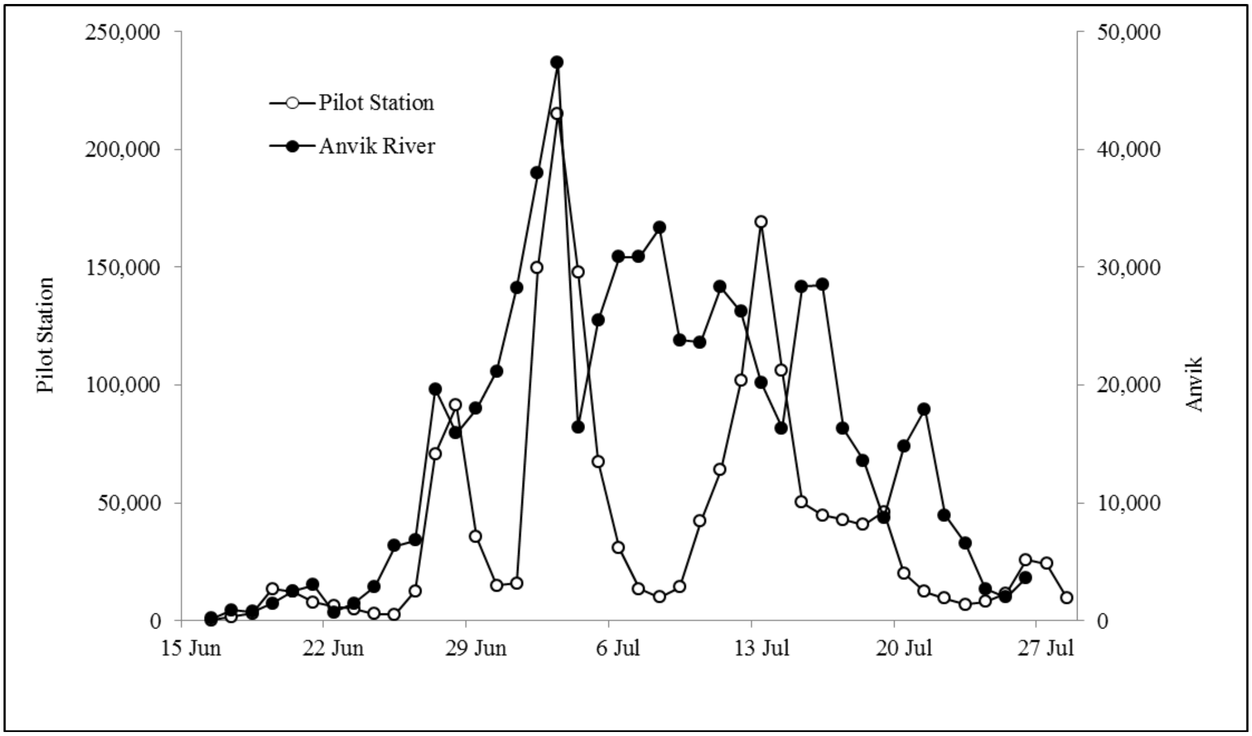


Figure 9.–Water temperature, Anvik River sonar, 2011.



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

Figure 10.–Comparison of daily summer chum salmon passage at Pilot Station sonar and Anvik River sonar, 2011.

