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Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2006

by

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March 2009

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)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

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 (DIDSON) was used to estimate chum salmon, (*Oncorhynchus keta*) escapement in the Sheenjek River from August 9 to September 24, 2006. This was the second season that DIDSON was used to estimate chum salmon passage in the Sheenjek River. The sonar-estimated escapement through September 24 was 160,178 chum salmon. For comparison with past years, only the expanded right bank estimate of 106,397 was used to evaluate whether the biological escapement goal (BEG) was obtained. Median passage was observed on September 8; peak single day passage was September 15 when an estimated 7,030 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, and fish present before or after the sonar equipment was in operation. One hundred eighty-two vertebrae samples were collected for age determination. Analysis of vertebrae collections showed age-5 fish dominated at 73.2%, age-4 fish represented 22.9%, and age-6 and age-3 were2.8% and 1.1% respectively. Female chum salmon comprised 54% of the sample and 46% were male.

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

INTRODUCTION

Five species of anadromous Pacific salmon *Oncorhynchus* 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 early to 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 2007). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s. Harvest peaked in 1981 at 677,257 fish (Appendix A1). In the mid 1980s, management strategies were implemented to reduce commercial exploitation on fall chum stocks and to improve escapement. 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 Alaska Department of Fish and Game (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 only 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. 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 was allowed from 2003 to 2006. Subsistence harvest in 2003 was 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 in 2005 or 2006.

ESCAPEMENT ASSESSMENT

Between 1960 and 1980, only 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 U.S. Fish and Wildlife Service (USFWS) reported chum salmon spawning in September. Between 1974 and 1981, escapement observations in the Sheenjek River were limited to aerial surveys flown between late September and early October (Barton 1984). Beginning in 1981, escapements were monitored using 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 1990 because the project typically started around August 25, after that portion of the run had passed. Between 1991 and 2005 the average startup date was August 8, early enough to measure the beginning of the run. The sonar-estimated escapements for the years 1986 through 1990 have been expanded to include estimated early fish passage (Barton 1995). Termination of sonar counting was consistent between 1981 and 2005, 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[1] single-

[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.

Escapement estimates averaged 97,277 spawners from 1992–2001 and approximately 145,872 spawners during the most recent 5 year period of 2001–2005 (Table 1). This increase in the average escapement over the last 5 years can be attributed to the extraordinary 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 which includes 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 (Eggers 2001).

STUDY AREA

This project site is located approximately 10 km upstream from the mouth of the Sheenjek River. While created by glaciers, the Sheenjek River has numerous clearwater tributaries. This makes water clarity in the lower river somewhat unpredictable, but generally clearer during periods of low water. Historically, the water level begins to drop in late August or early September. Upwelling ground water composes a significant proportion 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.

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 only 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 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 un-monitored 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 2009). Since 2005, only DIDSON has been the deployed to estimate chum salmon escapement on both banks of the Sheenjek River.

[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 2006 Sheenjek River sonar project were to:

1. Estimate daily and seasonal passage of chum salmon escapement using fixed, side looking DIDSON systems.
2. 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).
3. Collect selected climate and hydrologic data daily at the project site.

METHODS

HYDROACOUSTIC EQUIPMENT

On August 9 2006, DIDSON units were deployed on the right and left banks of the Sheenjek River at the historic sonar site (Figures 3 and 4). 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. A 152 m cable 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 a day. Sonar data was collected in forty-eight 30 minute digital file samples per bank and day by the DIDSON data acquisition software. Files were subsequently examined and edited by the field crew to produce an estimate of fish passage. The crew, consisting of 3 technicians, monitored the sonar and interpreted the data during three 6 to 7 hour shifts per day.

SITE SELECTION AND TRANSDUCER DEPLOYMENT

The gently-sloping river bottom and small cobble at the historic right bank counting location, and the 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 designed to permit raising and lowering of the transducers by sliding them up or down along 2 riser pipes that extended above the water and were secured in place with sandbags. Operators 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 m 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 minimum surface water velocities did not fall below 30 cm/s.

Technicians used an artificial acoustic target during deployment in order to ensure that the 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 the beams ability to detect targets at all ranges of interest. Beam aim adjustment and target drifts were repeated until a satisfactory result was achieved.

As in previous years, 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 5). 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 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 was divided by the known number of minutes counted and then multiplied by the number of fish counted in that period. Passage was estimated as:

$$P = (30/m_c)x_i \tag{1}$$

Where 30 is the number of minutes in a complete sample, m_c is the number of minutes in sample that where actually counted, and x_i is the count for each sample i.

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

$$P = \left(1/n\sum_{i=1}^{n} x_i\right)\begin{Bmatrix} s = 1, n = 4 \\ s = 2, n = 6 \\ s = 3, n = 8 \\ s = 4, n \geq 10 \end{Bmatrix} \tag{2}$$

Where n is the number of samples used for interpolation (half before and half after missing sample(s)), x_i is the count for each sample i, and s is the number of missed samples.

If data from one or more complete days was missing, linear interpolation of the counts directly preceding and following the event was used to estimate passage:

$$P_i = x_p + i\left(\frac{x_a - x_p}{n+1}\right) \quad (3)$$

Where P_i is the passage on missing day i, x_a is the count on the day after the event, x_p is the count the day prior to the event, and n is the total number of missing days.

Counts caused by fish other than salmon were 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 2007) 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 1 in 10 chance (precision) of not having the true age proportion (p_i) within the interval $p_i \pm 0.05$ for all i ages (accuracy).

The preferred method of aging Yukon River fall chum salmon, when in close proximity to their natal streams, is from vertebrae collections (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.

A beach seine was periodically fished at the sonar site to collect adult salmon for age and sex composition. The beach seine (3 inch stretch measure) was 30 m in length by 55 meshes deep (~3 m). Chum salmon were collected with the beach seine, enumerated by sex using external characteristics, and measured to the nearest 5mm, from mid eye to tail fork (METF). Additionally, 3 vertebrae were taken from each fish for age determination. Some samples were also taken from carcasses collected between river kilometer (rkm) 10 and 35.

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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.

