Fishery Data Series No. 15-06

Sonar Estimation of Chum Salmon Passage in the Aniak River, 2011

by

Malcolm S. McEwen

March 2015

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

The Aniak River sonar project has provided daily fish passage estimates for most years since 1980. During this time, the project has undergone important modifications including a change from the original Bendix sonar to dual-beam in 1996 and to a high frequency imaging sonar (DIDSON) in 2004. In 2011, the project maintained the sampling schedule adopted in 2003 in which the sonar operated for 4-hour blocks 3 times a day (0000–0400, 0800–1200, and 1600–2000 hours). The Aniak River sonar project was operational from June 26 through July 31, 2011. During this period, an estimated 345,974 fish (SE 9,851) passed through the ensonified area, the majority of which were assumed to be chum salmon *Oncorhynchus keta*. The peak daily passage of 23,178 fish occurred on July 11, and the 50% passage date occurred on July 20. Age-0.2, -0.3, -0.4, and -0.5 chum salmon comprised 2.9%, 55.1%, 41.2% and 0.8% of the escapement estimate.

Key words: Aniak River, Kuskokwim River, chum salmon *Oncorhynchus keta,* DIDSON, hydroacoustic, sonar.

INTRODUCTION

HISTORY

The Kuskokwim River subsistence and commercial salmon fishery in June and July is directed toward the harvest of chum salmon *Oncorhynchus keta* and Chinook salmon *O. tshawytscha.* For the last 2 years Kuskokwim River chum salmon escapements have been average. From 1990 to 2011, an average of 70,000 chum salmon were harvested annually for subsistence purposes in the Kuskokwim area. The 2010 and 2011 subsistence harvest was 46,143 and 49,717 chum salmon. Exploitation from commercial harvest has been limited due to Chinook salmon conservation measures. In 2010 and 2011, a modest commercial harvest of 93,148 and 118,256 chum salmon was caught (Elison et al. 2012). No market existed for chum salmon in the Kuskokwim River fishery from 2001 to 2003, and only modest commercial fisheries were prosecuted from 2004 to 2010 (Brazil et al. 2011).

Timely estimates of run strength and escapement are important to management of the Kuskokwim River fishery. Based on past sonar escapement estimates and aerial survey indices of abundance, the Aniak River is believed to be one of the largest producers of chum salmon in the Kuskokwim River drainage (Francisco et al. 1995). Prior tagging studies have shown that chum salmon migrate from the upper end of District 1 to the Aniak River sonar site in about 7 or 8 days (ADF&G 1961, 1962). Because of the Aniak River's proximity to the Kuskokwim River commercial and subsistence fisheries (Figure 1), the Aniak River sonar project provides timely estimates of chum salmon passage.

The Aniak River sonar project began operating in 1980 and has undergone numerous changes in equipment and methodologies during this time. From 1980 to 1995, Aniak River escapement data were collected using an echo counting and processing transceiver manufactured by Bendix Corporation[1]. Data were collected with a single transceiver mounted on an 18.3 m artificial substrate located on the right bank and expanded to estimate total fish passage beyond the ensonified range (Schneiderhan 1989). Cumulative adjusted daily totals were subjectively estimated to be 150% of the actual count for the initial years of operation. Behavior of chum salmon observed during aerial spawning surveys of the Aniak River, and visual observations of fish migration patterns reported for the Anvik River (Buklis 1981), lead to the supposition that approximately two thirds of the run passed through the ensonified portion of the river. A second sonar counter was temporarily operated for a few days in 1984 to refine the expansion factor

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

applied to the daily counts (Schneiderhan 1985). The second counter was deployed 1.5 km downstream from the existing counter and alternately operated on each bank. The proportions between daily counts at the historical site and each bank of the downstream site over a 16-day period resulted in a new expansion factor of 162%. This expansion factor was used from 1984 through 1995 to readjust the counts from 1980 to 1983. In addition to the expansion of daily totals, sonar estimates were extrapolated for salmon escapement occurring before and after the operational period.

In 1996, the Aniak River sonar project was redesigned to provide full river ensonification with user-configurable sonar equipment operating 24 hours per day on both banks throughout the chum salmon migration. A new sonar data collection site was established 1.5 km downstream from the historical site. Seasonal sonar estimates were not extrapolated for salmon escapement before or after the operational period, and estimates represent a minimum escapement. Sonar operations from 1997 to 2002 remained essentially unchanged. During the winter of 2002, a variety of sonar sampling regimes were explored in order to reduce operational costs. It was found that a sampling schedule consisting of an alternating 4 hours on, followed by 4 hours off, presented the least overall error (±2.7%) with a moderate amount of daily variability. In 2003, instead of sampling 24 hours per day, the project implemented the alternating schedule (Sandall and Pfisterer 2006). Preparations to transition to a dual frequency identification sonar (DIDSON) were also initiated in 2003 (Sandall and Pfisterer 2006), and in 2004, the dual-beam system was replaced with the DIDSON. Sonar operations from 2004 through 2011 were consistent with the changes made in 2003 and 2004 (Sandall and Pfisterer 2006).

Comparison of counts made in 2003 using BioSonics and DIDSON equipment showed a density-dependent relationship, with the BioSonics estimates approximately 70% of those derived using DIDSON (Sandall and Pfisterer 2006). Using the density-dependent relationship, the fish estimates from 1980 to 2003 have been adjusted to equivalent DIDSON estimates (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication; Figure 2).

In the early 1980s, sonar counts were apportioned to chum or Chinook salmon using catch information from test gillnets. In 1986, the Chinook salmon apportionment objective was discontinued because test fishing techniques were ineffective at capturing adequate sample sizes (Schneiderhan 1988). A 1995 Aniak River sonar test fish feasibility study indicated that a species apportionment program was logistically feasible at the current site (Knuepfer 1995). The primary impediment to implementing such a program was a lack of funding. In response to extremely poor returns of chum and coho salmon in 1997 and 1998, the federal government made funds available (Western Alaska Fisheries Disaster) for Kuskokwim River salmon fisheries research and management (Fair 2000). In 2001 and 2002, through these funds, a new species apportionment feasibility study was conducted. This study attempted to determine if test fishing with gillnets could provide an acceptable method of apportioning sonar counts to fish species. The primary reason for discontinuing the study in 2003 was that it is not possible to drift gillnets in the areas of highest fish passage due to the river profile and snags. Additionally, similar to 2001, 82% of the overall catches were chum salmon (McEwen 2006). Given the consistently high proportion of chum salmon observed during the apportionment portion of the project, Alaska Department of Fish and Game (ADF&G) staff do not consider the small increase in the accuracy and precision of the estimates as adequate to continue the apportionment program considering the expense, difficulty, and unacceptable mortality associated with drift gillnetting.

Given the high proportion of chum salmon encountered in netting activities, sonar counts are considered representative of chum salmon escapement.

Although fish passage estimates were not apportioned by species, periodic net sampling was employed to monitor broad changes in species composition, corroborate acoustically detected abundance trends, and obtain chum salmon age, sex, and length (ASL) samples. From 1981 through 1985, attempts at beach seine test fishing and carcass sampling proved unsuccessful at obtaining adequate sample sizes for ASL determination. In 1986, ASL sampling activities were discontinued to decrease operating costs when it was noted that the Aniak River chum salmon ASL data were similar to the commercial catch results from the lower Kuskokwim River districts (Schneiderhan 1988). In 1996, beach seining procedures were reexamined, and a method was devised to provide large enough samples to estimate ASL for chum salmon and has been conducted annually since that year. ASL sampling continues to be an important component of the project.

Escapement objectives for the Aniak River have undergone a number of modifications since the project's inception. Salmon escapement objectives were tentatively set at 250,000 chum salmon and 25,000 Chinook salmon in 1981 and formally established in 1982. The chum salmon objective was derived subjectively by relating historical sonar passage estimates to trends in harvest and aerial survey indices (Schneiderhan 1982). In 1983, a review of the escapement objective based upon sonar estimates and other escapement indices suggested that the 1980–1981 Aniak River sonar estimates likely represented record escapements, and much smaller escapements would probably provide adequate future spawning stocks and a sustainable harvest (Schneiderhan 1984).

With the discontinuation of species apportionment in 1985, the sonar-based escapement objective was changed from species-specific objectives to 250,000 estimated fish counts (Schneiderhan 1985). After the implementation of the *Salmon Escapement Goal Policy* in 1992, the Aniak River escapement objective was termed a biological escapement goal (BEG; Buklis 1993). During the winter of 2003 and 2004, the Arctic-Yukon-Kuskokwim (AYK) escapement goal team recommended a sustainable escapement goal (SEG) of 210,000 to 370,000 chum salmon (ADF&G 2004). In 2007, the SEG was revised upward to 220,000 to 480,000 chum salmon (Brannian et al. 2006). The SEG is defined as a level of escapement, indicated by an index or an escapement estimate, that is known to provide for sustained yield over a 5- to 10-year period and is used in situations where a BEG cannot be estimated due to the absence of a stock-specific catch estimate (Brannian et al. 2006). A timetable of developmental changes for the sonar project is presented in Appendix A1.

OBJECTIVES

The objectives of the Aniak River sonar project are as follows:

1. Estimate chum salmon abundance in the Aniak River using DIDSON sonar from June 26 through July 31.
2. Collect a minimum of 210 chum salmon samples during each of 3 to 4 stratum throughout the season to estimate the age, sex, and length (ASL) composition of the Aniak River chum salmon passage, such that simultaneous 95% confidence intervals of age composition in each sample are no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$).

