Fishery Data Series No. 10-79

Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2009

by

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November 2010

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

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ABSTRACT

Dual-Frequency Identification Sonar was used to estimate chum salmon *Oncorhynchus keta* escapement in the Sheenjek River from August 15 to September 24, 2009 for the fifth season. The sonar-estimated escapement through September 24 was 46,926 chum salmon. The estimate was subsequently expanded to a total abundance estimate of 54,126 using run time data from the Rampart tag recovery fish wheel. For comparison with past years, only the expanded right bank estimate of 33,203 was used to evaluate whether the biological escapement goal was obtained. The right bank estimate was 34% below the low end of the Sheenjek River biological escapement goal of 50,000 to 104,000 chum salmon. Median passage while the sonar was operating was observed on September 15. Peak single day passage was observed on September 17, when an estimated 3,263 fish passed the sonar site. A diel migration pattern showed most chum salmon passed the sonar site during periods of darkness or suppressed light. Range of ensonification was considered adequate for most fish which passed. The passage estimate should be considered conservative since it does not include fish migrating beyond the counting ranges or fish present before the sonar equipment was in operation. Because of the low abundance of fall chum salmon, no samples were collected in 2009.

Key words: chum salmon, *Oncorhynchus keta,* DIDSON, sonar, hydroacoustics, escapement, enumeration, Yukon River, Porcupine River, Sheenjek River.

INTRODUCTION

Five species of anadromous Pacific salmon *Oncorhynchus* spp. are found in the Yukon River drainage. However, chum salmon *O. keta* are the most abundant and occur in genetically distinct summer and fall runs (Seeb et al. 1995; Wilmot et al. 1992). Fall chum salmon are larger, spawn later, and are less abundant than summer chum salmon. Spawning occurs in upper portions of the drainage in spring-fed streams, which usually remain ice-free during the winter (Buklis and Barton 1984). Major fall chum salmon spawning areas occur within the Tanana, Chandalar, and Porcupine river systems, as well as portions of the upper Yukon River in Canada (Figure 1). The Sheenjek River (66°47.02′N, 144°27.82′W) is one of the most important producers of fall chum salmon in the Yukon River drainage. Located above the Arctic Circle, it heads in glacial ice fields of the Romanzof Mountains, a northern extension of the Brooks Range, and flows southward approximately 400 km to its terminus on the Porcupine River (Figure 2).

INRIVER FISHERIES

Fall chum salmon are harvested for commercial and subsistence uses. Commercial harvest is permitted along the entire Yukon River in Alaska and in the lower portion of the Tanana River. No commercial harvest is permitted in any other tributaries of the drainage including the Koyukuk and Porcupine River systems. Although commercial harvest occurs in the Canadian portion of the Yukon River near Dawson, most fish are taken commercially in the lower river, downstream of the village of Anvik. Subsistence use of fall chum salmon is greatest throughout the upper river drainage, upstream of the village of Koyukuk.

Although the Alaskan commercial fishery for Yukon River fall chum salmon developed in the early 1960s, annual harvests remained relatively low through the mid 1970s. Estimated total inriver utilization (U.S. and Canada commercial and subsistence) of Yukon River fall chum salmon was below 300,000 fish per year before the mid 1970s (JTC 2009). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s. Harvest peaked in 1981 at 677,257 fish (JTC 2009). In the mid 1980s, management strategies were implemented to reduce commercial exploitation on fall chum stocks and to improve low escapements observed throughout the drainage during the early 1980s. In 1987, the commercial fall chum fishery was closed in the Alaskan portion of the drainage. In 1992, commercial fishing was restricted to a portion of the Tanana River during the fall season. In addition to a commercial fishery closure, 1993 marked the first year in state history that ADF&G instituted a total closure of subsistence fishing in the Yukon River. The closure was in effect during the latter portion of the fall season in response to the extremely weak fall chum salmon run.

Yukon River fall chum salmon runs improved somewhat between 1994 and 1996. In 1994, limited commercial fishing was permitted in the Alaskan portion of the upper Yukon River, and in the Tanana River. Commercial fishing was permitted in all districts throughout the Alaska portion of the drainage in 1995. In 1996, limited commercial fishing was permitted in selected districts of the mainstem Yukon River and no commercial fishing was permitted in the Tanana River. Poor salmon runs to Western Alaska between 1997 and 2003 resulted in partial or total closures to commercial and subsistence fishing in Alaskan and Canadian portions of the drainage during those years. Commercial fishing was only permitted in the Tanana River and Canada in 1997. A total commercial fishery closure and limited subsistence fishing was required in 1998. Limited commercial harvest was permitted in 1999, and a total commercial fishery closure and severe subsistence fishing restrictions were required in 2000, 2001, and 2002. Limited commercial fishing for fall chum was allowed from 2003 through 2009. Subsistence harvest of fall chum in 2003 was also limited while the subsistence harvest in 2004 was unrestricted except within the Canadian portion of the Porcupine River. There were no restrictions on subsistence harvest from 2005 through 2008. In 2009 the subsistence harvest was limited in Alaska and Canada.

ESCAPEMENT ASSESSMENT

Between 1960 and 1980, some portions of Yukon River fall chum salmon runs were estimated from mark–recapture studies (Buklis and Barton 1984). Aside from these tagging studies, and aerial assessment of selected tributaries that have been conducted since the early 1970s, comprehensive escapement estimation studies were sporadic and limited to only 2 streams: the Delta River (Tanana River drainage) and the Fishing Branch River (Porcupine River drainage). In the early 1980s, comprehensive escapement assessment studies intensified on major spawning tributaries throughout the drainage.

The Sheenjek River is one of the most intensely monitored fall chum salmon spawning streams in Yukon River drainage. Escapement observations date back to 1960 when USFWS reported chum salmon spawning in September. Between 1974 and 1981, escapement observations in the Sheenjek River were limited to aerial surveys flown in late September and early October (Barton 1984). Beginning in 1981, escapements were monitored using Bendix[1]™ fixed-location, single-beam, side-looking sonar systems (Dunbar 2004). However, an early segment of the fall chum salmon run was not measured prior to 1991 because the project typically started around August 25, after that portion of the run had passed. Beginning in 1991, to include the early segment of the run, the project startup was changed to start about 2 weeks earlier. The sonar-estimated escapements for 1986 through 1990 have been expanded to include estimated early fish passage (Barton 1995). Termination of sonar counting was consistent between 1981 and 2009, averaging September 24, except in 2000 when the project was terminated early because of extremely low water (Barton 2002).

The Sheenjek River sonar project has estimated fall chum salmon escapement since 1981 while undergoing a number of changes in recent years. The project originally operated Bendix single-

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

beam sonar equipment and, although the Bendix sonar functioned well, the manufacturer ceased production in the mid 1990s and no longer supports the system. In 2000, ADF&G purchased a Hydroacoustic Technology, Incorporated™ (HTI) model 241 split-beam echosounder for use on the Sheenjek River. In 2000 and 2002 the new split-beam system was deployed alongside the existing single-beam sonar and produced comparable results (Dunbar 2004). In 2003 and 2004 the split-beam sonar system was used exclusively to enumerate chum salmon in the Sheenjek River.

Historically, because of unfavorable conditions for transducer placement on the left bank[2], only the right bank of the Sheenjek River has been used to estimate fish passage, except for 1985 through 1987 when single-beam sonar was tested on the left bank. Drift gillnet studies in the early 1980s suggested that distribution of the migrant chum salmon was primarily concentrated on the right bank of the river at the current sonar site, with a small but unknown proportion passing on the left bank (Barton 1985). In 2002, ADF&G began experimenting with a new Dual Frequency Identification Sonar (DIDSON), manufactured by Sound Metrics Corporation, for counting salmon in small rivers. This system appeared to be more accurate, easy to use, with the ability to operate across substrate profiles unacceptable for single-beam or split-beam systems (Maxwell and Gove 2004). The uneven substrate on left bank of the Sheenjek River was selected as an ideal candidate for experimenting with this system. In 2003, a DIDSON was deployed on the previously unmonitored left bank. Using DIDSON data it was estimated that approximately 33% of the fish were migrating up the left bank (Dunbar 2006). Given this surprisingly large number, it was proposed that DIDSON be deployed on both banks in the future. In 2004 and 2005, DIDSON and HTI split-beam sonar were deployed side-by-side on the right bank and found that DIDSON estimates were 20% higher than the split-beam estimates (Dunbar and Pfisterer 2009). Since 2005, only DIDSON has been deployed to estimate chum salmon escapement on both banks of the Sheenjek River.

Escapement estimates averaged 100,196 from 1981 to 2008 and 175,141 during the most recent 5-year period of 2004 to 2008 (Table 1). This increase in the average escapement over the last 5 years can be attributed to the extraordinarily large run (561,863 fall chum salmon) in 2005. From 1992 through 2000 the Sheenjek River biological escapement goal (BEG) was set at 64,000 fall chum salmon. This goal was based upon aerial survey and hydroacoustic data collected between 1974 and 1990 (Buklis 1993). In 2001, the department completed a review of the escapement goals for Yukon River fall chum stocks, including the Sheenjek River. Based on this review of long term escapement, catch, and age composition data, the BEG for the Sheenjek River was given a range of 50,000 to 104,000 fall chum salmon on the right bank (Figure 3) (Eggers 2001).

STUDY AREA

This project site is located approximately 10 km upstream from the mouth of the Sheenjek River (Figure 2). While created by glaciers, the Sheenjek River has numerous clearwater tributaries. Water clarity in the lower river is somewhat unpredictable, but generally clearest during periods of low water. Historically, the water level begins to drop in late August or early September. Upwelling ground water composes a significant portion of the river flow volume, especially in winter. It is in these spring areas that fall chum salmon spawn, particularly within the lower 160 km.