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 daily with a pocket thermometer. Minimum and maximum air temperatures, and wind velocity and direction were measured daily with a Weather Wizard III weather station. Other daily observations included 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 2006, the right bank transducer was deployed approximately in 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 8 the river bottom at the counting location dropped abruptly from the left bank at a rate of 33 cm/m (bottom slope ≈ 18.2°) to the thalweg that lay approximately one-fifth of the way across the channel, and then sloped gently up toward the right-bank, point bar at a rate of approximately 8 cm/m (bottom slope ≈ 4.8°) (Figure 6). River width measured 63 m, much of the nearshore zone along the left bank, was muddy and 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 2006. With respect to the initial reading of the water gauge upon deployment on August 9, the water level remained fairly consistent until August 15. The water level then steadily increased 298 cm until August 26 (Figure 7 and Appendix B1). These water levels presented flood conditions that necessitated moving the camp to higher ground and removing the right bank sonar for 9 days and the left bank sonar for 12 days between August 20 and August 31. After August 26 the water level quickly dropped 224 cm over the course of 4 days, and then continued to fall slowly the remainder of the season. Final measurement on September 27 was 43.0 cm below the initial level. Water temperature at the project site ranged from 6.0°C to 14.0°C based upon instantaneous surface measurements (≈ 30 cm below surface), and averaged 9.8°C (Figure 7 and Appendix B1).

Fluctuations in water level affected placement of the transducers with respect to shore. When the water level dropped the transducers were move out and when the water level increased the transducers were moved in. 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, routine maintenance, or moving the transducers.

ABUNDANCE ESTIMATION

The 2006 sonar-estimated escapement was 160,178 fall chum salmon for the 47 day period August 9 through September 24 (Table 2). Table 3 shows the amount of time by day that either expansion or interpolation was used when calculating hourly or daily passage estimates. Daily passage estimates were relayed to the fishery managers in Fairbanks every morning. The final sonar estimated escapement includes adjustments made post season. The daily estimates for the right bank, when the sonar was not operating, were adjusted using linear interpolation based on days before and after the flood. The same adjustments were not made for the left bank because it appeared that most of the fish had moved to the right bank as the water level increased, and it is not known when the fish moved back to the left bank (Table 2 and Figure 8).

TEMPORAL AND SPATIAL DISTRIBUTION

Chum salmon were present in the river when right and left bank sonar counting was initiated on August 9, as evidenced by the 246 fish estimated passing that day. A distinctly bimodal run occurred in 2006, with prominent peaks in passage observed on September 5 and 15 (Figure 9). Passage peaked at 7,030 fish on September 15. The interquartile portion of the run occurred between September 1 and September 16, with the median day of passage occurring on September 8. The average passage rate during the interquartile portion of the run was 5,135 fish per day. An estimated 3,423 chum salmon passed the project site on September 24, the final day of sonar operation (Table 2).

The diel pattern of migration of Sheenjek River chum salmon observed in most years (Dunbar 2004) was observed again in 2006 (Figure 10). 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. In contrast, the left bank passage was relatively constant. The period of minimal passage was 1200 hours, and maximum passage occurred at 0100 hours.

During the fall chum salmon run, excluding 12 days during the flood, 61% of migrating salmon passed on the right bank and 39% passed on the left bank (Figure 8). Early in the season, the majority of fish were migrating on the right bank. As the water level increased, the proportion of the fish on the right bank increased, until August 19 when all but one fish was detected on that bank. The next day (August 20) the sonar was removed from the left bank because of flooding conditions. When the left bank sonar was re-installed on September 1, 29 % of the fish were passing on that bank.

Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. On the right bank approximately 91% of the fish counted were passing through the first 14 m of the counting range (Figure 11). The first few meters had fewer fish due to the placement of the fish lead in relation to the transducer. On the left bank, 86% of the fish were detected within 9 m of the transducer. The unusual bimodal range distribution on the left bank, as seen in Figure 11, was most likely caused by natural diversions such as submerged debris and fallen clumps of riverbank.

AGE AND SEX COMPOSITION

In 2006, a total of 182 chum salmon (84 males; 98 females) were sampled for age, sex and length (Table 4). Forty-eight seine hauls were made between September 1 and September 20 at the sonar site (rkm 10). Between August 20 and September 20, fourteen carcasses were also collected for sampling between rkm 10 and 35. Three of the 182 vertebrae samples collected were unreadable. Of the remaining 179 samples, age-5 fish were the dominant age class at 73.2%. The age-4 fish were 22.9% of the sample with age-6 and age-3 fish representing 2.8%, and 1.1% of the sample respectively (Bales 2008) (Appendix C1).

DISCUSSION

ESCAPEMENT ESTIMATE

This was the second season (2005 being the first) that DIDSON was used to estimate fall chum salmon passage in the Sheenjek River, and only the second season since 1987 that both banks have been fully monitored. When deployed, the DIDSON systems performed well on both banks over the entire season with no major technical issues. The DIDSON, with its wide beam angle (29°) proved an excellent system on the previously unmonitored left bank despite the steep angle and uneven bottom. 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 2006 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 at the point when the project terminated in 2003, the sonar estimate may have underestimated the true 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 (unpublished memorandum from Bonnie Borba, ADF&G, 24 February 2004). This same scenario occurred in 2005 - with passage 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 escapement estimate of fall chum salmon into the Sheenjek River was 160,178 for the 47 day period between August 9 and September 24 2006. This would make the fourth largest escapement ever recorded in the Sheenjek River, and exceed the BEG of 50,000 to 104,000 chum salmon (Table 1 and Figure 12). Even if only the right bank estimate of 106,397 is used, as was the case before 2005, the estimate exceeds the BEG range. This large run was not expected because the major parent year escapements were 53,932 in 2001 (returning age-5 fish) and 31,642 in 2002 (returning age-4 fish).

For the second year in a row, 39% of the fish migrated on the previously unmonitored left bank. The assumption, based on drift gillnet studies conducted in the 1980s (Barton 1985), was 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 (Dunbar 2006). Continued estimation of salmon passage on both banks should yield more accurate information on the total escapement to the Sheenjek River.

High numbers of returning fall chum salmon were also reported in the neighboring Chandalar River, where 245,090 chum salmon were counted past the sonar station during the 50 day period between August 8 and September 26 (Melegari and Osborne 2007). This was the third largest escapement estimate ever recorded on the Chandalar River. During the 43 day period between September 2 and October 14, 21,942 (subsequently expanded to 30,849) chum salmon passed the DFO weir on the nearby Fishing Branch River (JTC 2007). The 2006 Fishing Branch River escapement was slightly above the interim escapement goal of 28,000 chum salmon.

The 2006 season was characterized by above average even-year fall chum salmon runs to most Yukon drainage river systems. All fall chum salmon escapement goals were achieved within the Yukon River drainage in 2006, and commercial fishing was limited only by market conditions and buyer interest. Subsistence restrictions were not necessary.