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

METHODS

SITE DESCRIPTION

The Aniak River sonar project site is located in Section 5 of T16N, R56W (Seward Meridian), approximately 19 km upstream from the mouth of the Aniak River on state land and permitted by Alaska Department of Natural Resources (DNR) permit # 13916. The main camp is situated at 61°30.163′N, 159°22.464′W (Figure 3). The Aniak River originates in the Aniak Lake basin about 145 km east and 32 km south of Bethel, Alaska. It flows north for nearly 129 km, where it joins the Kuskokwim River 1.6 km upstream from the community of Aniak.

The Aniak 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. Numerous bathymetric profile transects were conducted in the immediate vicinity of the sonar site, using a Lowrance model X-16 chart recording fathometer to determine the best location to deploy the sonar transducers. As in 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 left bank river bottom slopes gradually to the thalweg at roughly 63–68 m, while the right bank river bottom slopes steeply to the thalweg at about 17–22m, depending on water level.

HYDROACOUSTIC DATA ACQUISITION

Equipment

At the Aniak sonar site, 2 DIDSON units were deployed, 1 for each bank. The sonar units operate at 1.1 MHz on the right bank and 1.2 MHz on the left bank. The left-bank DIDSON was mounted on an aluminum tripod and manually aimed. The right-bank DIDSON was mounted on an aluminum tripod and remotely aimed with a set of HTI rotators allowing movement in 2 axes. A Remote Ocean Systems model pan and tilt control unit was connected to the rotators and provided horizontal and vertical positioning accurate to within ±0.3º.

Each DIDSON was controlled by a laptop computer running version 5.11 of the DIDSON software to acquire data. 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 between the topside box and a laptop computer. A RAID enclosure was connected to the laptop (Figure 4) for saving all data. The enclosure was configured as RAID 1, allowing redundant copies of the data on 2 separate hard drives within the enclosure in the event a mechanism failed.

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

Transducer Deployment

The transducers were attached to an aluminum tripod 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 7–12 m from the right bank and 15–20 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 width of the river (76%–80% depending on water level) was ensonified by sampling both the right and left banks out to 20 m.

Partial weirs were erected perpendicular to the current and extended from the shore 1–3 m beyond the transducers. These weirs moved chum salmon, Chinook salmon, and other large fish offshore and in front of the transducers, preventing 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 (longnose sucker *Catostomus catostomus*, whitefish *Coregonus* spp., and rainbow trout *O. mykiss*).

Sampling Procedures

Sonar project activities commenced on June 26 and ended on July 31, 2011. Hydroacoustic sampling began on June 26 at 1000 hours on the right bank and on June 28 at 0000 hours on the left bank and ran every day until 2000 hours on July 31. Daily estimates were transmitted via internet or satellite phone to area managers in Bethel at 0730 hours the following morning.

Acoustic sampling was conducted 3 times a day in 4-hour shifts on each bank, 7 days per week, except for short periods when the generator was serviced or transducer adjustments were made. This sampling was consistent with changes made during the 2003 and 2004 field seasons but was a significant change from seasons prior to 2003, when sampling occurred 24 hours per day. Three fishery technicians operated and monitored equipment at the sonar site while rotating through shifts (1 person per shift) occurring at 0000–0400, 0800–1200, and 1600–2000 hours. The technicians identified and tallied fish traces from the echogram recordings using software developed in house (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). All fish were counted except for very small fish, which are assumed not to be salmon. The number of fish traces were then summed over 15-minute periods and recorded onto forms. Completed data forms were entered into a spreadsheet and checked by the crew leader. All data were saved to the RAID drive in 15-minute intervals during the 4-hour shift for later review as an echogram and/or video. All 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 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.

Equipment Settings

The DIDSON is a high frequency, multi-beam sonar with a unique acoustic lens system designed to focus the beam to create high-resolution images. Sound pulses were generated by the sonar at center frequencies of 1.1 MHz for the standard DIDSON operated on the right bank and 1.2 MHz for the long-range DIDSON used on the left bank. DIDSON simultaneously transmits on and then receives from every fourth beam. Images or frames are built in sequences of these sets of pings. At the frequencies utilized, 48 beams (4 sets of 12) 0.6° apart from each other on a horizontal plane are composited to form the image. The right bank and left bank both sampled at a range from 0.83 m to 20 m and a rate of 4 frames per second.

ANALYTICAL METHODS

Abundance Estimation

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

$$r_{dzp} = \frac{\sum_{s=1}^{16} y_{dzps}}{4}, \tag{1}$$

where the rate is calculated by summing the 16 individual 15-minute observations *s*, collected during the 4-hour sample period and dividing by the total number of hours. The average hourly passage rate for the day $\hat{r}_{dz}$ is then estimated from the passage rates for the 3 periods,

$$\hat{r}_{dz} = \frac{\sum_{p=1}^{3} r_{dzp}}{3}. \tag{2}$$

Finally, the daily passage for bank *z* is estimated by multiplying the average hourly passage rate by 24 (the number of hours in the day):

$$\hat{y}_{dz} = 24\hat{r}_{dz}. \tag{3}$$

The total daily passage is estimated by adding the daily passage for both banks. Note that the same result is obtained by summing all of the individual 15-minute samples collected in a 24-hour period and multiplying by the reciprocal of the fraction of the day sampled (i.e., 24/12 = 2).

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 follows:

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

where n_{dz} is the number of periods sampled in the day (3), and f_{dz} is the fraction of the day sampled (12/24 = 0.5). Finally, since the passage estimates are assumed independent between zones and among days, the total variance was estimated as the sum of the variances:

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

Missing Data

Depending on the amount of time that was missed, the crew used different methods to make up for incomplete or missing counts.

If less than 10 minutes were missed in a sample, the count was expanded by the inverse of the fraction sampled:

$$\hat{y}_s = x_s\left(15 / m_c\right), \tag{6}$$

where 15 is the number of minutes in a complete sample, m_c is the number of minutes in the sample that were actually counted, and x_s is the number of fish counted.

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

$$\hat{y}_s = \left(1/n\sum_{i=1}^{n} x_i\right)\begin{Bmatrix} s = 1, n = 4 \\ s = 2, n = 6 \\ s = 3, n = 8 \end{Bmatrix}, \tag{7}$$

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 was then used to calculate missing fish counts for each missing sample s:

$$\hat{y}_s = a + bx_s, \tag{8}$$

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.

ASL Sampling

Equipment and Procedures

The gravel bar just upstream and on the opposite bank from the sonar camp was used as the sampling site over the past several years. Prior to 2003, the gravel bar in front of camp was used for collecting ASL samples, but this site became unusable due to snags. In recent years the gravel bar just upstream has been used exclusively because it has few snags, which allows the net to drift smoothly and has led to more efficient sampling. The crew fished a 3 m by 46 m (10 ft by 150 ft) green 7.0 cm mesh beach seine to obtain ASL samples from chum salmon. After attaching a 30 m line to 1 end of the seine, the seine was stacked in a plastic fish tote and placed in the stern of a skiff. The crew attached the opposite end of the seine to a pulley designed to pivot from the side of the skiff from the bow to the stern. As the skiff moved offshore, oriented upstream, the end of the 30 m lead was held in place by a crew member on shore. The skiff moved straight offshore until all of the lead line was deployed and the seine started to peel out of the tote. The driver maneuvered the skiff upstream and inshore, deploying the entire length of the seine. When the skiff reached the shore, the seine was released from the pulley and allowed to drift downstream while the crew guided it next to the shore. The lead was pulled in just enough to form a hook shape to the offshore end of the seine. The crew drifted the entire seine in this formation for approximately 100 m before the lead line was pulled in to close the set.

All captured fish except chum salmon were tallied by species, fin clipped, recorded, and released. Chum salmon were placed in a live box for sampling and 1 scale was taken from the preferred area of each chum salmon for use in age determination (INPFC 1963). Scales were wiped clean and mounted on gum cards. Sex was determined by visually examining external morphological characteristics, such as kype development, roundness of the belly, and the presence or absence of an ovipositor. Length was measured to the nearest 5 mm mid eye to tail fork. Fish that were sampled had the adipose fin clipped so that they were not sampled twice if recaptured. All measurements were recorded in a Rite in the Rain® notebook and later transcribed to standard mark–sense forms.

The crew followed a systematic sampling design whereby intensive sampling was conducted 3 days each week (Monday, Tuesday, and Thursday, or until the sample size goal of $n = 210$ was reached). The sampling goal of $n = 210$ was set such that simultaneous 95% confidence intervals of age composition in each weekly period were no wider than 0.20 ($\alpha = 0.05$ and $d = 0.10$) (Molyneaux and Dubois 1996). All scales and ASL data were sent to the ADF&G Bethel office for analysis by research staff.

To estimate the age and sex composition of chum salmon escapement in the Aniak River, daily passage estimates were temporally stratified to correspond with ASL sampling periods. Within each stratum, estimates of age and sex composition were applied to the sum of the chum salmon passage to generate an estimate of the number of fish in each age-sex category. The number of fish was then summed by age-sex category over all strata to estimate the total season passage.

ENVIRONMENTAL MEASUREMENTS

Water temperature was measured at the sonar site using a HOBO water temperature logger, which electronically recorded the temperature every hour on the hour. The data were downloaded to a laptop computer at the end of the season. At the main camp, the air temperature was recorded several times each day from a digital thermometer, and general weather and wind direction was noted. The crew used a staff gage to measure the water level. The benchmark, located at the sonar site, degraded and became unusable in 2002; consequently, readings are not comparable across years.