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[2] Left and right bank refers to the bank on the left or right side of the river when looking downstream.

OBJECTIVES

Objectives for the 2009 Sheenjek River sonar project were to:

- Estimate daily and seasonal passage of chum salmon escapement using fixed, side looking DIDSON systems.
- Collect a minimum of 30–35 vertebrae samples per week, up to 180 for the season, to estimate age and sex composition of the spawning chum salmon population, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 (α=0.05 and d=0.10).
- Collect selected climate and hydrologic data daily at the project site.

METHODS

HYDROACOUSTIC EQUIPMENT

DIDSON units were deployed on August 15 on the right and left banks of the Sheenjek River at the historic sonar site (Figures 4 and 5). The right bank DIDSON (long range) operated at 1.2 MHz, its high frequency option, and the left bank DIDSON (standard) was operated at 1.1 MHz, its low frequency option. Both the low and high frequency modes have a viewing angle of 29° in the horizontal axis, and 14° in the vertical axis. Both DIDSON units were mounted on an H-shaped stand equipped with a manual crank-style rotator to facilitate aiming (Figure 6). A 152 m cable on the right bank and a 30 m cable on the left bank carried power and data between the DIDSON units in the water and the topside breakout boxes. A wireless router was used to transfer data between the left bank breakout box and a laptop computer on the right bank. All surface electronics were housed in a small self-supporting tent on the left bank and a 10x12 wall tent on the right bank. All electronics were powered with 2 portable 1000 W generators (one on each bank) run continuously.

Sampling was accomplished with DIDSON software running on laptop computers. After establishing the parameters that maximize sonar effectiveness, both left and right bank systems were left to operate 24 hours per day. Sonar data was collected in twenty-four 60-minute digital samples per bank and day by the DIDSON data acquisition software. Files were transferred to, and stored on, an external hard drive enclosure, configured for RAID 1 data storage. Files were later examined and edited by the field crew to produce an estimate of fish passage. The crew, consisting of 2 technicians, monitored the sonar and interpreted the data during 6 to 7 hour shifts twice daily.

SITE SELECTION AND TRANSDUCER DEPLOYMENT

The gently-sloping river bottom and small cobble at the historic right bank counting location, and the silty cut bank directly across the river, were adequate for ensonification. A bottom profile was obtained after initial transducer placement at the counting location by stretching a rope across the river and measuring water depth at one meter increments with a calibrated pole. The transducers and manual crank-style rotators were mounted on stands made of aluminum pipe and deployed from each bank. The stands were secured in place with sandbags and designed to permit raising and lowering of the transducers by sliding them up or down along 2 riser pipes that extended above the water. Technicians adjusted the aim by viewing the video image and relaying aiming instructions to a technician at the transducers stand via handheld VHF radio. The transducers were deployed in water ranging from 0.5 to 1.0 m in depth, and aimed perpendicular to the current along the natural substrate. An attempt was made to ensure the transducers were deployed at locations where there was sufficient current, i.e., areas without eddies or slack water where fish milling behavior can occur.

Technicians used an artificial acoustic target during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beams. The target, an airtight 250 ml weighted plastic bottle, was allowed to drift downstream along the river bottom and through the acoustic beams. Drifts were made at multiple ranges in order to verify target detection at all ranges of interest. Beam aim adjustment and target drifts were repeated until a satisfactory result was achieved.

A fish lead was constructed shoreward from the transducer on the right bank to prevent upstream salmon passage inshore of the transducer. The fish lead was constructed of 5 cm by 5 cm by 1.2 m high galvanized chain-link fencing attached to 2.5 m metal "T" stakes. The lead was positioned to guide fish beyond the nearfield of the sonar transducer. Whenever a transducer was relocated because of rising or falling water level, the beam was re-aimed to ensure proper ensonification, and the lead was repositioned as appropriate. Installation of a fish lead on the left bank was prevented due to deep water and floating debris close to shore. This transducer was placed very close to shore, and natural diversions such as submerged debris and fallen clumps of riverbank were relied on to keep the salmon from passing behind or to close to the transducer.

SONAR COUNT ADJUSTMENTS

Data collected by the DIDSON were transferred to another computer for counting and editing using DIDSON editing software. Upstream migrating fish were counted by marking each fish track on the DIDSON echogram (Figure 7). Upstream direction of travel was verified using the DIDSON video feature. Counts were saved as text files and recorded on a count form. Brief interruptions in sampling intermittently occurred when routine maintenance (i.e. silt removal) or relocation of the transducers was required.

Whenever a portion of a sample was missing, passage was estimated by expansion based on the known portion of the sample. The number of minutes in a complete sample period (60) was divided by the number of minutes counted m, and then multiplied by the number of fish counted x in that period i. Passage y_i was estimated as:

$$\hat{y}_i = (60 / m_i) x_i \tag{1}$$

If data from one or more complete sample periods was missing, passage for that portion of the day y_m was estimated by averaging passage from the sample periods immediately before (y_b) and after (y_a) the missing sample period(s), and then multiplying by the number of sample periods missed n:

$$\hat{y}_m = \left(\frac{y_b + y_a}{2} \right) n \tag{2}$$

If data from one or more complete days d was missing, passage for each missing day y_d was estimated using simple linear interpolation, based on the known passage y for the day immediately before (x_b) and the day immediately after (x_a) the missing day(s) x_d:

$$\hat{y}_d = y_b + (x_d - x_b)\left(\frac{y_a - y_b}{x_a - x_b}\right) \quad (3)$$

The proportion of fish other than fall chum salmon in the daily counts was assumed insignificant based upon historic visual "tower" observations and test fishing records collected at the site. After editing was complete, an estimate of daily and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone. The estimates produced during the field season were further scrutinized post season and adjusted as necessary.

TEMPORAL AND SPATIAL DISTRIBUTIONS

Fish range distributions were examined postseason by importing text files containing all fish track information into *R* (R Development Core Team 2009) where the fish counts were binned by range. Microsoft® *Excel* was used to plot the binned data and investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were also created in Microsoft® *Excel* to investigate diel patterns of migration.

TEST FISHING AND SALMON SAMPLING

Region-wide standards have been set for the sample size needed to describe the age composition of a salmon population. These standards apply to the period or stratum in which the sample is collected. These goals are based on a one in ten chance (precision) of not having the true age proportion (p_i) within the interval $p_i \pm 0.05$ for all *i* ages (accuracy).

Vertebrae collections are the preferred method of aging Yukon River fall chum salmon when in close proximity to their natal streams (Clark 1986[3]). As described in Bromaghin (1993), a sample size of 150 chum salmon is needed, assuming 2 major age classes with minor ages pooled, and no unreadable vertebrae. Allowing for 20% unreadable vertebrae, the Sheenjek River sample size goal was set at 30 chum salmon per week up to a maximum of 180 for the season.

Normally a beach seine is periodically fished at the sonar site to collect adult salmon for age and sex composition. The beach seine (3-inch stretch measure) is 30 m in length by 55 meshes deep (~3 m). Chum salmon are collected with the beach seine, enumerated by sex using external characteristics, and measured to the nearest 5 mm, from mid eye to tail fork (METF). Additionally, 3 vertebrae are taken from each fish for age determination. No samples were collected this season because of low abundance.

CLIMATE AND HYDROLOGIC OBSERVATIONS

A water level gauge was installed at the sonar site and monitored daily, with readings made to the nearest centimeter. Surface water temperature was measured approximately 30 cm below the surface daily, with a HOBO U22™ water temperature data logger, and a pocket thermometer. The data logger was suspended from a float tied to the water level gauge and set to record 6 times a day. Minimum and maximum air temperatures, and wind velocity and direction were measured daily with a Weather Wizard III™ weather station. Other daily observations included

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[3] Clark, R. A. 1986. Sources of variability in three ageing structures for Yukon River fall chum salmon (*Oncorhynchus keta Walbaum*) escapement samples. Alaska Department of Fish and Game, Division of Sport Fish, (Region III unpublished report), Fairbanks.

occurrence of precipitation and percent cloud cover. Climate and hydrologic observations were recorded at approximately 1800 hours daily.

RESULTS

RIVER AND SONAR COUNTING CONDITIONS

In 2009, the right bank transducer was deployed in approximately the same location on the point bar that has been used in recent years, while the cutbank directly across the river continued to work well for the other transducer. On August 15 the river bottom at the counting location dropped abruptly from the left bank at a rate of 21 cm/m (bottom slope ≈11.7°) to the thalweg approximately 14 m from shore, and then sloped gently up toward the right-bank point bar at a rate of approximately 7 cm/m (bottom slope ≈4.3°) (Figure 8). River width measured 63 m, and much of the nearshore zone along the left cutbank was cluttered with fallen trees and other woody vegetation, while the right bank consisted of small cobble with no debris.

The water level was moderately high upon arrival at the project site in 2009. With respect to the initial reading of the water gauge upon deployment on August 14, the water level dropped during the first 4 days, climbed slightly for 2 days, and then dropped for about 6 days. On August 27 the water level abruptly began to rise. Over the next 5 days the water level climbed 157 cm. (Figure 9, Appendix A1). These water levels presented flood conditions that necessitated removing both right and left bank sonar units for 4 days between September 1 and September 4. After September 1 the water level gradually dropped until, by September 24, it was 4 cm above the initial reading. Water temperature at the project site ranged from 2.8°C to 12.0°C, and averaged 8.9°C.

Fluctuations in water level affected placement of the transducers with respect to shore. As the water level dropped the transducers were moved out away from shore and when the water level increased the transducers were moved in toward shore. With installation of sonar on both banks, efforts were made to insure that the counting ranges of each DIDSON did not overlap. While no attempt was made to estimate fish passage beyond the counting range, occasional expansions or interpolations of sonar counts were made to estimate fish passage for periods when data was missing because of flood conditions (prompting transducer removal), system failures, and routine maintenance or moving the transducers.