ACKNOWLEDGMENTS

The author wishes to acknowledge the sonar field camp personnel, ADF&G technicians Susan Klock, Elizabeth Smith and Yukon River Drainage Fisheries Association technician Harry George for their dedication to the project and collecting most of the data used in this report. Thanks to Bruce McIntosh, Malcolm McEwen and Carl Pfisterer for logistical support. Finally, I thank Carl Pfisterer, Toshihide Hamazaki, Bruce McIntosh, and an anonymous peer reviewer for their review and editorial comments on this manuscript. This investigation was partially funded by U.S./Canada Salmon Research Cooperative under NOAA Cooperative Agreement Award Number NA04NMF4380264.

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TABLES AND FIGURES

Table 1.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981–2006.

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	
1982-91	24-Aug	25-Sep	33	75,267	80,675
1992-01	08-Aug	23-Sep	47	99,390	97,277
2001-05	09-Aug	24-Sep	47	120,005	145,872

[a] Sonar-estimate is based on counts from both right and left bank sonar operations, all other years are left 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 and 2005 were based upon run time data from the Rampart tag recovery fish wheel.

Table 2.–Sonar-estimated passage of fall chum salmon in the Sheenjek River, 2006.

	Daily			Cumulative			% of Total
Date	Right Bank	Left Bank	Total	Right Bank	Left Bank	Total	Passage
8/09	157	89	246	157	89	246	0.00
8/10	229	72	301	386	161	547	0.00
8/11	177	105	282	563	266	829	0.01
8/12	197	144	341	760	410	1,170	0.01
8/13	189	132	321	949	542	1,491	0.01
8/14	184	243	427	1,133	785	1,918	0.01
8/15	354	369	723	1,487	1,154	2,641	0.02
8/16	804	337	1,141	2,291	1,491	3,782	0.02
8/17	1,543	151	1,694	3,834	1,642	5,476	0.03
8/18	1,655	18	1,673	5,489	1,660	7,149	0.04
8/19	1,511	1	1,512	7,000	1,661	8,661	0.05
8/20	1,224	ND	1,224	8,224	1,661	9,885	0.06
8/21	1,409 [a]	ND	1,409	9,633	1,661	11,294	0.07
8/22	1,594 [a]	ND	1,594	11,227	1,661	12,888	0.08
8/23	1,779 [a]	ND	1,779	13,006	1,661	14,667	0.09
8/24	1,964 [a]	ND	1,964	14,970	1,661	16,631	0.10
8/25	2,149 [a]	ND	2,149	17,119	1,661	18,780	0.12
8/26	2,334 [a]	ND	2,334	19,453	1,661	21,114	0.13
8/27	2,519 [a]	ND	2,519	21,972	1,661	23,633	0.15
8/28	2,704 [a]	ND	2,704	24,676	1,661	26,337	0.16
8/29	2,889 [a]	ND	2,889	27,565	1,661	29,226	0.18
8/30	3,078	1,257 [b]	4,335	30,643	2,918	33,561	0.21
8/31	3,148	1,286 [b]	4,434	33,791	4,204	37,995	0.24
9/01	3,621	1,514	5,135	37,412	5,718	43,130	0.27 [c]
9/02	3,603	1,844	5,447	41,015	7,562	48,577	0.30
9/03	3,716	2,194	5,910	44,731	9,756	54,487	0.34
9/04	3,896	2,250	6,146	48,627	12,006	60,633	0.38
9/05	3,920	2,559	6,479	52,547	14,565	67,112	0.42
9/06	3,834	2,167	6,001	56,381	16,732	73,113	0.46
9/07	2,716	1,970	4,686	59,097	18,702	77,799	0.49
9/08	2,120	2,271	4,391	61,217	20,973	82,190	0.51
9/09	1,785	2,014	3,799	63,002	22,987	85,989	0.54
9/10	2,147	1,689	3,836	65,149	24,676	89,825	0.56
9/11	1,749	1,894	3,643	66,898	26,570	93,468	0.58
9/12	2,226	1,695	3,921	69,124	28,265	97,389	0.61
9/13	3,299	1,437	4,736	72,423	29,702	102,125	0.64
9/14	2,274	1,909	4,183	74,697	31,611	106,308	0.66
9/15	4,141	2,889	7,030	78,838	34,500	113,338	0.71
9/16	4,556	2,267	6,823	83,394	36,767	120,161	0.75
9/17	4,390	1,958	6,348	87,784	38,725	126,509	0.79
9/18	2,679	2,658	5,337	90,463	41,383	131,846	0.82
9/19	2,854	2,696	5,550	93,317	44,079	137,396	0.86
9/20	2,886	2,172	5,058	96,203	46,251	142,454	0.89
9/21	2,499	2,338	4,837	98,702	48,589	147,291	0.92
9/22	2,559	1,952	4,511	101,261	50,541	151,802	0.95
9/23	3,406	1,547	4,953	104,667	52,088	156,755	0.98
9/24	1,730	1,693	3,423	106,397	53,781	160,178	1.00
Total	106,397	53,781	160,178	106,397	53,781	160,178	

Note: ND = No data collected.

[a] Calculated using linear interpolation for days sonar was not operating because of flood conditions.

[b] Calculated using relationship of left:right bank estimates from day immediately following re-installation of sonar after flood.

[c] Single boxed area identifies central half of the run, and the bold box identifies the mid-point.

Table 3.–Number of minutes by bank that were either expanded or interpolated to calculate the hourly or daily passage estimate, 2006.

Date	Right Bank	Left Bank
8/9	870	1,020
8/10		6
8/11		
8/12		2
8/13		
8/14		
8/15	88	81
8/16		
8/17		
8/18		
8/19		
8/20	279	782
8/21	1,440	1,440
8/22	1,440	1,440
8/23	1,440	1,440
8/24	1,440	1,440
8/25	1,440	1,440
8/26	1,440	1,440
8/27	1,440	1,440
8/28	1,440	1,440
8/29	1,440	1,440
8/30	1,031	1,440
8/31		1,440
9/1		968
9/2		
9/3	6	153
9/4		14
9/5		44
9/6		23
9/7		
9/8	2	
9/9		
9/10		
9/11		18
9/12		123
9/13		
9/14		
9/15		108
9/16		
9/17		
9/18		
9/19		
9/20		
9/21		
9/22		
9/23		
9/24		
Total	15,236	19,182

Table 4.–Sheenjek River test fishing (beach seine) and carcass collection results, 2006.