RESULTS

FISH PASSAGE ESTIMATES

During the 2011 season, 345,974 (SE 9,851) fish are estimated to have passed the sonar site. Of those, 40.0% passed on the left bank and 60.0% passed on the right bank (Table 1). Daily passage rates by bank along with cumulative season estimate were calculated (Figure 5). The peak total daily passage of 23,178 occurred on July 11 (Table 1). The 25%, 50%, and 75% quartile dates of passage were July 12, July 20, and July 25, respectively. The 2011 run was 4 to 6 days later than the historical median (Figure 6).

MISSING DATA

A total of 2.5 hours on the left bank and 1.2 hours on the right bank of sampling time were missed because of maintenance, system diagnostic tests, moving the tripod, or aiming the transducer to compensate for changing water levels throughout the season.

ASL SAMPLING

A total of 14 beach seine sets were completed, and, from these, 480 ASL samples from migrating chum salmon were obtained. Of those samples, 379 scales were analyzed postseason. Because of the low number of samples, it was not possible to stratify as planned. ASL estimates were computed using a single stratum, with 55.1% falling in the age-0.3 class, 41.2% falling in the age-0.4 class, 2.9% falling in the age-0.2 class, and 0.8% falling in the age-0.5 class (Table 2). Female chum salmon accounted for 49.1% of the overall run.

ENVIRONMENTAL INFORMATION

Climate and River Measurements

Water levels steadily went down for most of the season due to sunny, clear conditions. Late in the season, rain caused the water level to remain steady until the end of the season (Figure 7). Daily air temperatures fluctuated between -1.3°C (July 4) and 25.5°C (July 22) over the project operational period (Figure 8). Water temperatures fluctuated between 7.9°C (June 29 and July 18) and 12.5°C (July 28 to July 29) (Figure 9). The average water and air temperature over the operational period of the project was 10.2°C and 11.8°C, respectively.

DISCUSSION

When staff arrived at the sonar site in late June, the water level was high but caused no delay in sonar deployment. The right bank sonar was operational on June 26, but the left bank sonar deployment was delayed 2 days until June 28 because of a mechanical problem. The ASL sampling was delayed until in the middle of July due to construction projects. This was the final year of the Aniak sonar project; the project has been discontinued and has been replaced by the Salmon River weir project to obtain escapement information on Chinook, coho, and sockeye salmon in addition to chum salmon.

FISH PASSAGE ESTIMATES

We were able to meet Objective 1 of collecting fish abundance data using sonar. The estimated passage of 345,974 was below the long-term 16-year average (415,239, 1996–2011) and the running 5-year average (512,661, Figure 10). The fish count was the lowest in the last 10 years

(Figure 2). Similar to 2002 through 2008 and 2010, the 2011 daily passage estimates followed a roughly sinusoidal pattern with peaks separated in time by 2 or 3 days (Figure 5). The estimated passage of 345,974 fell within the SEG range of 220,000 to 480,000 chum salmon for the Aniak River.

ASL Sampling

We did not meet the ASL data collection objectives in 2011. Construction of a new sonar platform delayed the start of ASL sampling, and due to the delay, we were not able to obtain sufficient samples for the first temporal strata, which is typically the first 35.5% (June 26–July 15) of the chum salmon run. This resulted in only enough samples for a single stratum. During the 6 days that ASL sampling took place (July 16 to July 27), approximately 177,025 salmon passed by the sonar. For the period from July 16 to July 31, a total of 223,183 salmon passed by the sonar. Given that the majority of the fish in the later portion of the run occurred during the ASL sampling period, the single stratrum likely represents this portion of the run reasonably well. It may not be reasonable to assume these samples accurately represent the run prior to July 16, which is approximately 35% of the run. While the age distribution of the catch in 2011 did not exhibit any anomalies, we do not have a full picture of the run due to the delay in sampling. As in past years, the 2011 chum salmon run was predominantly age-0.3 (55.1%) and age-0.4 (41.2%) fish, which is consistent with the past 10 years where these 2 age classes have comprised between 94% and 99% of the overall run (Figure 11). The exception was 2004 when a strong age-0.2 class returned and only 75% of the run were ages 0.3 and 0.4. There are no discernable trends in the age-0.3 and -0.4 classes over the past 11 years. The percentage of age-0.3 fish has been higher than age-0.4 fish in all years except 2008, and these 2 age classes were similar in 2004 and 2011 (Figure 11). Female chum salmon accounted for 49.1% of the overall run to the Aniak River in 2011, very close to the recent 6-year average of 50.5%. Although the percentage of females was very high in the age-0.2 class (92.0%), over the past 11 seasons this has generally been the case, with the only exceptions occurring 2003 and 2004 when males slightly dominated the age-0.2 class. Given this historical trend of a high proportion of females in the age-0.2 class, we do not doubt the accuracy of sex determination as the proportion has been consistently high across many changes of personnel.

Environmental Information

We were able to meet Objective 3, monitoring selected climatic and hydrological parameters daily at the project site. When we arrived, the water level was moderate to high, but we were able to install the water height gage and electronic water temperature sensors in a timely fashion. Water levels steadily went down through the first half of the season. Due to rain (mostly in the headwaters), water levels remained steady/unchanged during the second half (Figure 7) of the season. Over the last 5 years, water levels have varied on the Aniak River. In 2009, heavy rains in late July caused the river to rise precipitously to well above the level observed when we arrived. In 2006, there was no change in water level for the season, and water level trends in 2007, 2008, and 2010 were similar to this year. The average water temperature of 10.2°C in 2011 was colder than the 10-year (2001–2010) average water temperature of 12.2°C (Figure 12). The minimum (7.9°C) and maximum (12.5°C) temperatures for this year were within the range for the past 10 years of 8.0°C and 21.6°C. The average air temperature of 11.8°C in 2011 was similar compared to the 10-year (2001–2010) average air temperature of 11.7°C (Figure 13). The minimum air temperature (-1.3°C) was colder than observed in the previous 10 seasons, while the maximum (25.5°C) was generally lower than the previous 10-year maximum.

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REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 1961. Kuskokwim River salmon tagging studies, 1961. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kuskokwim Salmon Stock Separation Report No. 1, Anchorage.

ADF&G (Alaska Department of Fish and Game). 1962. Kuskokwim River salmon tagging studies, 1962. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kuskokwim Salmon Stock Separation Report No. 2, Anchorage.

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

Brannian, L. K., M. J. Evenson, and J. R. Hilsinger. 2006. Escapement goal recommendations for select Arctic-Yukon-Kuskokwim region salmon stocks, 2007. Alaska Department of Fish and Game, Fishery Manuscript No. 06-07, Anchorage.

Brazil, C., D. Bue, H. Carroll, and T. Elison. 2011. 2010 Kuskokwim area management report. Alaska Department of Fish and Game, Fishery Management Report No. 11-67, Anchorage.

Buklis, L. S. 1981. Yukon River salmon studies. Project No. AFC-63-4, Anadromous Fish Conservation Act. NOAA National Marine Fisheries Service. Technical report for period July 1, 1980 to June 30, 1981, Anchorage.

Buklis, L. S. 1993. Documentation of Arctic-Yukon-Kuskokwim region salmon escapement goals in effect as of the 1992 fishing season. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 3A93-03, Anchorage.

Elison, T. B., K .L. Schaberg, and D. J. Bergstrom. 2012. Kuskokwim River salmon stock status and Kuskokwim area fisheries, 2012; a report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Special Publication No. 12-27, Anchorage.

Fair, L. 2000. Aniak River sonar project report, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A00-10, Anchorage.

Francisco, K. R., C. A. Anderson, C. Burkey Jr., M. Fogarty, D. B. Molyneaux, C. Utermohle, and K. Vaught. 1995. Annual management report for the subsistence and commercial fisheries of the Kuskokwim Area, 1994. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A95-15, Anchorage.

INPFC (International North Pacific Fisheries Commission). 1963. Annual report, 1961. Vancouver, British Columbia.

Knuepfer, G. 1995. Aniak River sonar test fishing feasibility report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A95-34, Anchorage.

McEwen, M. S. 2006. Sonar estimation of chum salmon passage in the Aniak River 2002. Alaska Department of Fish and Game, Fishery Data Series No. 06-33, Anchorage.

REFERENCES CITED (Continued)

Molyneaux, D. and L. Dubois. 1996. Salmon age, sex and length catalog for the Kuskokwim area, 1995 progress report. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report 3A96-31, Anchorage.

Pfisterer, C. T. 2002. Estimation of Yukon River salmon passage in 2001 using hydroacoustic methodologies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-24, Anchorage.

Sandall, H., and C. T. Pfisterer. 2006. Sonar estimation of chum salmon passage in the Aniak River, 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-32, Anchorage.

Schneiderhan, D. J. 1982. 1982 Aniak River sonar studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kuskokwim Escapement Report No. 26, Anchorage.

Schneiderhan, D. J. 1984. 1983 Aniak River sonar studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, AYK Region, Kuskokwim Escapement Report No. 32, Anchorage.

Schneiderhan, D. J. 1985. 1984 Aniak River sonar studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Kuskokwim Escapement Report No. 36, Anchorage.