ABUNDANCE ESTIMATION AND ADJUSTMENTS

The 2009 sonar-estimated escapement was 46,926 fall chum salmon for the 41-day period from August 15 through September 24 (Table 2). A total of 92.3 hours on the left bank and 81.7 hours on the right bank of sampling time were missed because of routine maintenance, system diagnostic test, system malfunction, moving and aiming the transducer, or flooding. Most of the missed time was from days the project site was flooded, September 1 through September 4. Equations used for in season adjustments are detailed in the methods section of this report.

When sonar operations ceased on September 24 there was relatively high (1,596 fish per day) passage at the project site and projects downriver experienced passage of relatively large numbers of fall chum salmon that would not have reached the sonar site by the time the project terminated. Given these circumstances, the sonar-estimated escapement was expanded to 54,126 to account for chum salmon that were most likely not counted after termination of the project (Table 1) (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication). The expansion was calculated by using a second order polynomial equation calculated to October 9. October 9 was chosen as an end date using a 15 day lag time correlated to the end of the run at Rampart Rapids test fish project. The resulting equation for determining the chum salmon passage for each day expanded for after sonar operations ceased was:

$$y_i = \frac{L}{d^2}(x_i - d)^2 \qquad (4)$$

Where y_i is the ith daily passage estimate, L is the count on the last day, d is the total number of days expanding for, and x_i is the day number being estimated (where i=1 through 15). Table 3 shows resulting daily counts from September 25 through October 9.

TEMPORAL AND SPATIAL DISTRIBUTION

Chum salmon were present in the river when right bank sonar counting was initiated on August 15, as evidenced by the 87 fish estimated passing that day. The largest passage estimate of 3,263 fish occurred on September 17 (Table 2 and Figure 10). An estimated 1,596 chum salmon passed the project site on September 24, the final day of sonar operation.

The diel pattern of migration of Sheenjek River chum salmon typically observed in most years (Dunbar 2004) was observed again in 2009 (Figure 11). Overall upstream migration was heaviest in periods of darkness or suppressed light, with fish moving in greater numbers close to shore. This pattern was most prevalent on the right bank. Left bank migration was heaviest during daylight hours. Total river average fish passage between 1900 and 0700 the following day was 53%, while between 0700 and 1900, 47% of the fish passed. The period of minimal passage was 1400 hours, while the highest average passage occurred at 1900 hours.

During the fall chum salmon run, 39% of migrating salmon passed on the left bank and 61% passed on the right bank (Figure 10). The highest proportional passage on the left bank occurred on August 12 (61%), while the lowest occurred on August 31 (7%). Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. On the right bank approximately 84% of the fish counted were passing through the first 10 m of the counting range (Figure 8). The first few meters had fewer fish due to the placement of the fish lead in relation to the transducer. On the left bank, 95% of the fish were detected within 8 m of the transducer. The unusual bimodal range distribution on the left bank, as seen in Figure 8, was most likely caused by natural diversions such as submerged debris and fallen clumps of riverbank just downstream of the transducer.

AGE AND SEX COMPOSITION

Because of the low abundance of fall chum salmon and the subsequent closure of the commercial fisheries and the reduction of subsistence fisheries, no samples were collected in 2009. Historic values of age composition estimates can be found in Appendix B1.

DISCUSSION

ESCAPEMENT ESTIMATE

This was the fifth season that DIDSON was used to estimate fall chum salmon passage in the Sheenjek River, and the fifth season since 1987 that both banks have been fully monitored. The DIDSON systems performed well on both right and left banks over the entire season with no major technical difficulties or failures. The DIDSON, with its wide vertical beam angle (14°) was the ideal system for the previously unmonitored left bank, where the profile is steep and less linear than the right bank. Procedures used for counting DIDSON files worked well for estimating salmon passage at the site. All data files were processed in a reasonable amount of time. Factors affecting termination of sonar counting in 2009 included logistics associated with closing down camp, and impending winter weather.

Although sonar has been used to monitor chum salmon escapements in the Sheenjek River since 1981, project operational dates have only been consistent since 1991. Barton (1995) used run timing data from the nearby Chandalar River to expand Sheenjek River run size estimates for 1986–1988, and 1990 to a comparable time period (Table 1). The 1989 estimate was expanded using Sheenjek River aerial survey observations made before sonar operations in that year (Table 1). Barton (2002) used Sheenjek River run timing data from 1986 to 1999 to expand the estimated escapement for 2000, when sonar operations terminated early. Because of unusually high and increasing passage when the project terminated in 2003, the escapement estimate may not have reflected the actual amount of salmon escapement to the Sheenjek River. In order to assess whether the BEG was achieved, the escapement estimate was subsequently expanded using run timing data from the Rampart tag recovery fish wheel (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, unpublished memorandum 24 February 2004). The same scenario occurred in 2005 and 2008, when passage was both high and increasing when operations ceased. With downriver projects reporting late runs, the escapement estimate was again expanded using run timing data from the Rampart tag recovery fish wheel (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

The 2009 sonar estimated escapement of 46,926 chum salmon, for the 41-day period August 15 through September 24, was expanded to 54,126 to account for chum salmon that may have passed after sonar operations ceased (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication). The expanded right bank estimate of 33,203 chum salmon was 34% below the low end of the BEG of 50,000 to 104,000 chum salmon. Since 1992 the right bank estimate has been used to assess the BEG because it was the only bank monitored. Until more data is collected, the right bank estimate will continue to be used for assessing the BEG. The fact that the DIDSON estimates may be 20% higher than split-beam estimates must also be taken into consideration when evaluating whether or not the BEG has been met. This low escapement was somewhat expected because the major parent year escapement of 37,878 in 2004 (returning age 0.4 fish) was low, and the extremely high escapement of 561,863 in 2005 (returning age 0.3 fish) created uncertainty based on experience from past large runs.

Drift gillnet studies conducted in the 1980s concluded that only a small proportion of the salmon pass on the left bank. In 2003 preliminary work with the DIDSON on both banks at the sonar site indicated as many as 33% of the fish migrated on the left bank. This season 39% of the fish migrated on the formerly unmonitored left bank, compared to 39% in 2005 and 2006, 40% in 2007, and 16% in 2008. Continued estimation of salmon passage on both banks should yield more accurate information on the total escapement to the Sheenjek River.

The 2009 season was characterized by a low odd-year fall chum salmon run to the Yukon River. Commercial fishing opportunity was extremely restricted and subsistence and personal use opportunities were limited. With these restrictions most drainages met escapement goals. Both the Canadian mainstem Yukon River and the Fishing Branch River exceeded spawning escapement goals. The Chandalar and Tanana River goals were most likely met based on a combination of genetic mixed stock analysis (MSA) and the passage of adequate numbers to the Upper Yukon mainstem and the Fishing Branch River spawning areas. (Bue, F., and B. Borba. 2009. 2009 Yukon River fall season summary. Alaska Department of Fish and Game, Division of Commercial Fisheries, 2009 Yukon River Fall Salmon Fishery News Release #38, Fairbanks). The Sheenjek River was an exception with one of the weakest stocks in the Yukon River drainage.

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TABLES AND FIGURES

Table 1.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981–2009.

Year	Starting Date	Ending Date	Project Duration	Sonar Estimate	Expanded Estimate
1981	31 Aug	24 Sep	25	74,560	
1982	31 Aug	22 Sep	23	31,421	
1983	29 Aug	24 Sep	27	49,392	
1984	30 Aug	25 Sep	27	27,130	
1985 [a]	02 Sep	29 Sep	28	152,768	
1986 [a]	17 Aug	24 Sep	39	83,197 [b]	84,207
1987 [a]	25 Aug	24 Sep	31	140,086	153,267
1988	21 Aug	27 Sep	38	40,866	45,206
1989	24 Aug	25 Sep	33	79,116	99,116
1990	22 Aug	28 Sep	38	62,200	77,750
1991	09 Aug	24 Sep	47	86,496	
1992	09 Aug	20 Sep	43	78,808	
1993	08 Aug	28 Sep	52	42,922	
1994	07 Aug	28 Sep	53	150,565	
1995	10 Aug	25 Sep	47	241,855	
1996	30 Jul	24 Sep	57	246,889	
1997	09 Aug	23 Sep	46	80,423	
1998	17 Aug	30 Sep	45	33,058	
1999	10 Aug	23 Sep	45	14,229	
2000	08 Aug	12 Sep	36	18,652 [c]	30,084
2001	11 Aug	23 Sep	44	53,932	
2002	09 Aug	24 Sep	47	31,642	
2003	09 Aug	26 Sep	49	38,321 [d]	44,047
2004	08 Aug	25 Sep	49	37,878	
2005 [a]	10 Aug	24 Sep	46	438,253 [d]	561,863
2006 [a]	09 Aug	24 Sep	47	160,178	
2007 [a]	11 Aug	24 Sep	45	65,435	
2008 [a]	09 Aug	24 Sep	47	42,842 [d]	50,353
2009 [a]	15 Aug	24 Sep	41	46,926 [e]	54,126
1981-08	15 Aug	24 Sep	41	92,968	100,196
2004-08	09 Aug	24 Sep	47	148,917	175,141

[a] Sonar estimate is based on counts from both right and left bank sonar operations, all other years are right bank estimates only.

[b] Sonar-estimated escapement in these years was subsequently expanded to include fish passing prior to sonar operations (Barton 1995). Expansions for 1986–1988 and 1990 were based upon run timing data collected in the nearby Chandalar River. The 1989 estimate was expanded based upon aerial survey observations made in the Sheenjek River prior to sonar operations in that year.