Date	Number of Sets	Location (rkm)[a]	Chum Salmon Captured Male		Female		Total	Other Fish
8/20	0[b]	10	1		0		1	0
9/01	5	10	5		1		6	8
9/02	3	10	6		6		12	2
9/03	4	10	8		8		16	5
9/05	3	10	2		4		6	2
9/06	4	10	5		14		19	7
9/08	0[b]	10	1		1		2	0
9/08	3	10	5		7		12	5
9/11	4	10	6		7		13	4
9/12	6	10	3		5		8	3
9/14	5	10	4		7		11	3
9/15	5	10	13		8		21	0
9/16	0[b]	10	0		1		1	0
9/17	0[b]	22-35	7		1		8	0
9/18	0[b]	10	0		1		1	0
9/18	3	10	12		16		28	3
9/20	0[b]	10	0		1		1	0
9/20	3	10	6		10		16	0
Total	48		84	(46%)	98	(54%)	182	42

[a] Locations are river kilometer (rkm); camp is at 10 rkm.

[b] Carcass collection.

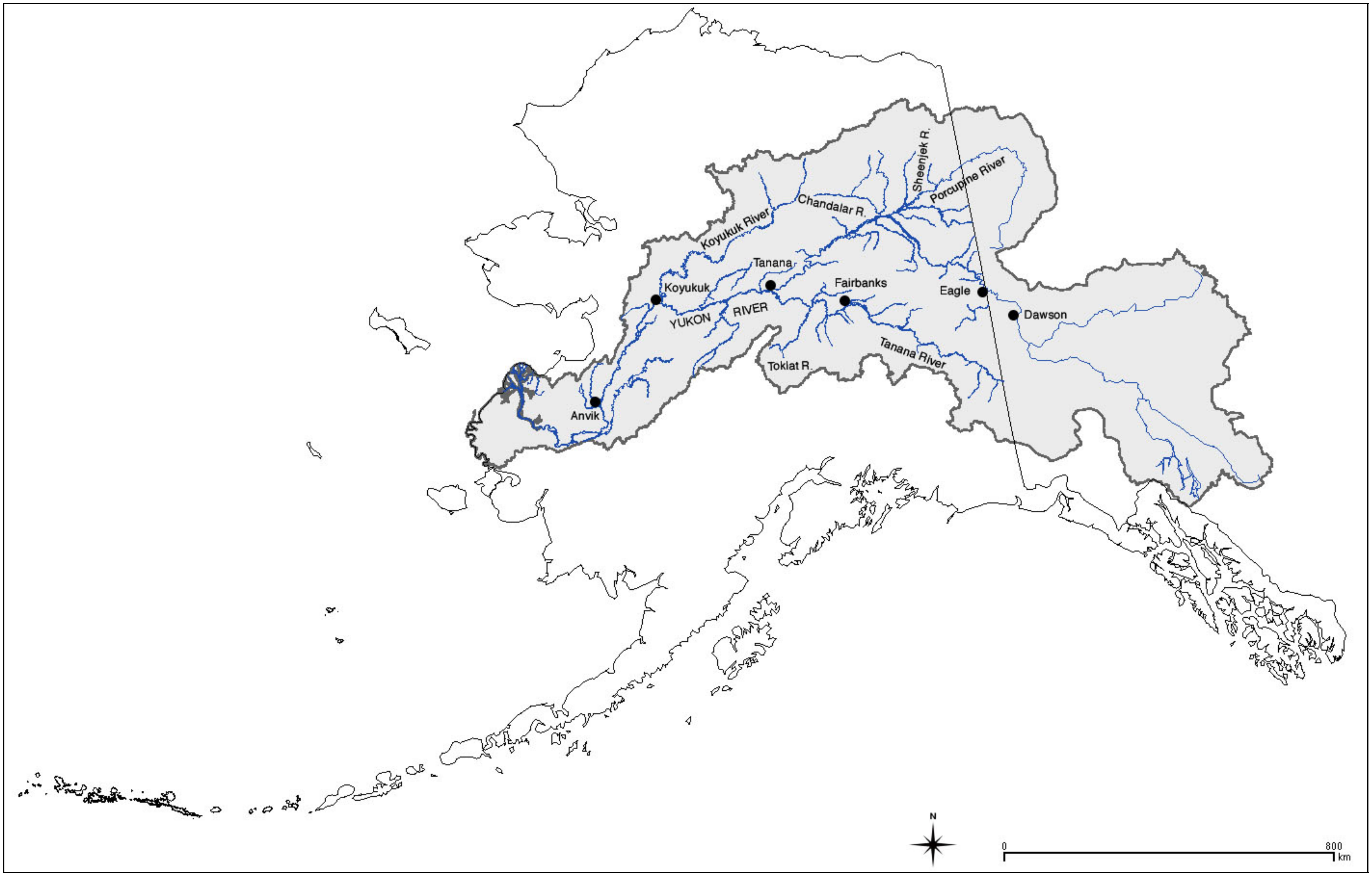

Figure 1.–The Yukon River drainage showing selected locations.