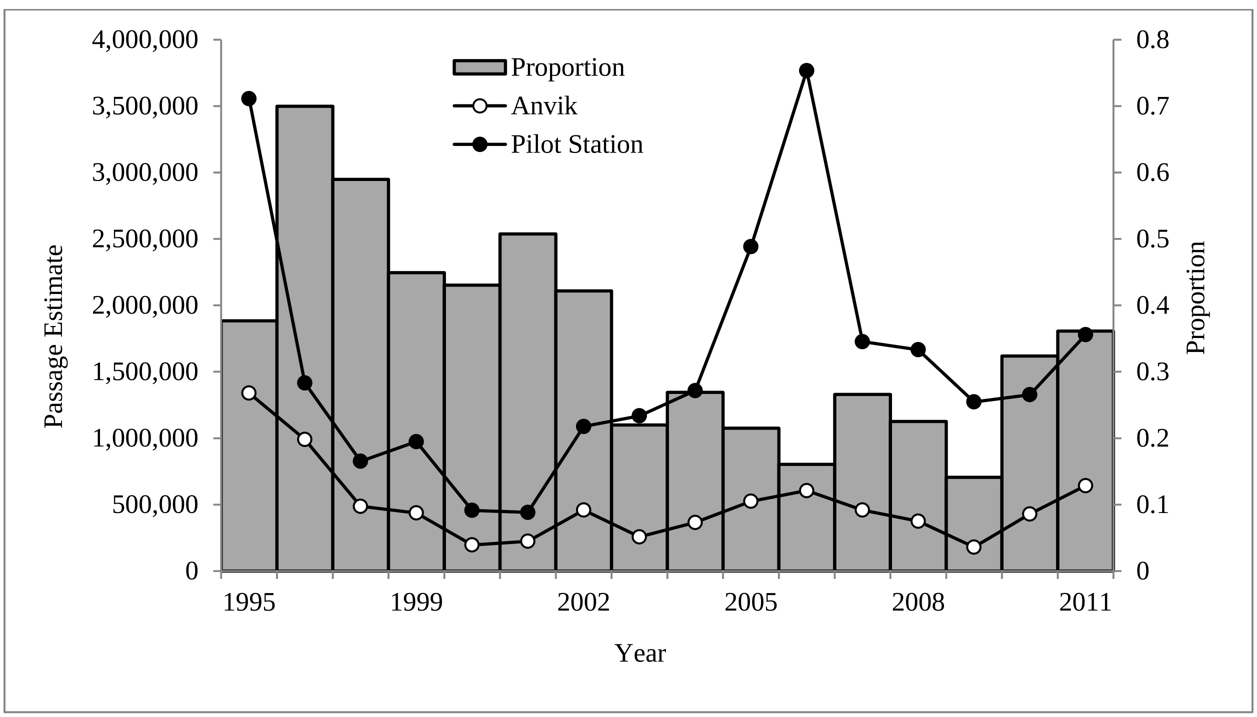
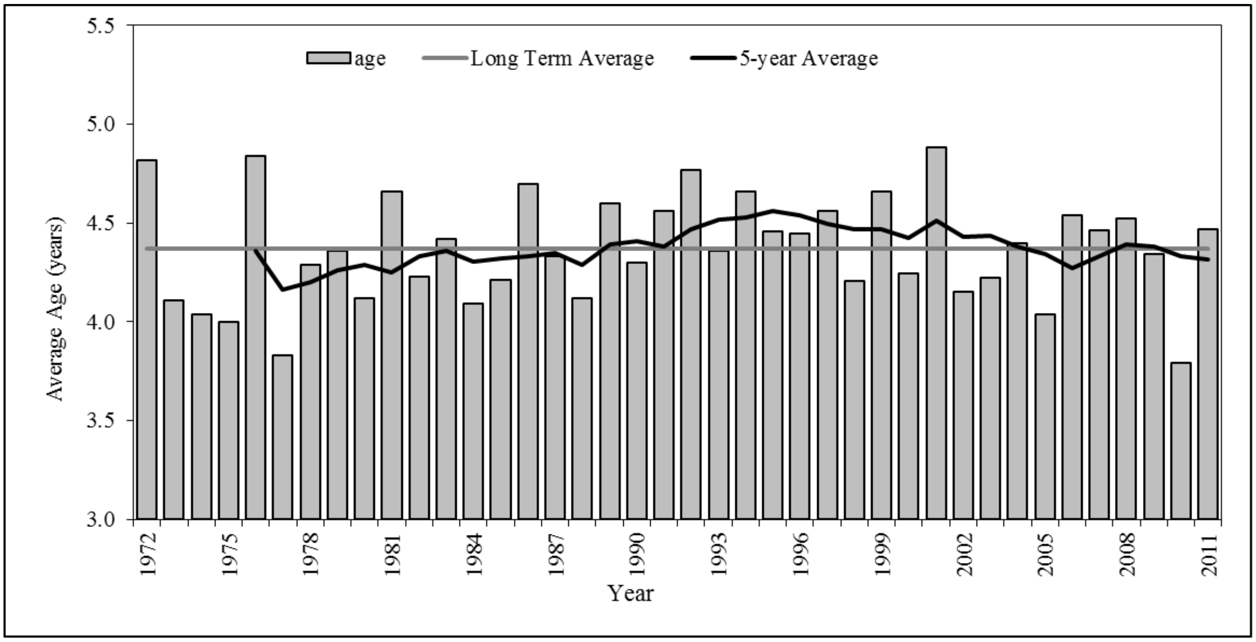