Schneiderhan, D. J. 1988. Aniak River salmon escapement study, 1985-1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A88-17, Anchorage.

Schneiderhan, D. J. 1989. Aniak River salmon escapement studies, 1989. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A89-23, Anchorage.

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

TABLES AND FIGURES

Table 1.–Daily and cumulative fish passage estimates for left and right banks, percent passage for left and right banks, and cumulative passage, Aniak River sonar, 2011

Date	Left bank	Right bank	Daily total	Cumulative total	Cumulative percent passage
26 Jun	0	158	158	158	0.0%
27 Jun	0	544	544	702	0.2%
28 Jun	265	380	645	1,347	0.4%
29 Jun	266	300	566	1,913	0.6%
30 Jun	285	406	691	2,604	0.8%
1 Jul	698	716	1,414	4,018	1.2%
2 Jul	1,365	1,458	2,823	6,841	2.0%
3 Jul	2,093	2,806	4,899	11,741	3.4%
4 Jul	1,348	2,160	3,508	15,249	4.4%
5 Jul	1,236	1,906	3,142	18,391	5.3%
6 Jul	2,116	4,646	6,762	25,153	7.3%
7 Jul	1,430	2,378	3,808	28,961	8.4%
8 Jul	2,945	3,574	6,519	35,480	10.3%
9 Jul	2,582	7,598	10,180	45,660	13.2%
10 Jul	3,710	5,304	9,014	54,674	15.8%
11 Jul	9,030	14,148	23,178	77,852	22.5%
12 Jul	4,237	8,572	12,809	90,661	26.2%
13 Jul	8,442	10,370	18,812	109,473	31.6%
14 Jul	2,632	4,428	7,060	116,533	33.7%
15 Jul	2,379	3,878	6,257	122,790	35.5%
16 Jul	3,228	4,738	7,966	130,756	37.8%
17 Jul	6,402	12,352	18,754	149,510	43.2%
18 Jul	3,425	8,482	11,907	161,417	46.7%
19 Jul	2,094	2,634	4,728	166,145	48.0%
20 Jul	10,026	12,107	22,133	188,278	54.4%
21 Jul	4,948	10,140	15,088	203,366	58.8%
22 Jul	5,574	4,244	9,818	213,184	61.6%
23 Jul	9,220	13,356	22,576	235,759	68.1%
24 Jul	4,256	7,286	11,542	247,301	71.5%
25 Jul	6,768	6,274	13,042	260,343	75.2%
26 Jul	9,362	12,388	21,750	282,093	81.5%
27 Jul	9,522	8,200	17,722	299,815	86.7%
28 Jul	4,838	7,484	12,322	312,137	90.2%
29 Jul	6,399	11,402	17,801	329,939	95.4%
30 Jul	2,886	6,490	9,376	339,315	98.1%
31 Jul	2,597	4,062	6,659	345,974	100.0%
Season total	138,605	207,369	345,974		

Note: The bounding box indicates the central 50% of the run (second and third quartiles). Historical median passage date is 12 July.

Table 2.–Age and sex composition of chum salmon, Aniak River sonar, 2011.

			Age									
			0.2		0.3		0.4		0.5		Total	
Date	Sample size	Sex	Number fish	%	Number fish	%	Number fish	%	Number fish	%	Number fish	%
July 16, 17, 20, 21, 24, 27	379	Male	518	8.0	64,070	52.0	48,833	53.0	0	0.0	113,600	50.9
(7/16–31)		Female	5,954	92.0	58,903	48.0	43,118	47.0	1,785	100.0	109,583	49.1
		Subtotal	6,472	2.9	122,974	55.1	91,951	41.2	1,785	0.8	223,183	100.0

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

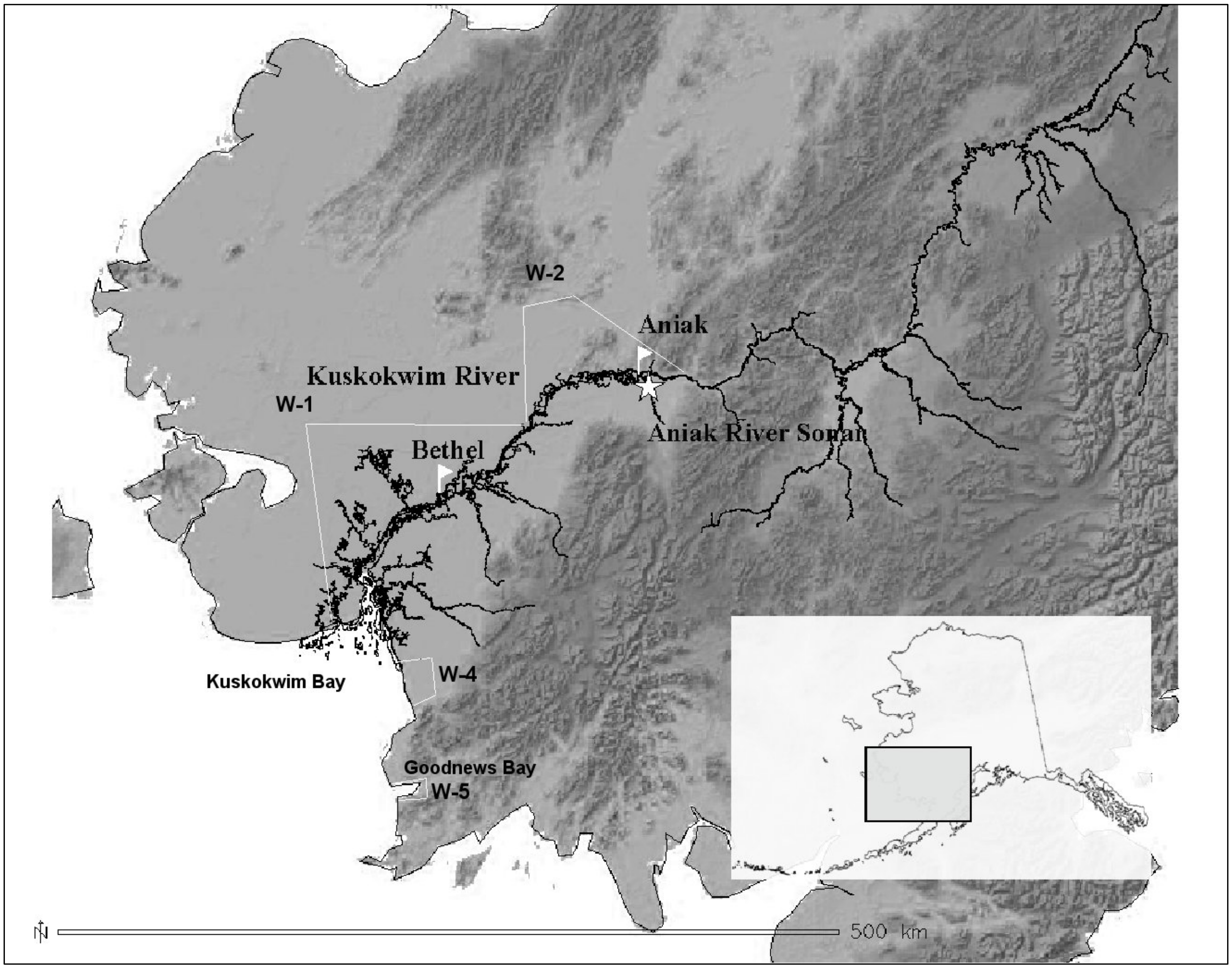

Figure 1.–Kuskokwim River Area, with lower river fishing districts (W-1, W-2, W-4, W-5) delineated.

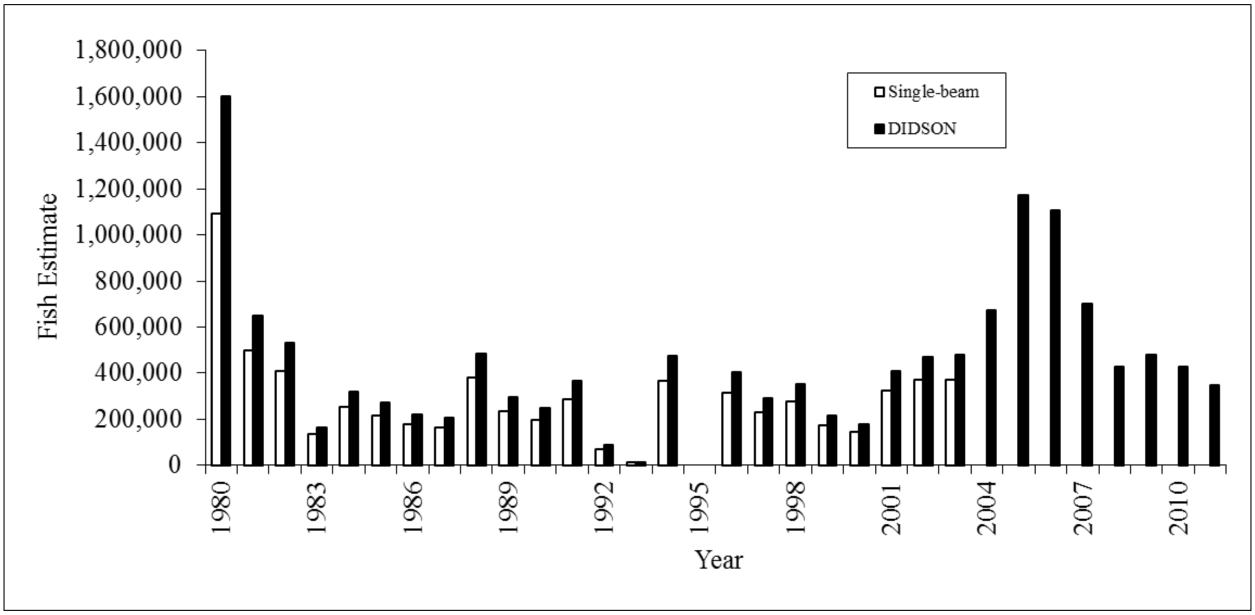

Figure 2.–Historical sonar passage from 1980 to 2011, Aniak River sonar.