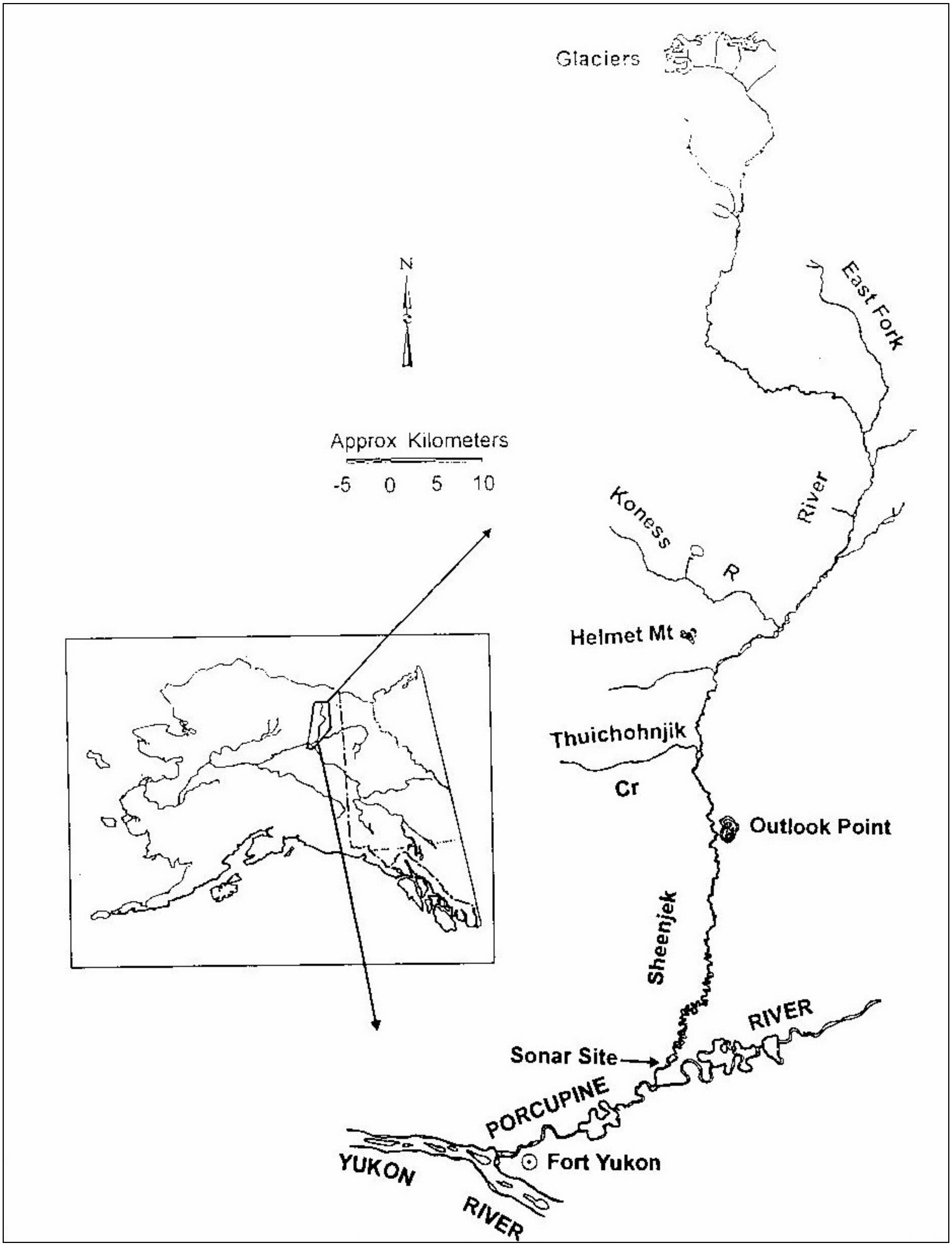

Figure 2.–The Sheenjek River drainage.

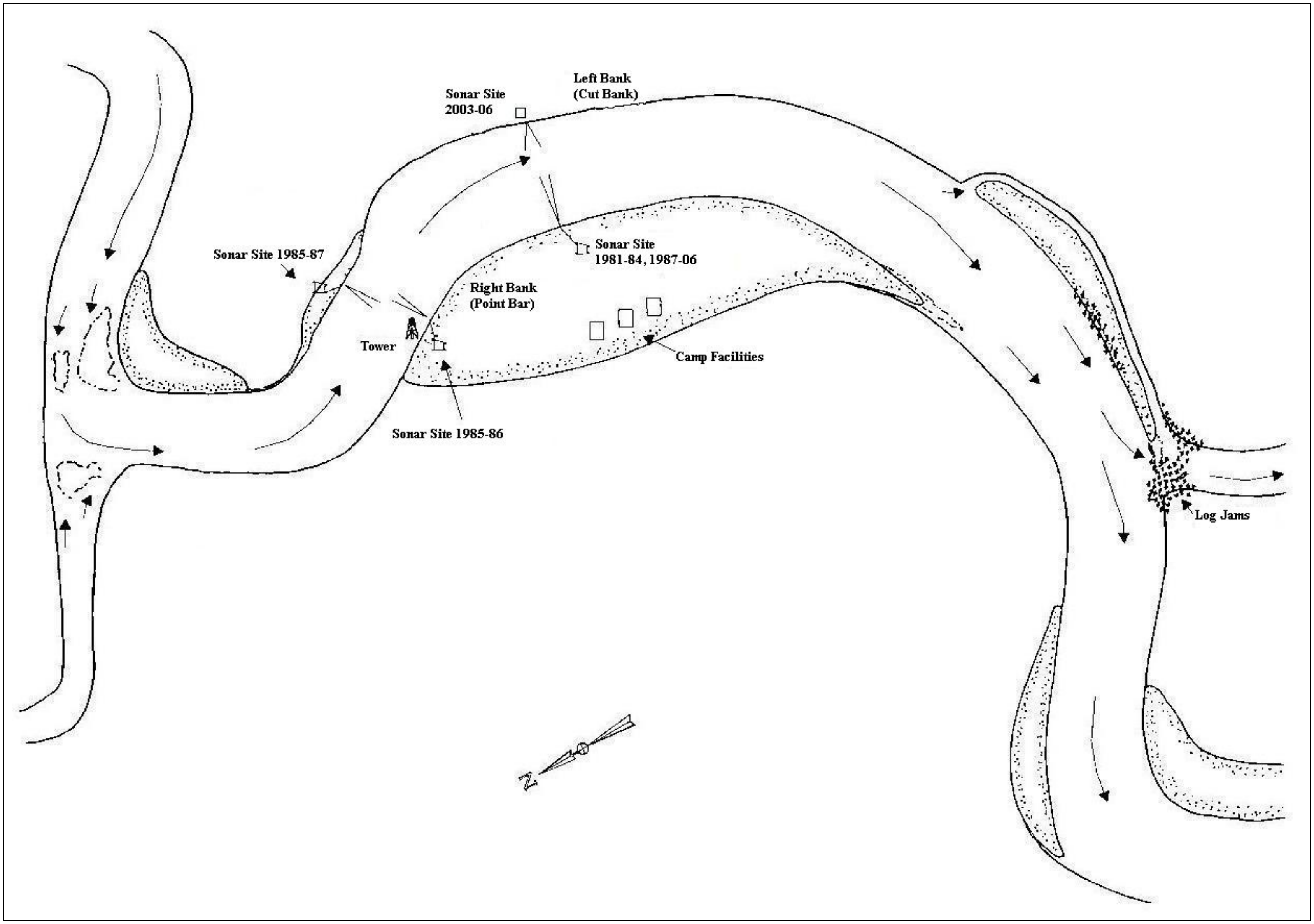

Figure 3.–The Sheenjek River sonar project site.