Figure 11.–Yearly passage estimate comparison between Pilot Station sonar project and Anvik River sonar project with the proportion of the Pilot Station estimate that was observed at the Anvik River in each year.



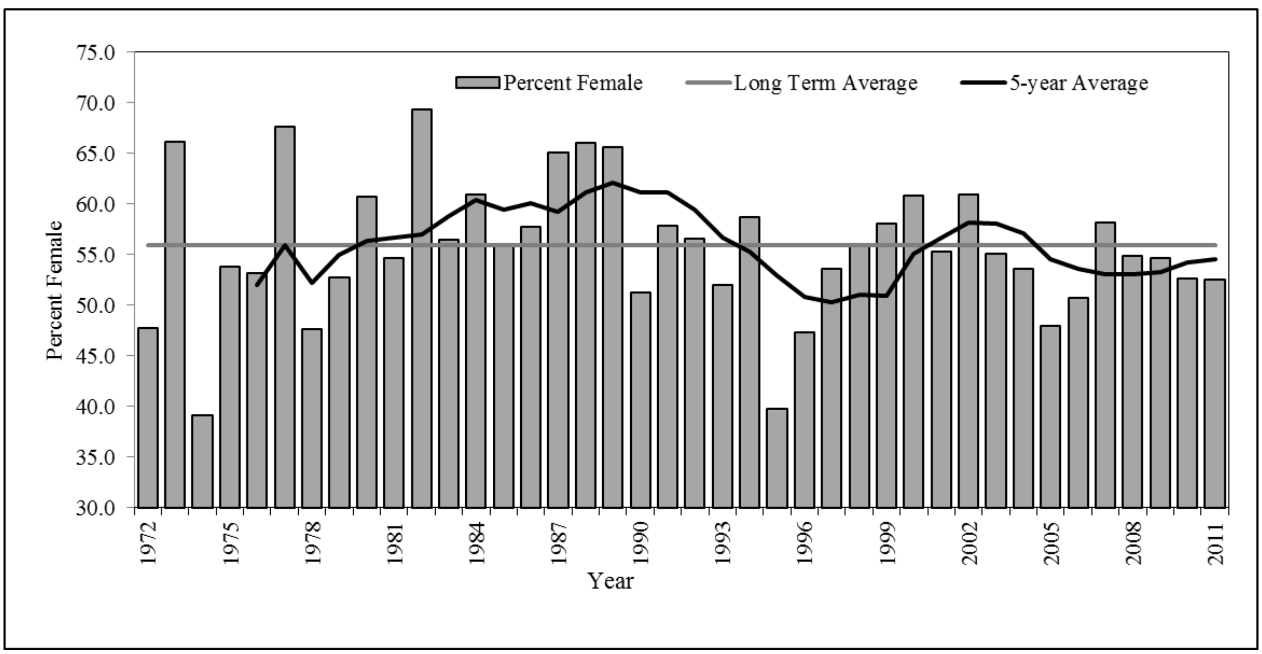


Figure 12.–Annual age at maturity (top) and percentage of females (bottom) of the Anvik River chum salmon escapement, 1972–2011.