Note: From 1980 to 1994 Bendix sonar was used; from 1996 to 2003 BioSonics sonar was used. Bendix and BioSonics sonar counts from 1980 to 1994 and 1996 to 2003 were adjusted to DIDSON equivalent. No data were collected in 1995.

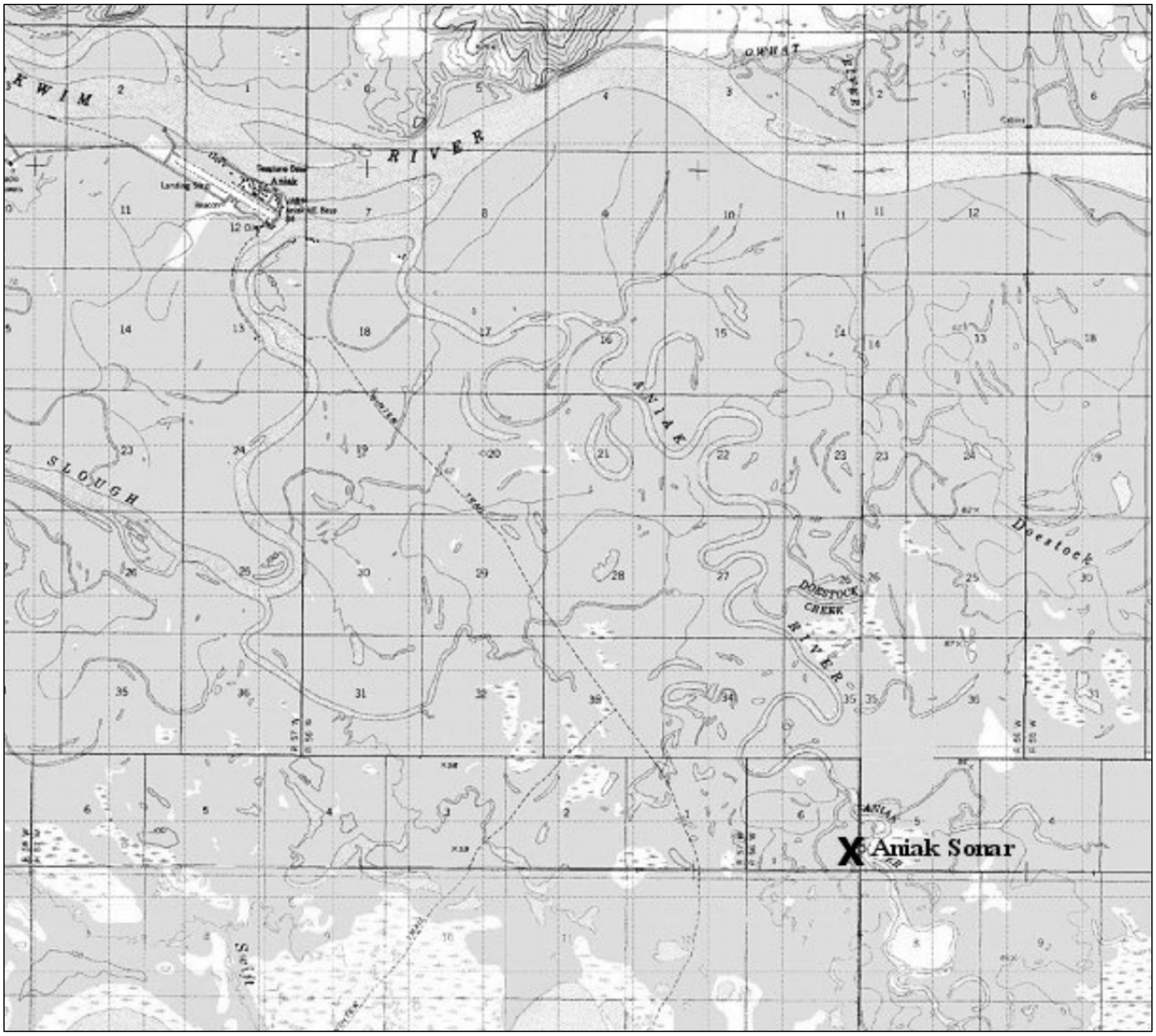

Figure 3.–Location of Aniak River sonar site, 2011.

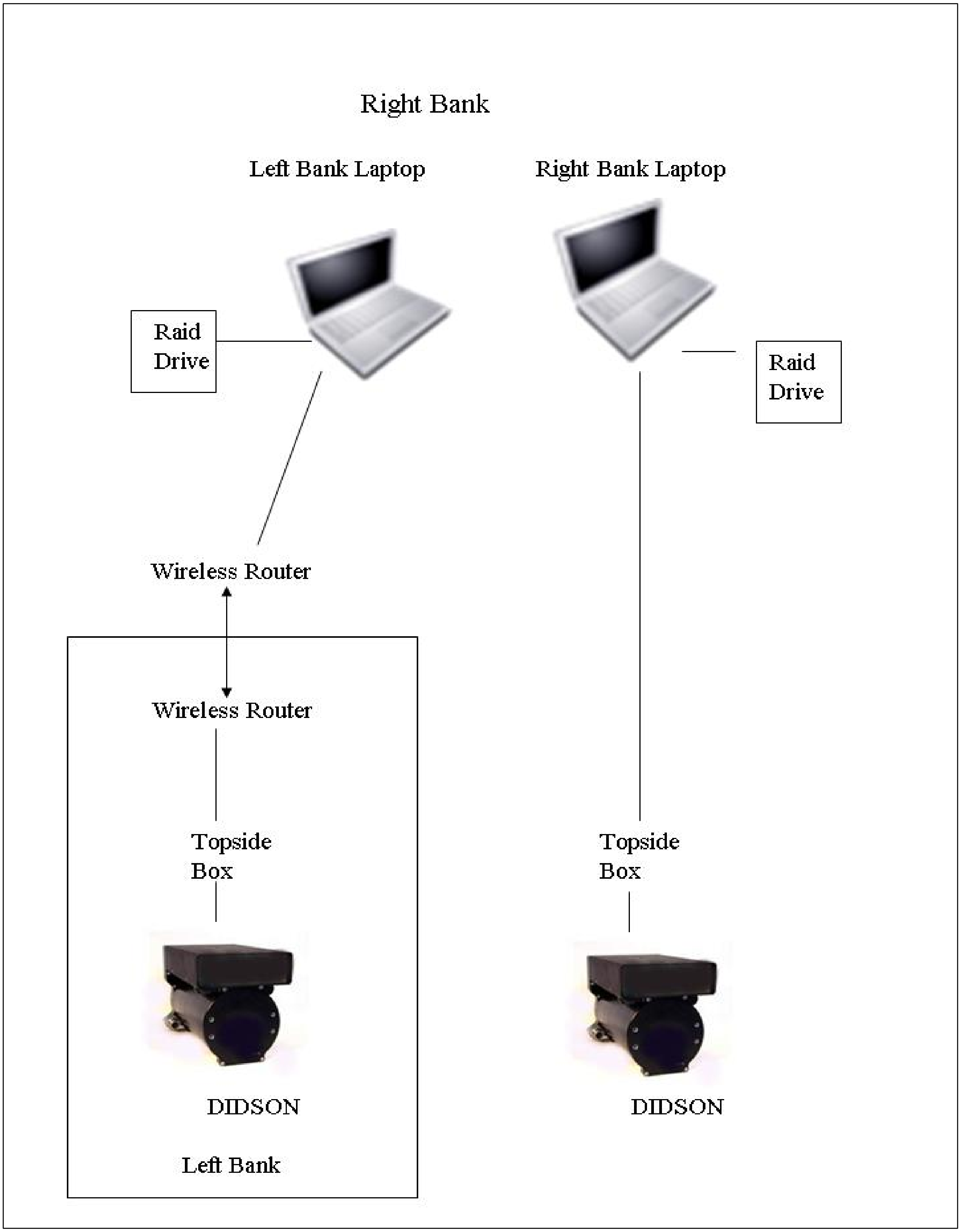

Figure 4.–DIDSON sonar equipment schematic, Aniak River sonar, 2011.

Note: Both the left-bank and right-bank laptops were housed in the right-bank sonar tent.