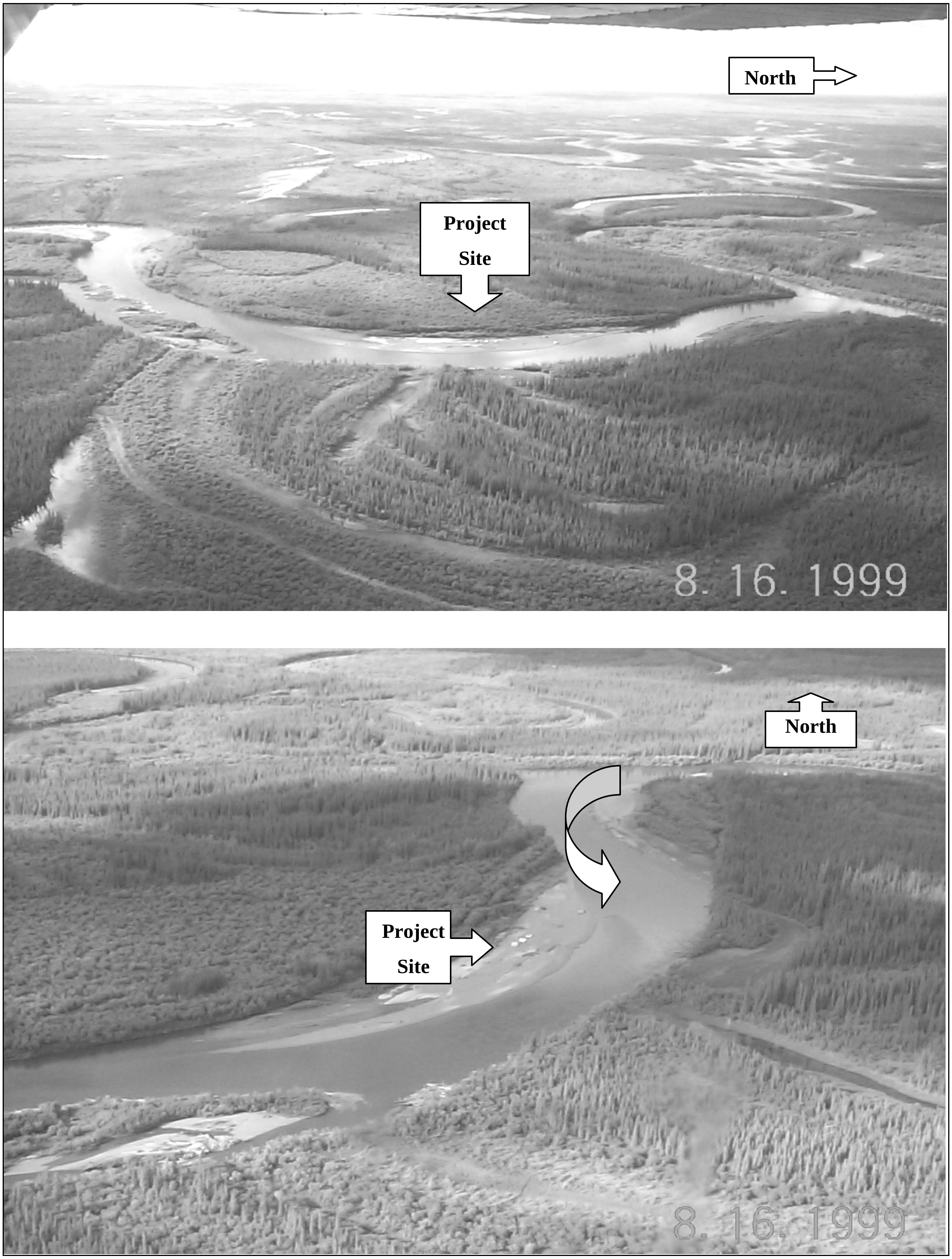

Figure 4.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

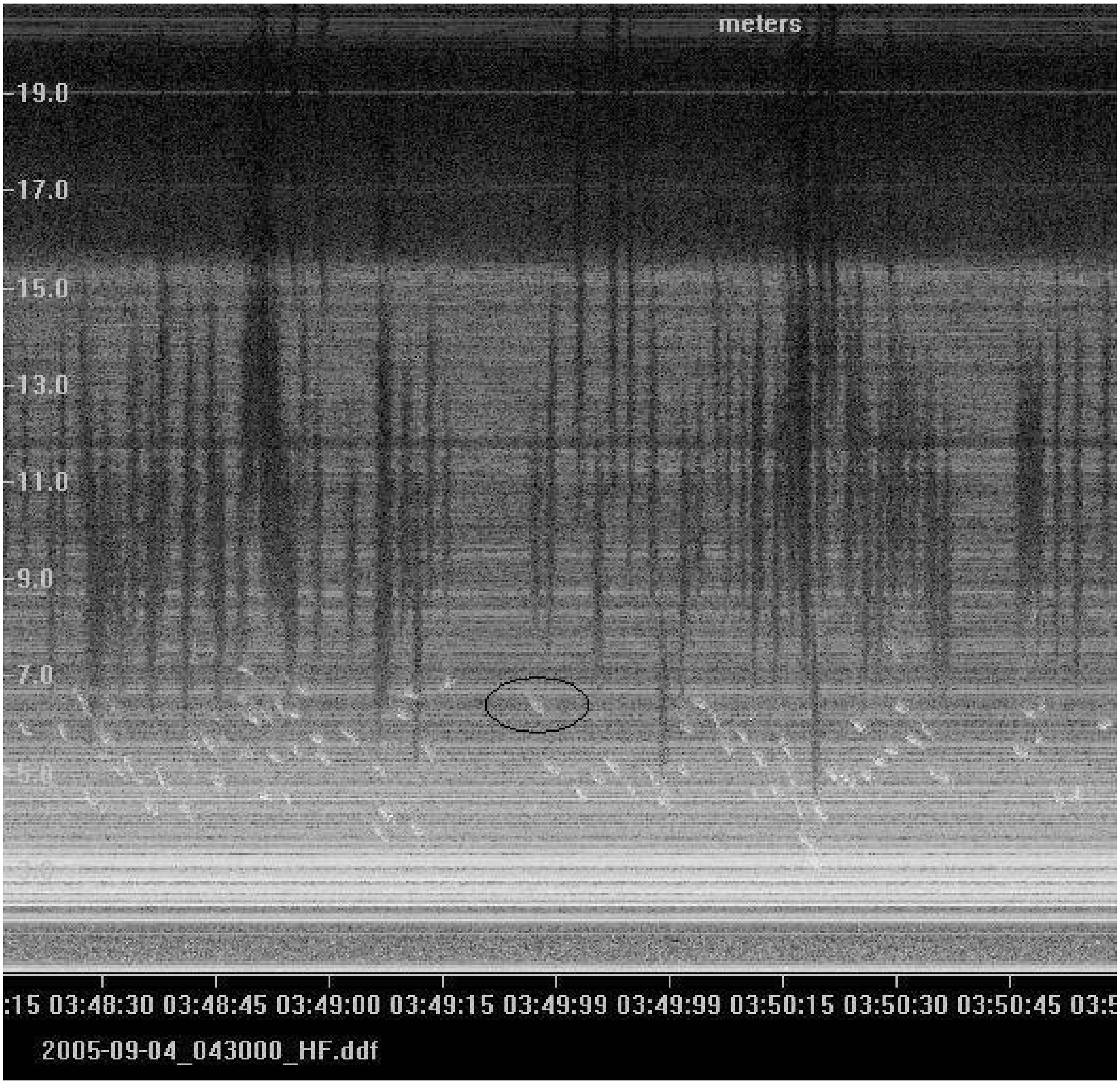

Figure 5.–Screenshot of DIDSON echogram with oval around representative fish.

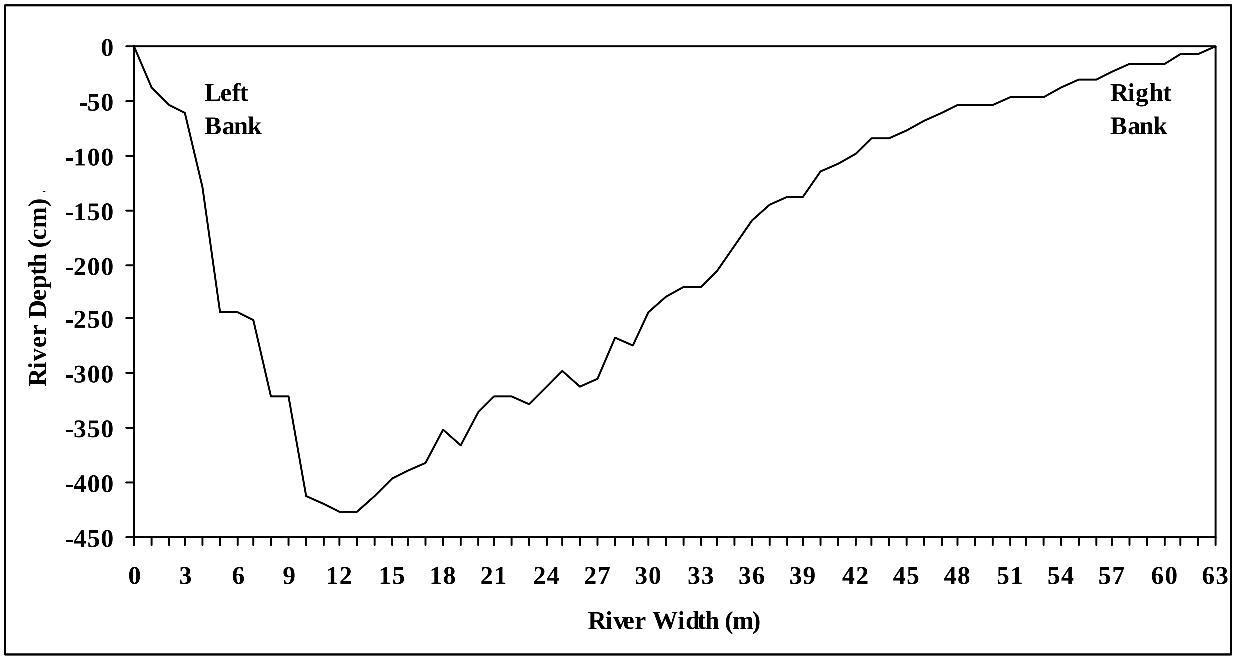