[c] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated (Barton 2002). Expansions for 2000 were based upon average run time data from the Sheenjek River 1986–1999.

[d] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansions for 2003, 2005 and 2008 were based upon run time data from the Rampart Rapids tag recovery fish wheel (Dunbar 2006; Dunbar and Pfisterer 2009; Dunbar 2009).

[e] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansion was based upon run time data from the Rampart Rapids tag recovery fish wheel (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, personal communication).

Table 2.–Sonar-estimated passage of fall chum salmon in the Sheenjek River, 2009.

Date	Daily			Cumulative			% of Total
	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total	Passage
8/15 [a]	53	34	87	53	34	87	0.00
8/16	44	26	70	97	60	157	0.00
8/17	24	25	49	121	85	206	0.00
8/18	50	25	75	171	110	281	0.01
8/19	44	28	72	215	138	353	0.01
8/20	22	23	45	237	161	398	0.01
8/21	24	21	45	261	182	443	0.01
8/22	39	40	79	300	222	522	0.01
8/23	37	21	58	337	243	580	0.01
8/24	25	19	44	362	262	624	0.01
8/25	52	22	74	414	284	698	0.01
8/26	40	21	61	454	305	759	0.02
8/27	69	18	87	523	323	846	0.02
8/28	64	38	102	587	361	948	0.02
8/29	203	40	243	790	401	1,191	0.03
8/30	264	52	316	1,054	453	1,507	0.03
8/31	367	29	396	1,421	482	1,903	0.04
9/01 [b,c]	258	61	319	1,679	543	2,222	0.05
9/02 [b,d]	383	64	447	2,062	607	2,669	0.06
9/03 [b,d]	508	67	575	2,570	674	3,244	0.07
9/04 [e,c]	633	69	702	3,203	743	3,946	0.08
9/05	545	101	646	3,748	844	4,592	0.10
9/06	546	235	781	4,294	1,079	5,373	0.11
9/07	521	389	910	4,815	1,468	6,283	0.13
9/08	596	551	1,147	5,411	2,019	7,430	0.16
9/09	665	571	1,236	6,076	2,590	8,666	0.18
9/10	1,037	905	1,942	7,113	3,495	10,608	0.23
9/11	1,241	1,152	2,393	8,354	4,647	13,001	0.28 [f]
9/12	919	1,445	2,364	9,273	6,092	15,365	0.33
9/13	1,258	1,435	2,693	10,531	7,527	18,058	0.38
9/14	1,238	1,621	2,859	11,769	9,148	20,917	0.45
9/15	1,307	1,516	2,823	13,076	10,664	23,740	**0.51** [g]
9/16	1,952	1,307	3,259	15,028	11,971	26,999	0.58
9/17	2,143	1,120	3,263	17,171	13,091	30,262	0.64
9/18	2,088	908	2,996	19,259	13,999	33,258	0.71
9/19	1,676	1,196	2,872	20,935	15,195	36,130	0.77
9/20	1,652	993	2,645	22,587	16,188	38,775	0.83
9/21	1,839	722	2,561	24,426	16,910	41,336	0.88
9/22	1,579	482	2,061	26,005	17,392	43,397	0.92
9/23	1,428	505	1,933	27,433	17,897	45,330	0.97
9/24 [h]	1,047	549	1,596	28,480	18,446	46,926	1.00

[a] Both right and left bank sonar operational.
[b] Sonar operations suspended due to high water.
[c] Counts extrapolated to 24 hours based on partial counts.
[d] Counts interpolated.
[e] Sonar operations resume.
[f] Single boxed area identifies central half of the observed run.
[g] Bold box identifies the observed midpoint.
[h] Last day of sonar operation.

Table 3.–Postseason daily expansion.

Day	Date	Daily Expansion
1	9/25	1,390
2	9/26	1,199
3	9/27	1,021
4	9/28	858
5	9/29	709
6	9/30	575
7	10/1	454
8	10/2	348
9	10/3	255
10	10/4	177
11	10/5	113
12	10/6	64
13	10/7	28
14	10/8	7
15	10/9	0
Sum		7,200
Sonar Estimate Through 9/24		46,926
Total Season Estimate		54,126

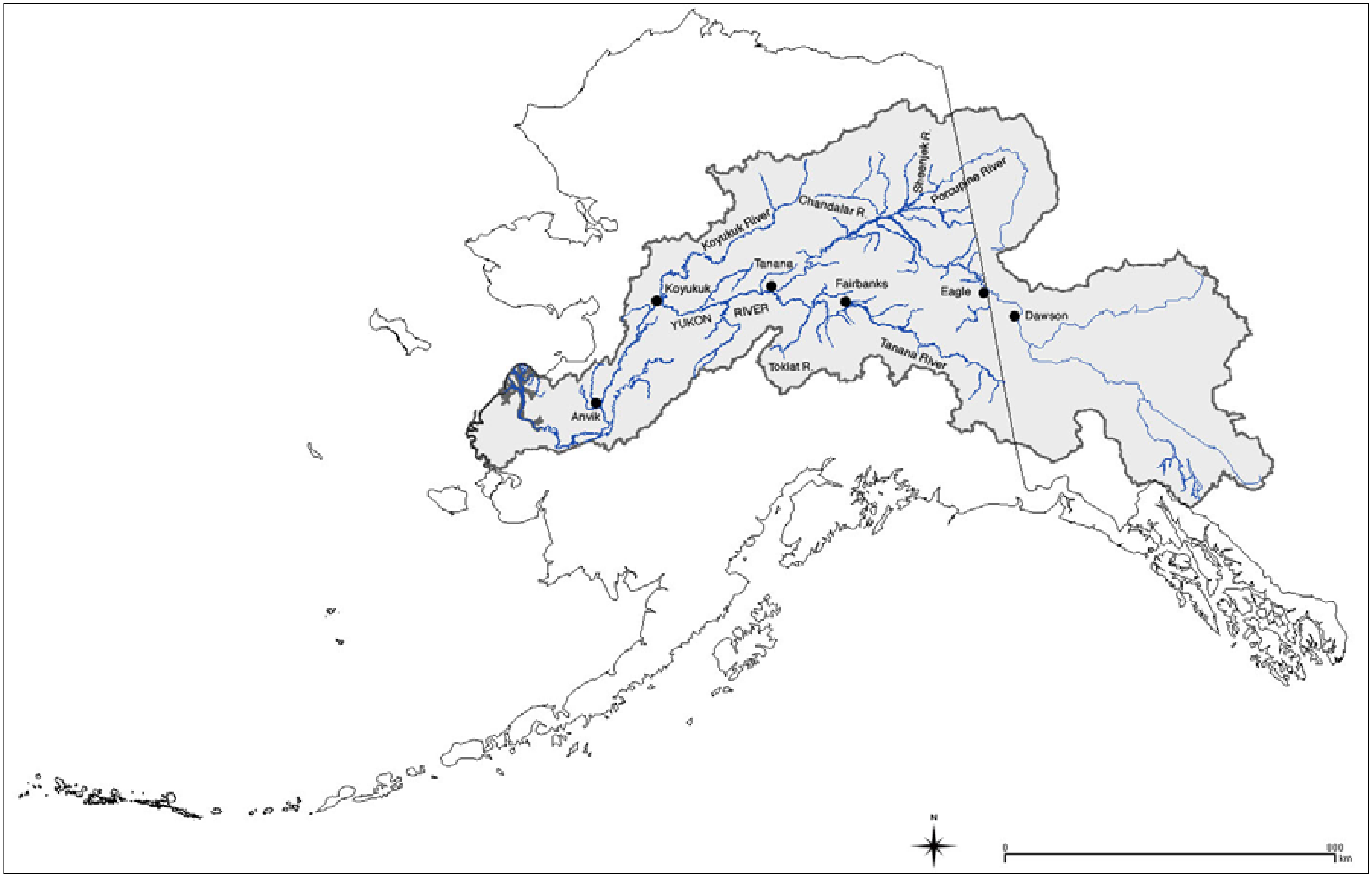


Figure 1.–The Yukon River drainage showing selected locations.