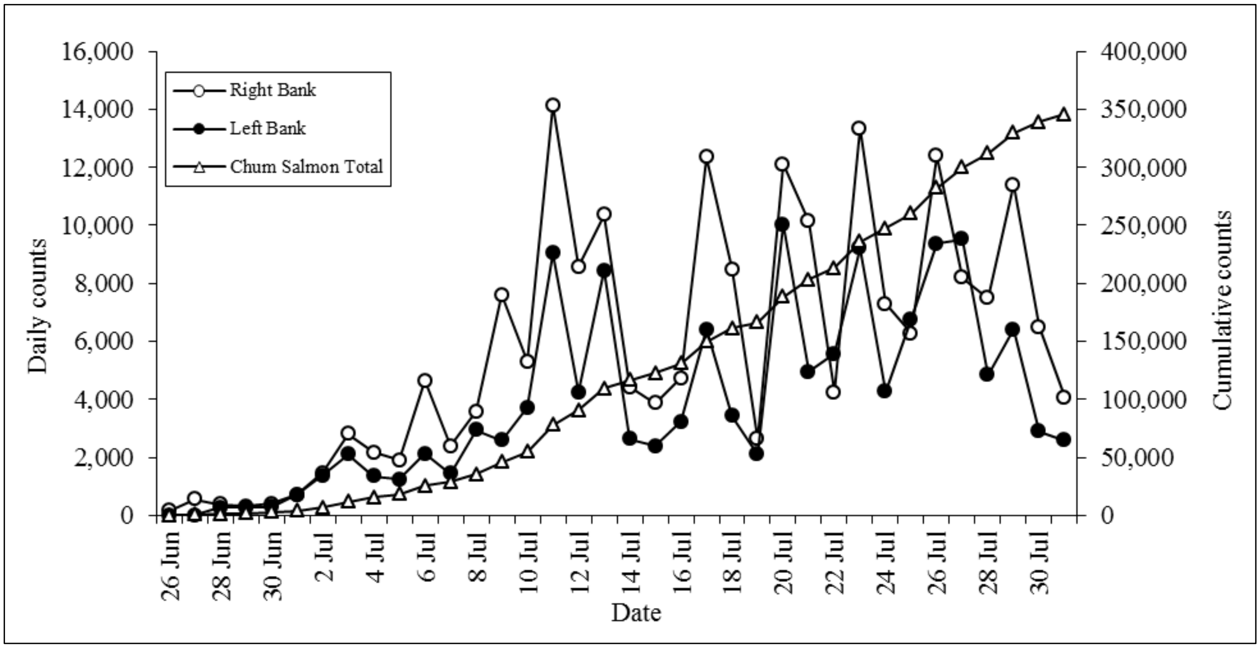

Figure 5.–Daily passage estimates on left bank and right bank and cumulative passage estimates for chum salmon at Aniak River sonar, 2011.

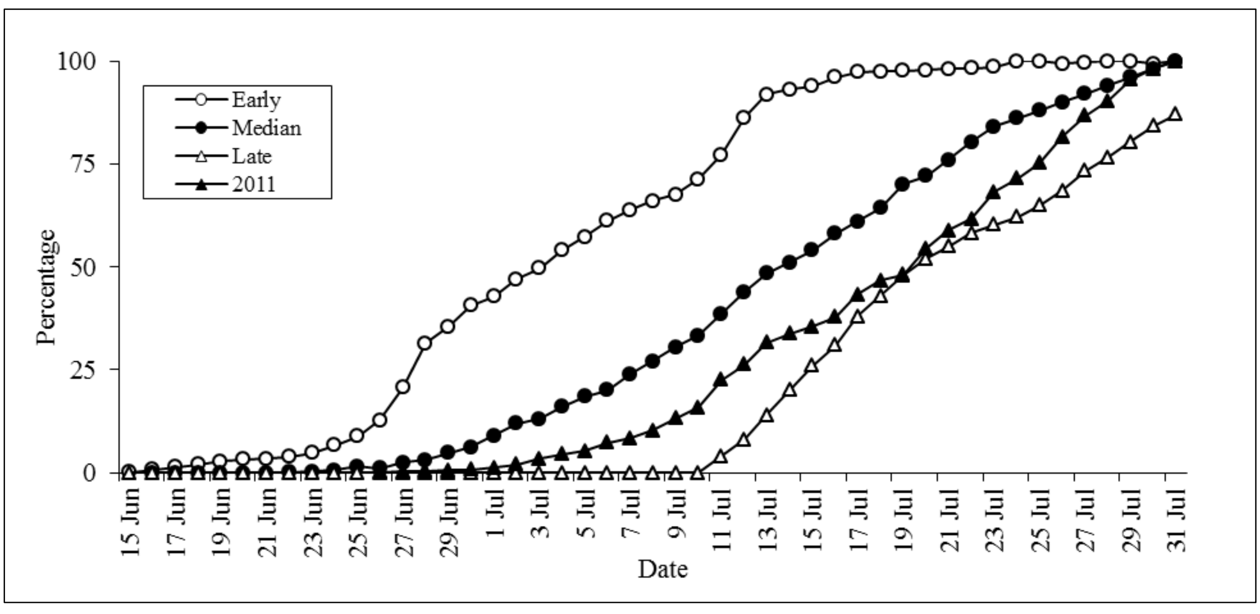

Figure 6.–Historical run timing at the Aniak River sonar, 1980–2011.

Note: Early, late, and median values were derived from the maximum, minimum, and median cumulative percentages across all years.

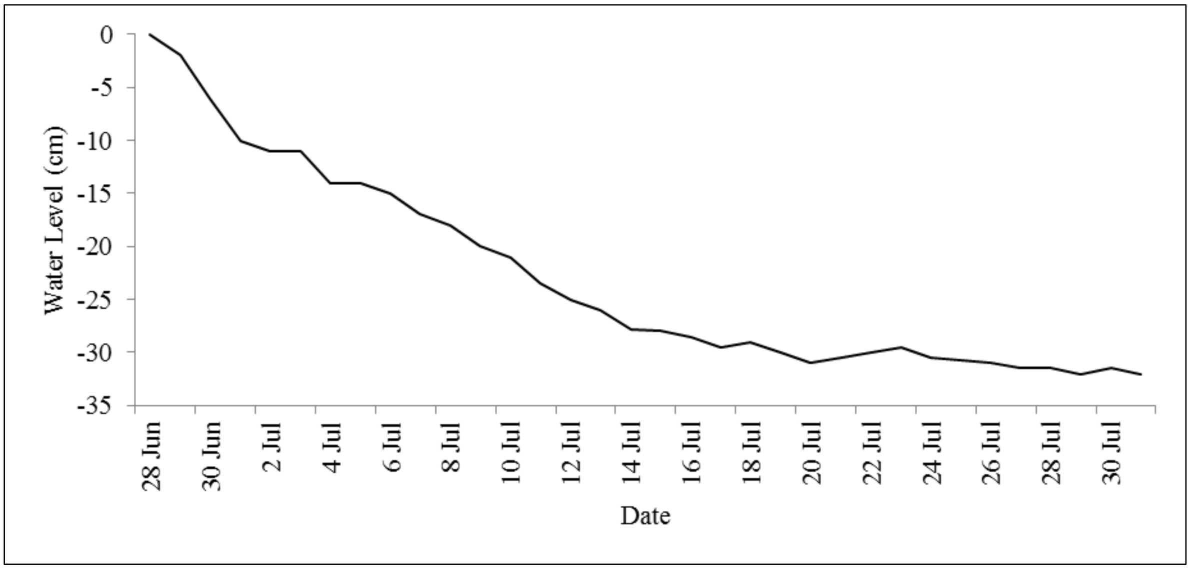

Figure 7.–Water level, Aniak River sonar, 2011.

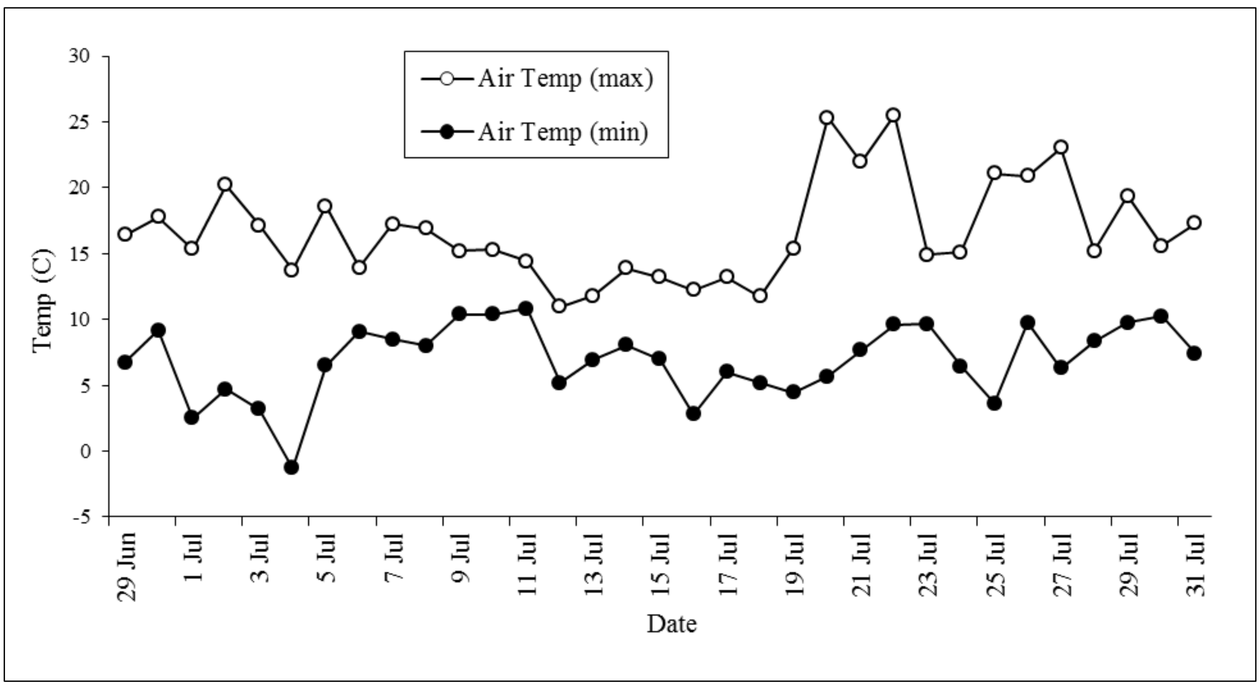

Figure 8.–Air temperature, Aniak River sonar, 2011.