Figure 6.–Depth profile (downstream view) made August 8, 2006 at the Sheenjek River sonar project site.

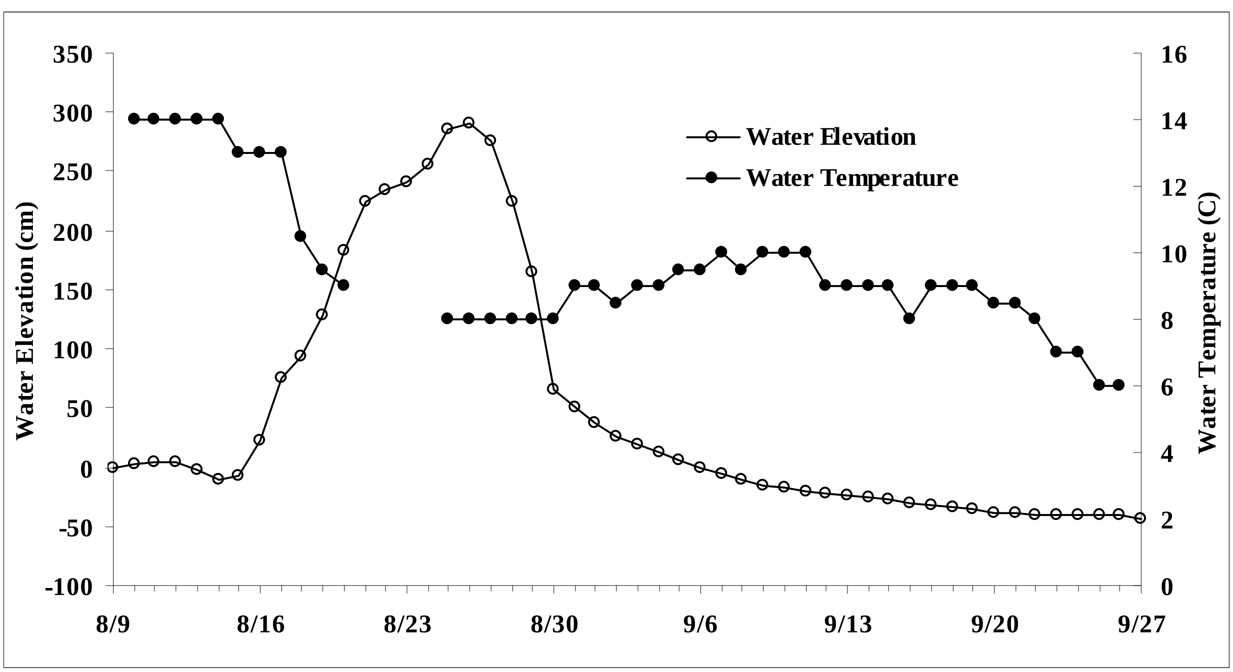

Figure 7.–Changes in daily water elevation relative to August 9, and water measured at the Sheenjek River sonar project site, 2006.