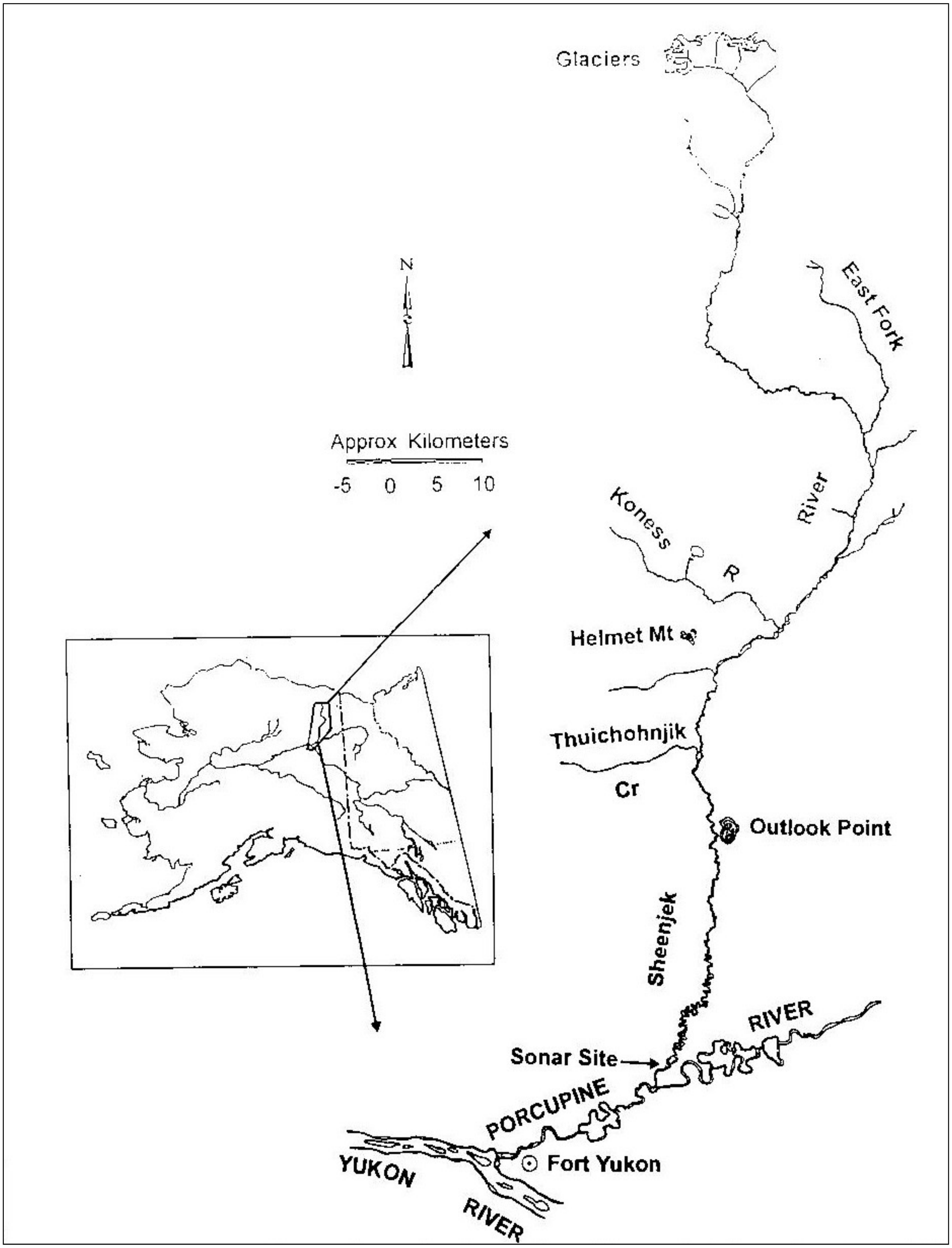
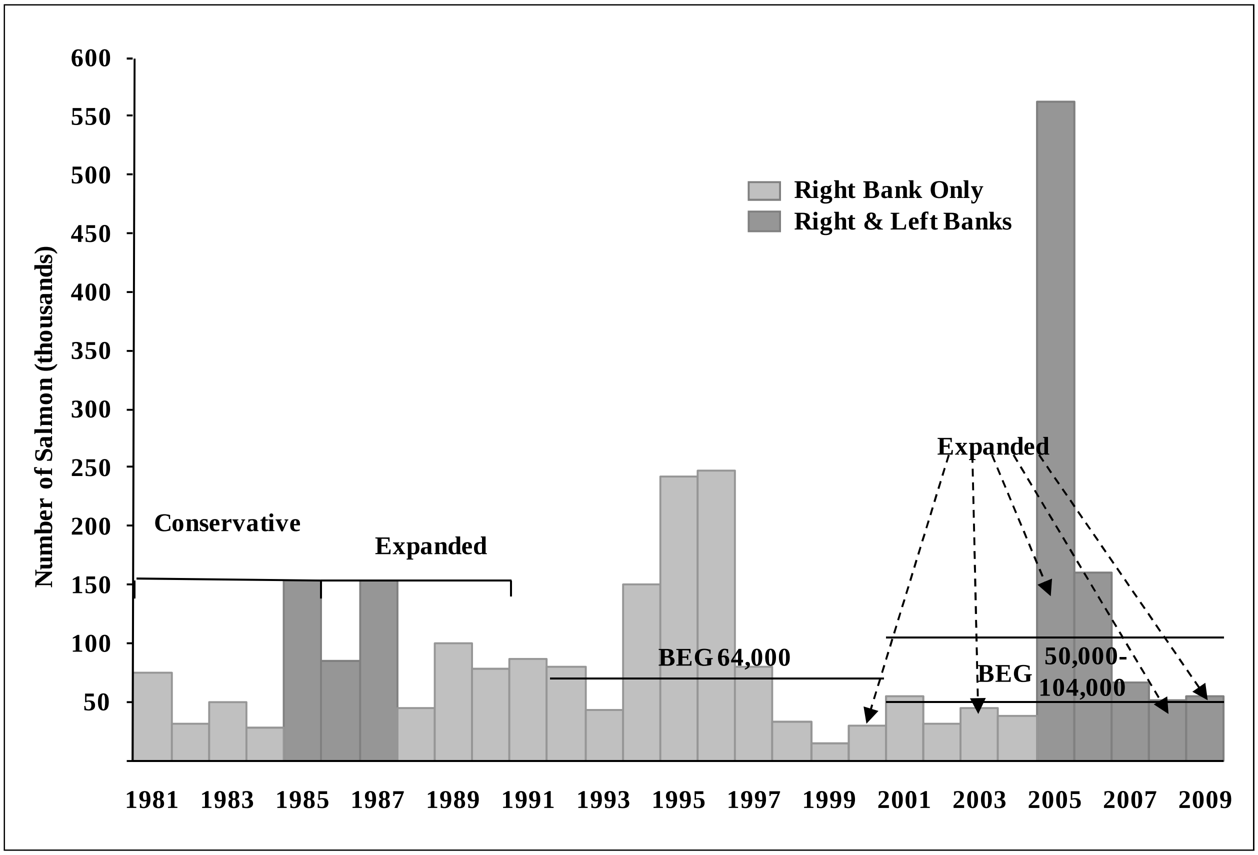


Figure 2.–The Sheenjek River drainage.



Note: Although the total escapement estimates for 2007 through 2009 were greater than the low end of the current BEG, the BEG was not achieved because it was based on right bank estimates only.

Figure 3.–Sonar-estimated escapement and BEG (horizontal lines) of fall chum salmon in the Sheenjek River, 1981–2009.

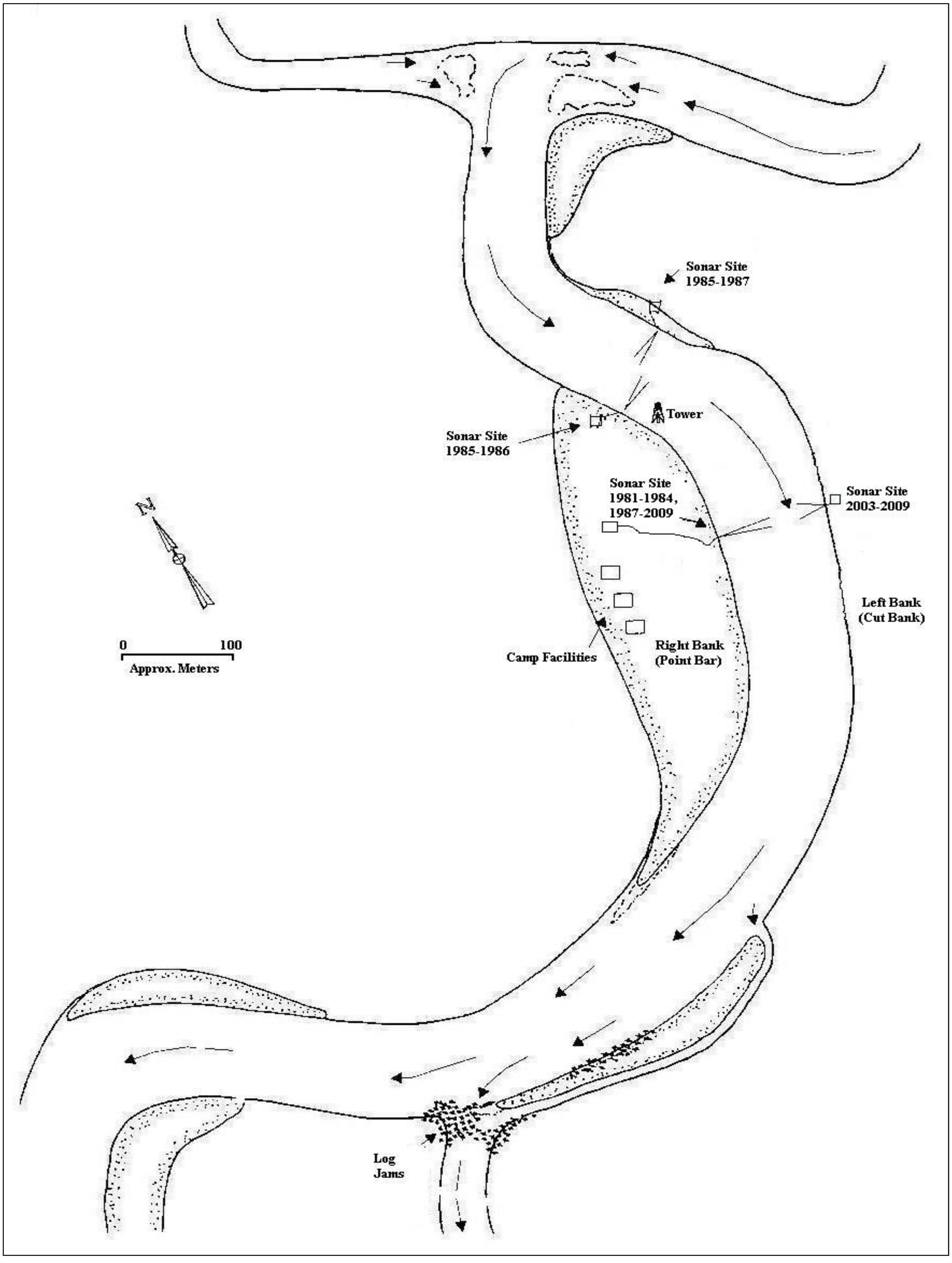


Figure 4.–The Sheenjek River sonar project site.