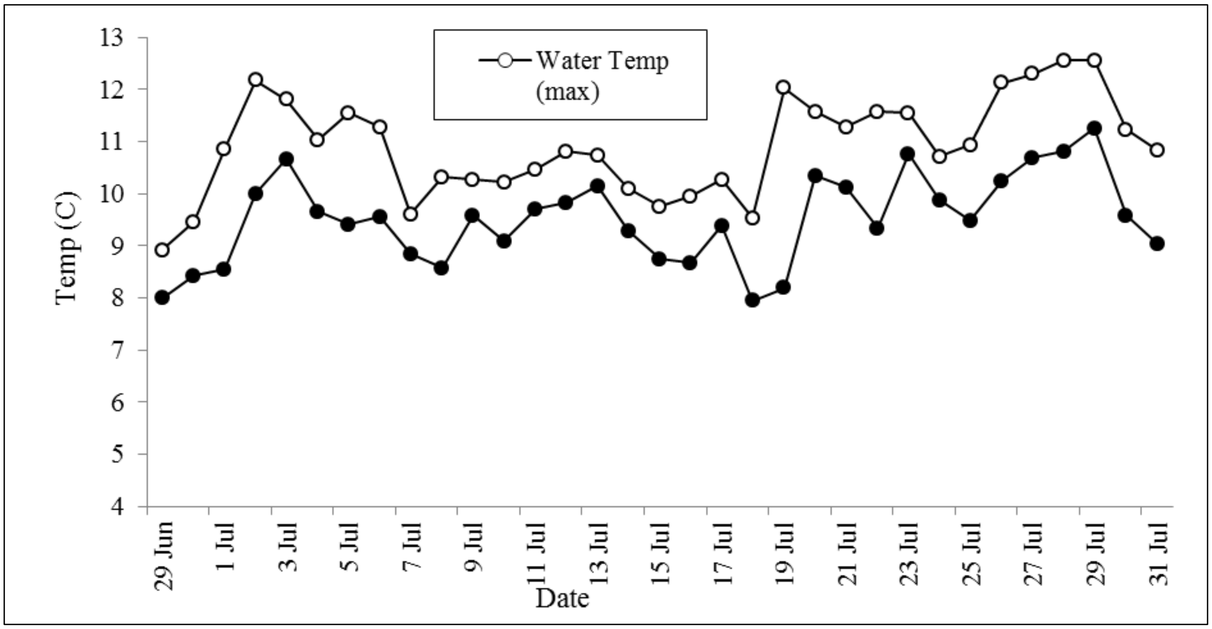

Figure 9.–Water temperature, Aniak River sonar, 2011.

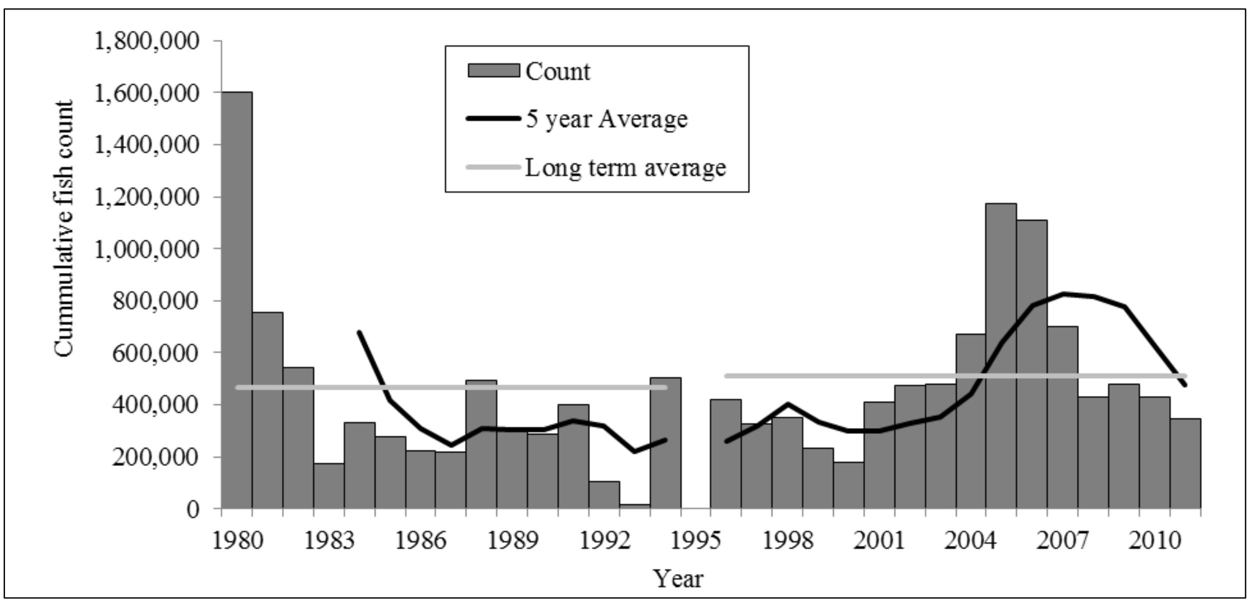

Figure 10.–Corrected historical passage with running average at the Aniak River sonar project, 1980 to 2011.

Note: No data were collected in 1995.

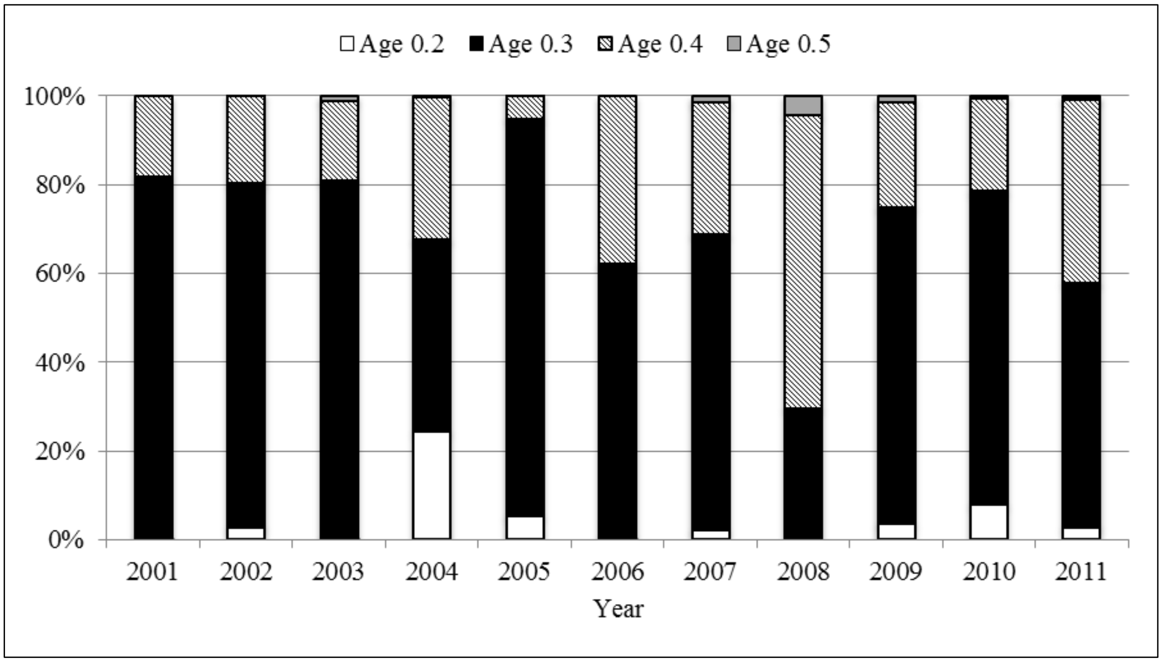

Figure 11.–Historical age composition at the Aniak River sonar project, 2001 to 2011.