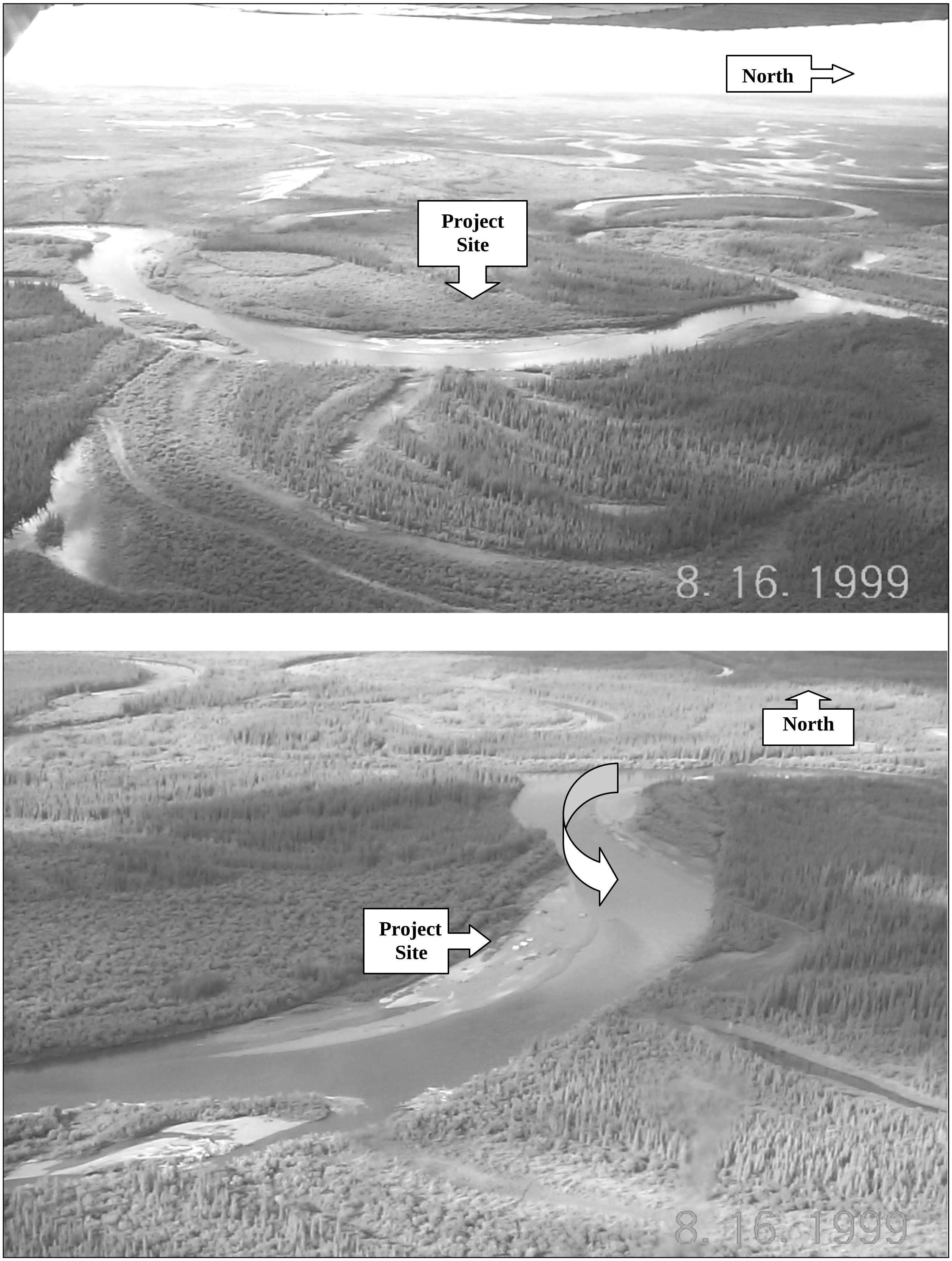


Figure 5.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

Figure 6.–DIDSON attached to H-style mount with manual rotator prior to deployment.

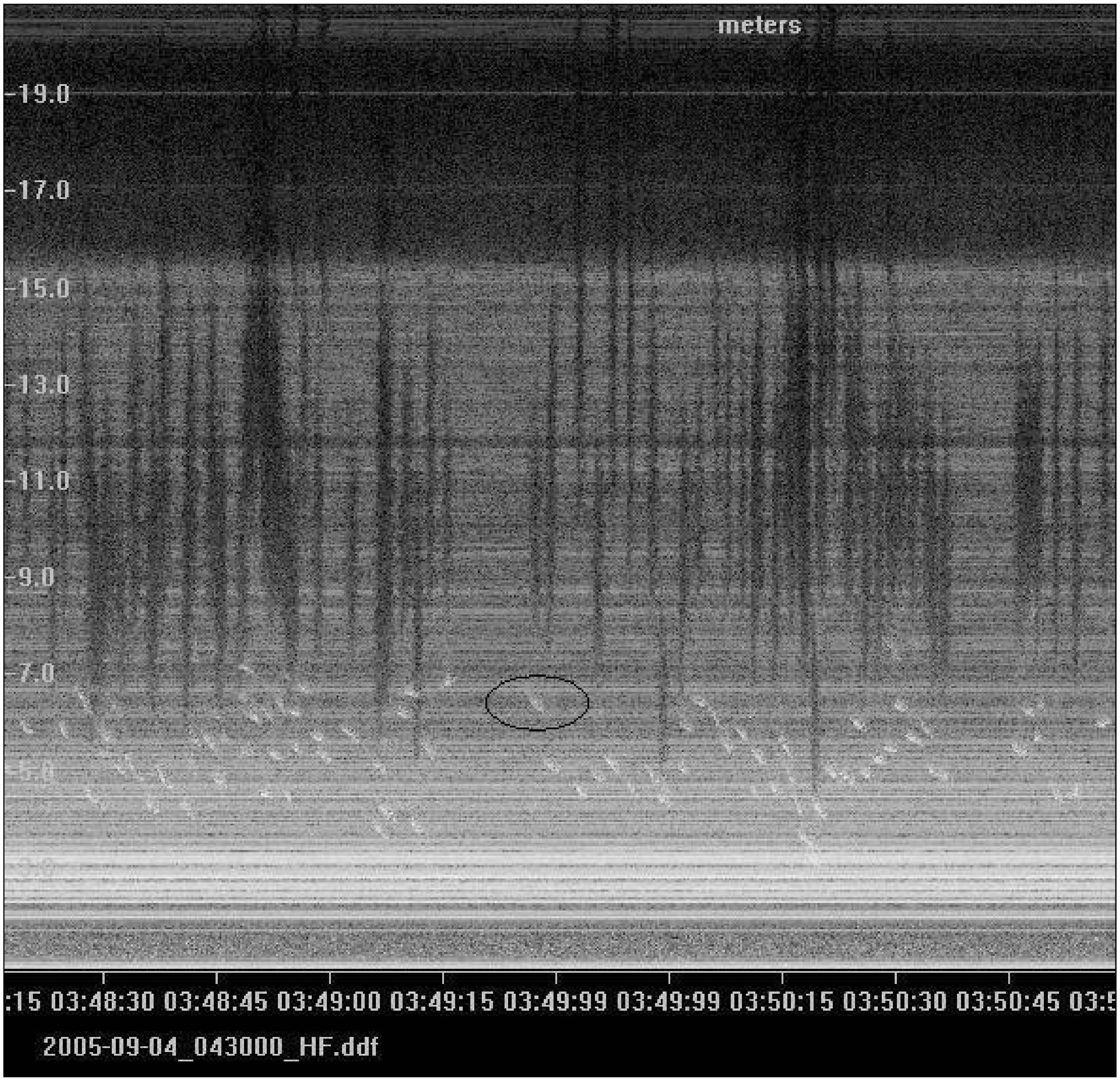
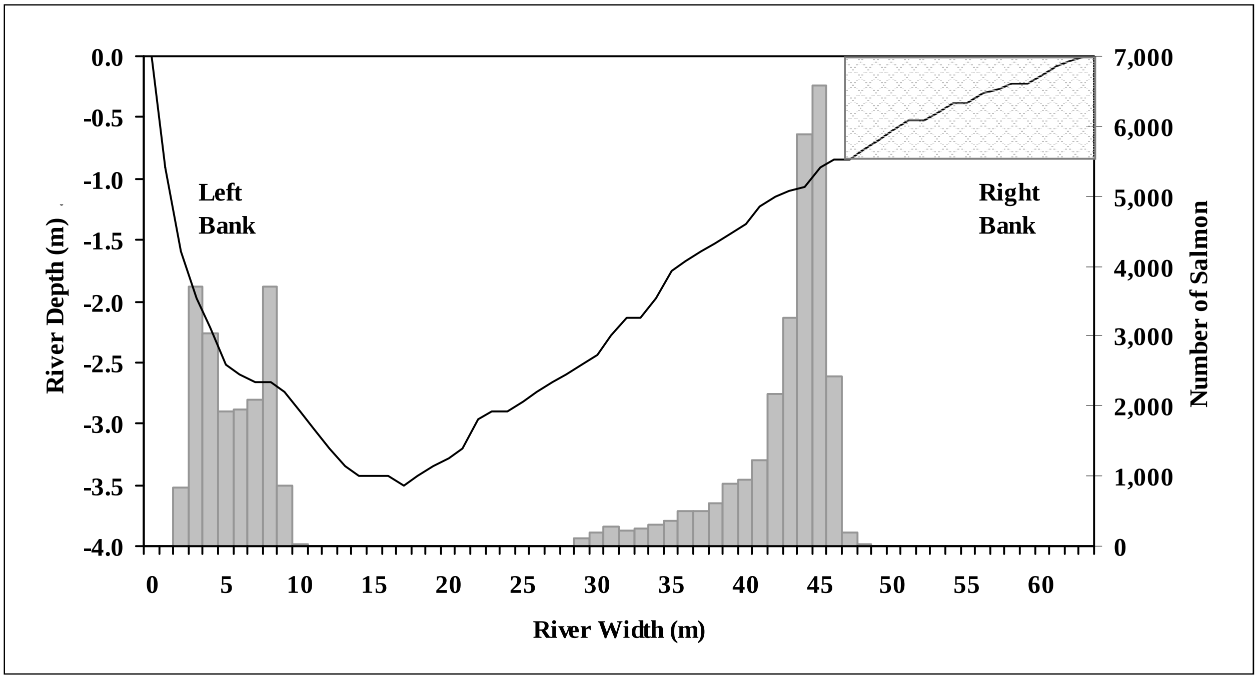


Figure 7.–Screenshot of DIDSON echogram with oval around representative fish.



Note: Cross hatch represents portion of river blocked by fish lead and vertical bars represent horizontal distribution of upstream fall chum salmon passage through ensonified zone of the Sheenjek River, 2009.

Figure 8.–Depth profile (downstream view) made August 15, at the project site.

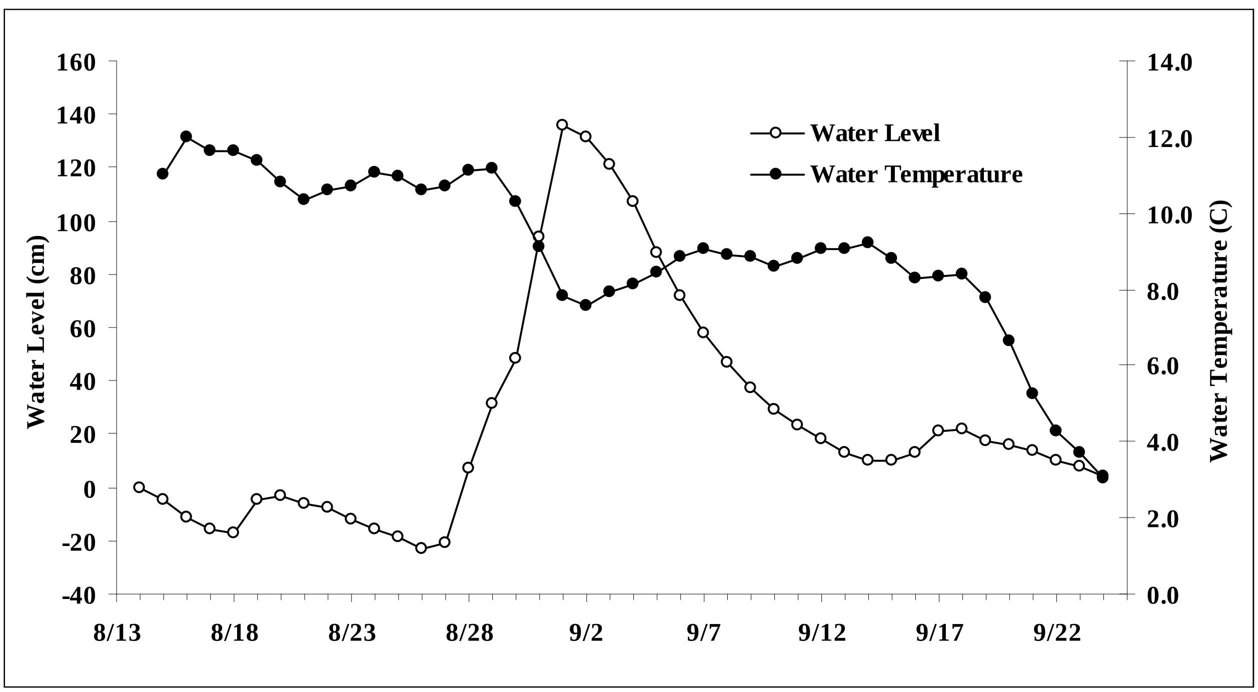


Figure 9.–Changes in daily water level relative to August 14, and water temperature measured at the Sheenjek River sonar project site, 2009.

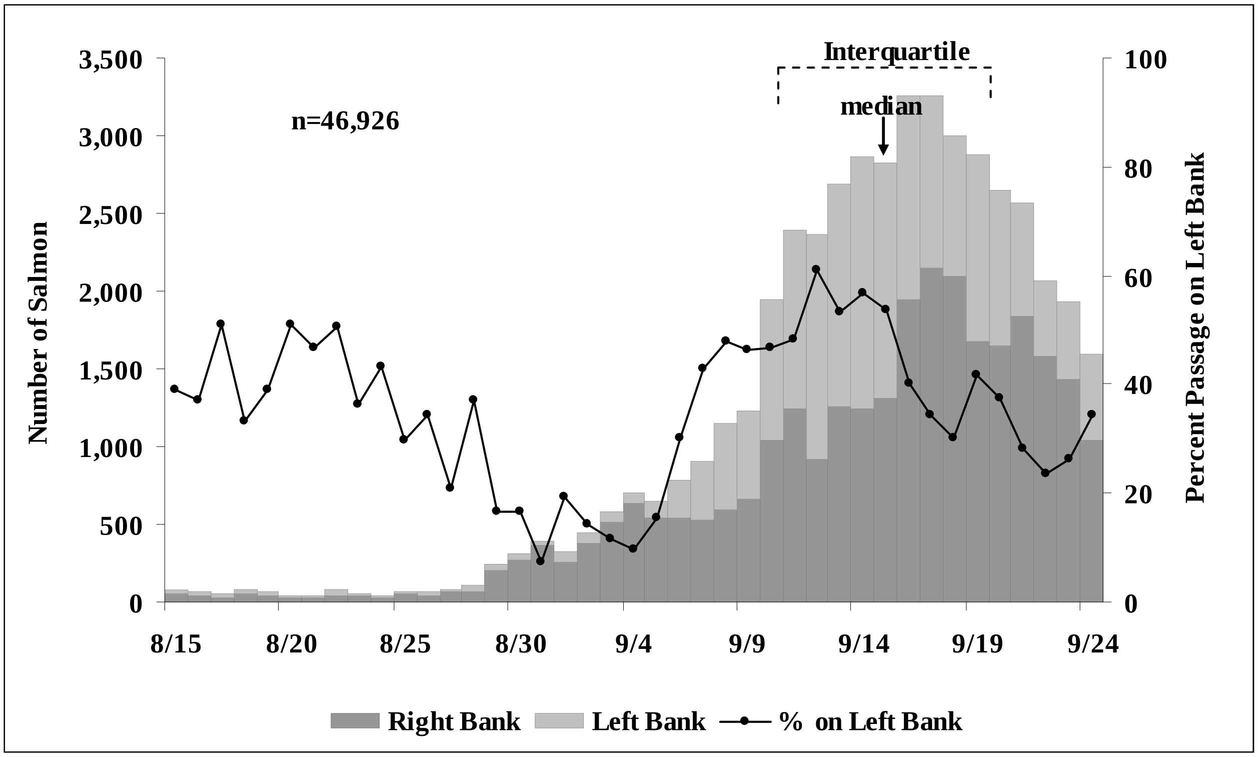


Figure 10.–Fall chum salmon sonar counts by day, and percentage of passage on the left bank at Sheenjek River sonar site, August 15 through September 24, 2009.