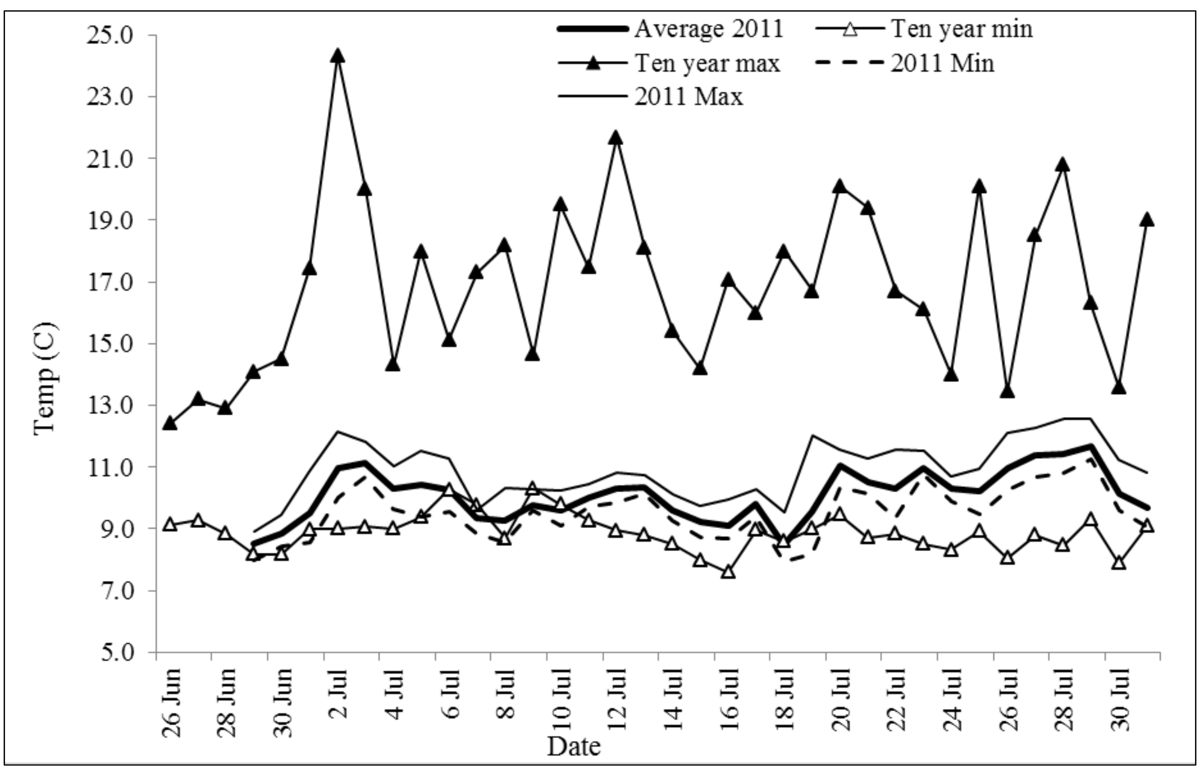

Figure 12.–Historical water temperature compared with 2011 data, Aniak River.

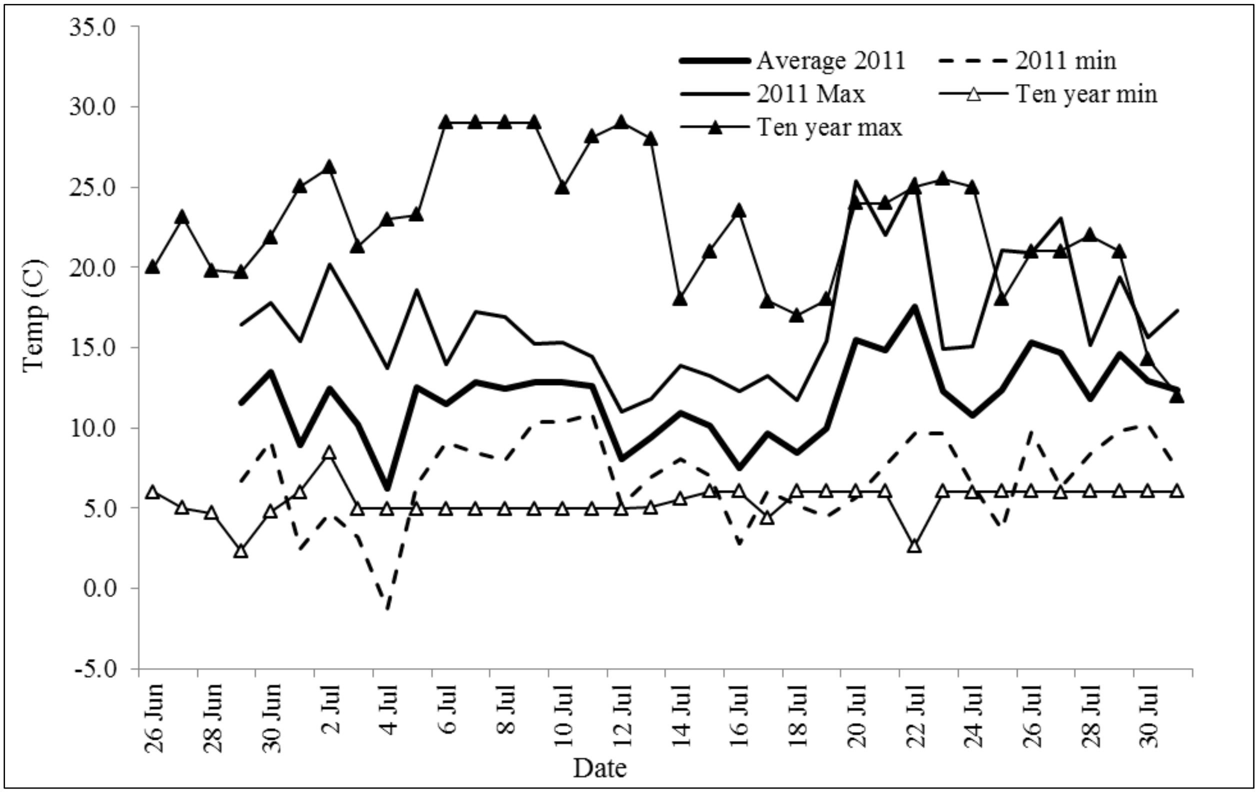

Figure 13.–Historical air temperature compared with 2011 data, Aniak River.

APPENDIX A: PROJECT HISTORY

Appendix A1.–Timetable of developmental changes of the Aniak River sonar project, 1980–2011.

Year	Event
1980	• Aniak River sonar project established • 1978 model, non-configurable Bendix sonar counter used with 60 ft. artificial substrate • Single bank operation (1980–1995) • Cumulative adjusted daily sonar estimates expanded by 150% to account for salmon passing outside the ensonified area • Sonar estimates are extrapolated for pre- and post-season salmon escapement (1980–1982, 1985–1989, and 1991–1996) • Gillnet test fishing to provide species apportionment and ASL information • Three correction factor calibrations per day averaged to adjust daily estimates
1981	• 1981 model, non-configurable Bendix sonar counter used with 60 ft artificial substrate • A tentative escapement goal of 250,000 chum and 25,000 Chinook salmon is established for the Aniak River • Gillnet and beach seine test fishing to provide species apportionment and ASL information
1982	• Sonar equipment unchanged • Escapement goals for AYK Region updated; 250,000 chum and 25,000 Chinook salmon escapement goal is established for the Aniak River • Gillnet test fishing to provide species apportionment and ASL information • Four correction factor calibrations applied to 6 hour time periods to adjust daily estimates
1983	• Sonar equipment unchanged • Review of escapement goal based upon sonar estimates indicated 1980–1981 Aniak River • Sonar estimates likely represented unusual record escapements, and much smaller escapements would probably provide adequate future spawning stocks as well as catches for user groups • Goal remains 250,000 chum and 25,000 Chinook salmon • Sonar estimates are not extrapolated for preseason and postseason salmon escapement (1983–1984, 1990, 1996–1997)
1984	• Sonar equipment unchanged • No apportionment of estimates made due to insufficient test gillnets catches • In the absence of sufficient species apportionment data, the sonar based escapement objective would be 250,000 estimated salmon counts • Cumulative adjusted daily sonar estimates expanded by 162% to account for salmon passing outside the ensonified area
1985	• Sonar equipment unchanged • Gillnet test fishing and carcass samples provide ASL information
1986	• Sonar equipment unchanged • ASL sampling activities are discontinued to decrease operating costs • Species apportionment activities are discontinued due to inadequate sample sizes

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Year	Event
1988	• Sonar operations eliminated use of the 60 ft artificial substrate • Sampling range unknown
1989	• Sonar operations same as 1988
1990	• No formal project documentation (1990–1995)
1993	• Fire destroys 1981 model Bendix sonar counter • Replaced with a 1978 model Bendix sonar counter • Historic data in Kuskokwim Area Management Report is adjusted to reflect 162% expansion factor applied to 1980–1983 season estimates
1994	• Sonar operations continue with 1978 model counter
1995	• Sonar operations continue with 1978 model counter • Reliable escapement estimates are not generated
1996	• Established a new sonar data collection site 1.5 km downstream from the historical site • Project operations redesigned to provide full river ensonification with user-configurable sonar equipment 24 hours per day on both banks • Periodic net sampling to monitor broad changes in species composition, corroborate acoustically detected abundance trends, and obtain ASL samples of chum salmon • Sonar estimates are not extrapolated for preseason and postseason salmon escapement (1996–1997) • Regional Information Report documents project operations and data collection activities
1997–2000	• Project operations remain the same as 1996 for years 1997 through 2000
2001	• Sonar operations remain the same as 1996 for years 1997 through 2001 • Species Apportionment Program is added to the project, which involved test fishing twice daily and expanding the crew size
2002	• Sonar operations remain the same as years 1996–2001 • Species apportionment program operates for last season with similar methodology to 2001.
2003	• Sampled three 4-hour periods on each bank instead of operating 24-hours/day. • Species apportionment discontinued • DIDSON sonar was tested at the site in preparation to migrate from BioSonics to DIDSON • Escapement goal updated: SEG to provide a range of 210,000 – 370,000 fish
2004-2006	• Operated DIDSON exclusively on both banks

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Appendix A1.–Page 2 of 3.

Year	Event
2007	• Operated DIDSON exclusively on both banks • Escapement goal updated: SEG revised to a range of 220,000 to 480,000 fish
2008-2011	• Operated DIDSON exclusively on both banks