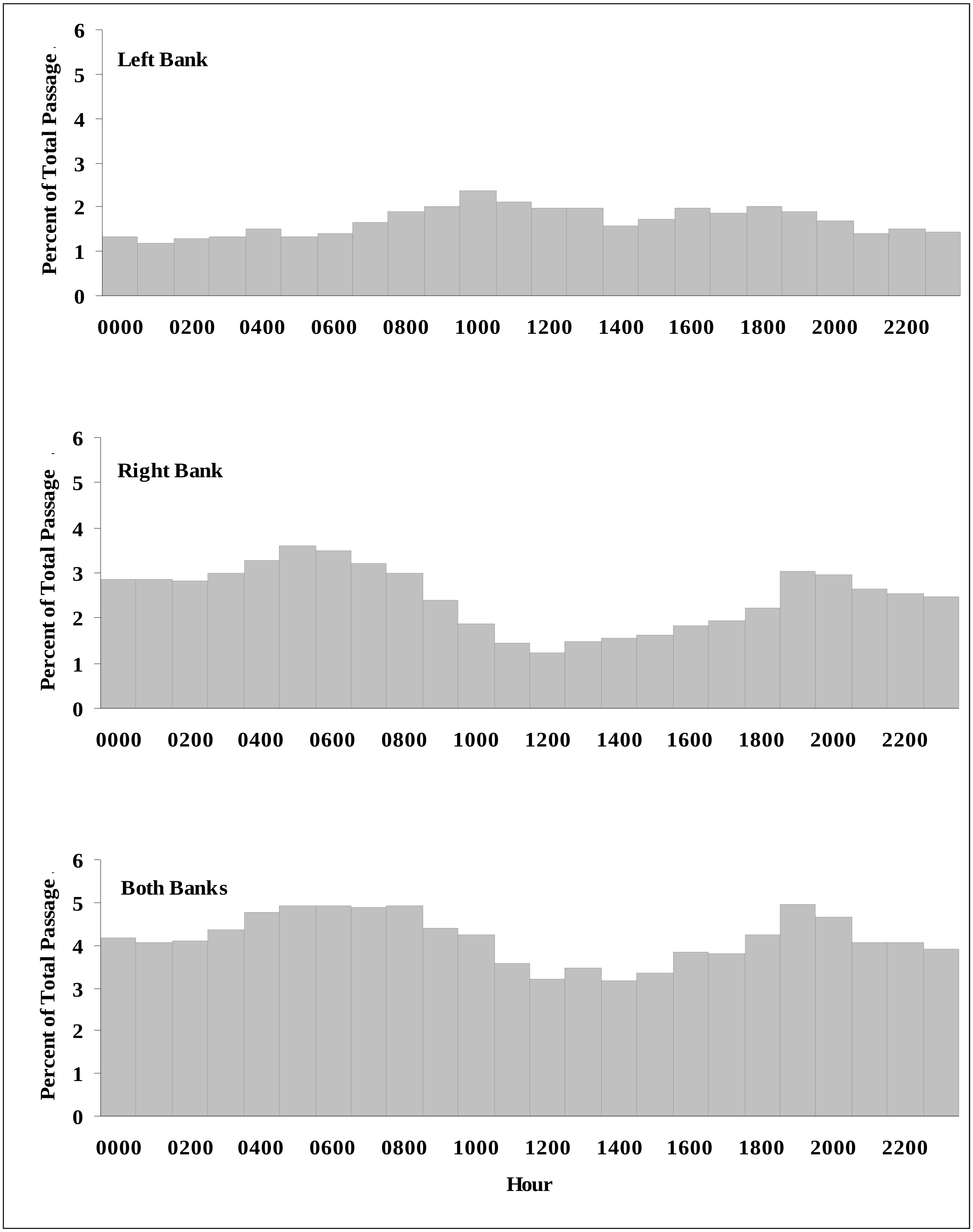


Figure 11.–Diel migration pattern of fall chum salmon on the left bank (top), right bank (middle), and both banks combined (bottom) of the Sheenjek River, from August 15 through September 24, 2009, excluding September 1 through September 4.

APPENDIX A. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climate and hydrologic observations at the Sheenjek River project site, 2009.

					Temperature (C°)			Water Level (cm)		
		Cloud								Water
	Precipitation	Cover	Wind		Water	Air		± 24 h	Relative to	Color
Date	(code)[a]	(code)[b]	Direction	Velocity (mph)	Surface[c]	Minimum	Maximum	Change	Zero Datum	(code)[d]
8/14	ND	ND	ND	ND	ND	ND	ND	zero datum	0	A
8/15	B	O	S	4	11.0	ND	ND	-5	-5	A
8/16	B	S	NE	6	12.0	10	23	-6	-11	A
8/17	A	S	SSW	3	11.6	3	22	-5	-16	A
8/18	B	O	SW	10	11.6	6	19	-1	-17	A
8/19	A	B	W	0	11.4	6	14	12	-5	A
8/20	A	C	SE	2	10.8	0	18	2	-3	A
8/21	A	C	NNE	0	10.4	-1	21	-3	-6	A
8/22	A	C	SSW	3	10.6	4	21	-2	-8	A
8/23	A	B	N	4	10.7	1	22	-4	-12	A
8/24	A	B	S	1	11.0	8	20	-4	-16	A
8/25	B	B	S	1	11.0	7	15	-3	-19	A
8/26	A	S	SW	0	10.6	3	18	-4	-23	A
8/27	A	C	N	7	10.7	7	19	2	-21	A
8/28	A	B	WSW	2	11.1	10	18	28	7	B
8/29	A	C	SSW	4	11.2	7	16	24	31	C
8/30	B	B	SW	4	10.3	7	15	17	48	C
8/31	C	O	SSW	6	9.1	2	11	46	94	D
9/01	A	S	S	1	7.8	6	16	42	136	D
9/02	A	S	N	3	7.6	10	17	-5	131	D
9/03	A	B	WSW	0	7.9	2	20	-10	121	D
9/04	A	C	NW	0	8.1	1	22	-14	107	D
9/05	A	C	NNE	0	8.4	2	22	-19	88	D
9/06	A	C	SSW	2	8.9	2	22	-16	72	C
9/07	A	C	NE	7	9.1	3	19	-14	58	B
9/08	A	C	NNE	7	8.9	5	17	-11	47	B
9/09	A	S	N	4	8.9	6	17	-10	37	B
9/10	A	S	N	3	8.6	6	18	-8	29	B
9/11	A	B	SSE	5	8.8	7	17	-6	23	B

-continued-

Appendix A1.–Page 2 of 2.

Date	Precipitation (code)[a]	Cloud Cover (code)[b]	Wind		Temperature (C°)			Water Level (cm)		Water Color (code)[d]
			Direction	Velocity (mph)	Water Surface[c]	Air Minimum	Air Maximum	± 24 h Change	Relative to Zero Datum	
9/12	A	S	S	0	9.1	5	18	-5	18	B
9/13	A	O	NE	4	9.1	4	18	-5	13	B
9/14	A	C	NE	1	9.2	7	16	-3	10	A
9/15	A	C	N	2	8.8	3	18	0	10	A
9/16	B	O	N	3	8.3	7	15	3	13	A
9/17	A	O	WNW	1	8.3	9	15	8	21	A
9/18	B	O	NNE	1	8.4	8	10	1	22	A
9/19	B	O	NNE	5	7.8	1	8	-5	17	A
9/20	A	O	NNE	4	6.6	0	5	-1	16	A
9/21	F	O	NNE	12	5.2	-1	3	-2	14	A
9/22	B	O	NNE	2	4.3	1	7	-4	10	A
9/23	G	O	SW	2	3.7	0	1	-2	8	A
9/24	A	C	SSW	0	3.1	-3	6	-4	4	A
9/25	B	O	N	8	2.8	-6	3	ND	ND	A
9/26	B	O	N	0	ND	-2	5	ND	ND	A
Average					8.9	4	15			

[a] Precipitation code for the preceding 24-hr period: A = none; B = intermittent rain; C = continuous rain; D = snow and rain mixed; E = light snowfall; F = continuous snowfall; G = thunderstorm w/ or w/o precipitation.

[b] Cloud cover code: C = ceiling and visibility unlimited (CAVU); S = scattered (<60%); B = broken (60–90%); O = overcast (100%); F = fog or thick haze or smoke.

[c] Water temperature collected 30 cm below surface with pocket thermometer on 8/15 and 8/16, and HOBO data logger 8/17–9/24.

[d] Water color code: A = clear; B = slightly murky or glacial; C = moderately murky or glacial; D = heavily murky or glacial; E = brown, tannic acid stain.

APPENDIX B. AGE COMPOSITION ESTIMATES

Appendix B1.–Age composition estimates of Sheenjek River fall chum salmon, 1974–2009.

Year[a]	Sample (readable)	Age 0.2	0.3	0.4	0.5	Estimated Escapement
1974 [b]	136	0.669	0.301	0.029	0.000	89,966
1975 [b]	197	0.036	0.949	0.015	0.000	173,371
1976 [b]	118	0.017	0.441	0.542	0.000	26,354
1977 [b]	178	0.112	0.725	0.163	0.000	45,544
1978 [b]	190	0.079	0.821	0.100	0.000	32,449
1979	ND					91,372
1980	ND					28,933
1981 [c]	340	0.029	0.850	0.118	0.003	74,560
1982 [c]	109	0.030	0.470	0.490	0.010	31,421
1983 [c]	108	0.065	0.870	0.065	0.000	49,392
1984 [d]	297	0.101	0.805	0.094	0.000	27,130
1985 [d]	508	0.012	0.927	0.061	0.000	152,768
1986 [d]	442	0.081	0.412	0.500	0.007	84,207
1987 [d]	431	0.021	0.898	0.072	0.009	153,267
1988 [d,e]	120	0.025	0.683	0.292	0.000	45,206
1989 [d,e]	154	0.052	0.766	0.169	0.013	99,116
1990 [d]	143	0.028	0.706	0.252	0.014	77,750
1991 [d]	147	0.000	0.592	0.395	0.014	86,496
1992 [d]	134	0.000	0.179	0.806	0.015	78,808
1993 [d,e]	192	0.005	0.640	0.339	0.016	42,922
1994 [d]	173	0.012	0.561	0.405	0.023	153,000
1995 [d]	166	0.012	0.542	0.386	0.060	235,000
1996 [d]	191	0.016	0.330	0.618	0.037	248,000
1997	ND					80,423
1998	3					33,058
1999	ND					14,229
2000	ND					30,084
2001 [f]	71	0.000	0.352	0.648	0.000	53,932
2002 [g]	31	0.000	0.613	0.387	0.000	31,642
2003 [d]	84	0.012	0.821	0.155	0.012	44,047
2004 [d]	104	0.115	0.615	0.250	0.019	37,878
2005 [d]	194	0.000	0.923	0.067	0.010	561,863
2006 [d,h]	179	0.012	0.229	0.732	0.028	160,178
2007 [d]	76	0.000	0.526	0.355	0.118	65,435
2008 [d]	116	0.090	0.431	0.517	0.350	50,353
2009 [i]	ND					54,126
Avg 1974–08		0.056	0.620	0.311	0.026	94,123
Avg 1999–08		0.029	0.564	0.389	0.067	104,964
Even Years		0.085	0.506	0.401	0.034	70,357
Odd Years		0.025	0.742	0.215	0.018	119,043

[a] Age determination from scales for years 1974–1985; and from vertebrae since 1986.
[b] Carcass samples from spawning grounds.
[c] Escapement samples taken with 5-7/8 inch gillnets at rkm 10.
[d] Escapement samples taken with beach seine rkm 5 and 20.
[e] Escapement samples were predominantly taken late in run.
[f] 68 carcass samples and 5 beach seine samples collected between rkm 11 and 25.
[g] 30 beach seine samples collected at rkm 13 and 1 carcass collected at rkm 10.
[h] 14 carcass samples collected between rkm 10 and 35.
[i] No samples were collected because of low abundance.