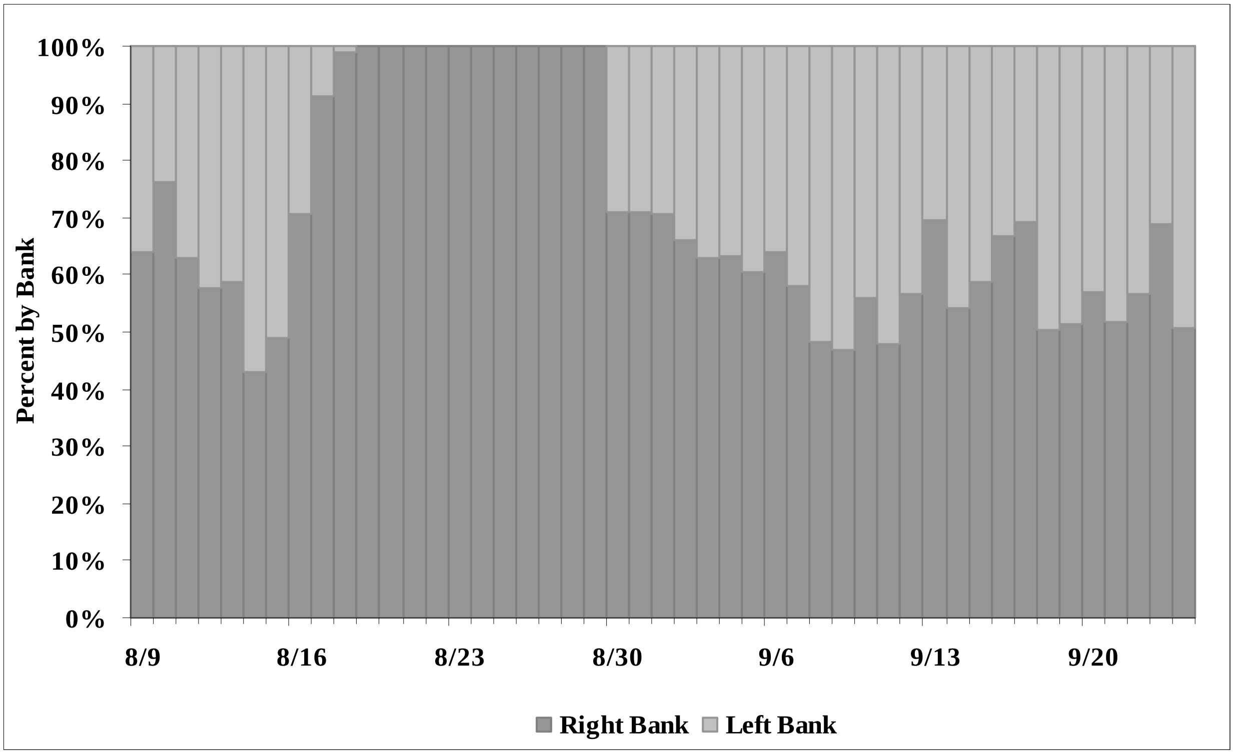

Figure 8.–Percentage of fish by bank at Sheenjek River sonar site, August 9 through September 24, 2006.

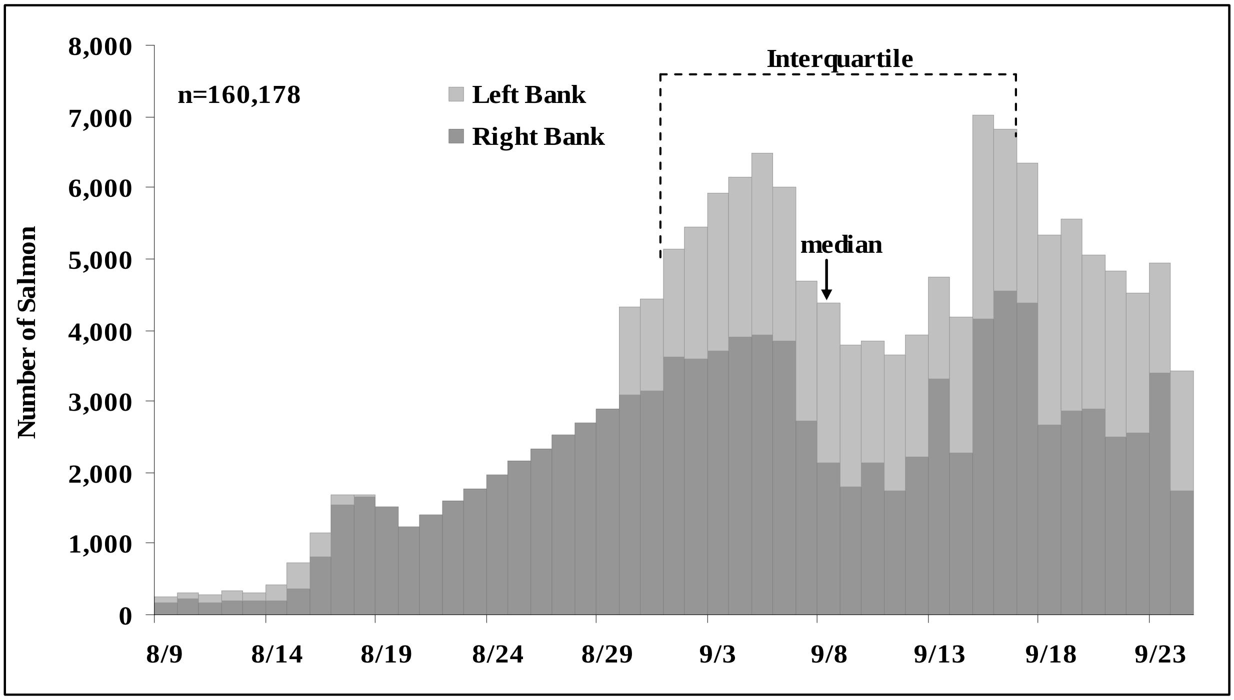

Figure 9.–Adjusted fall chum salmon sonar counts by date, Sheenjek River, 2006.

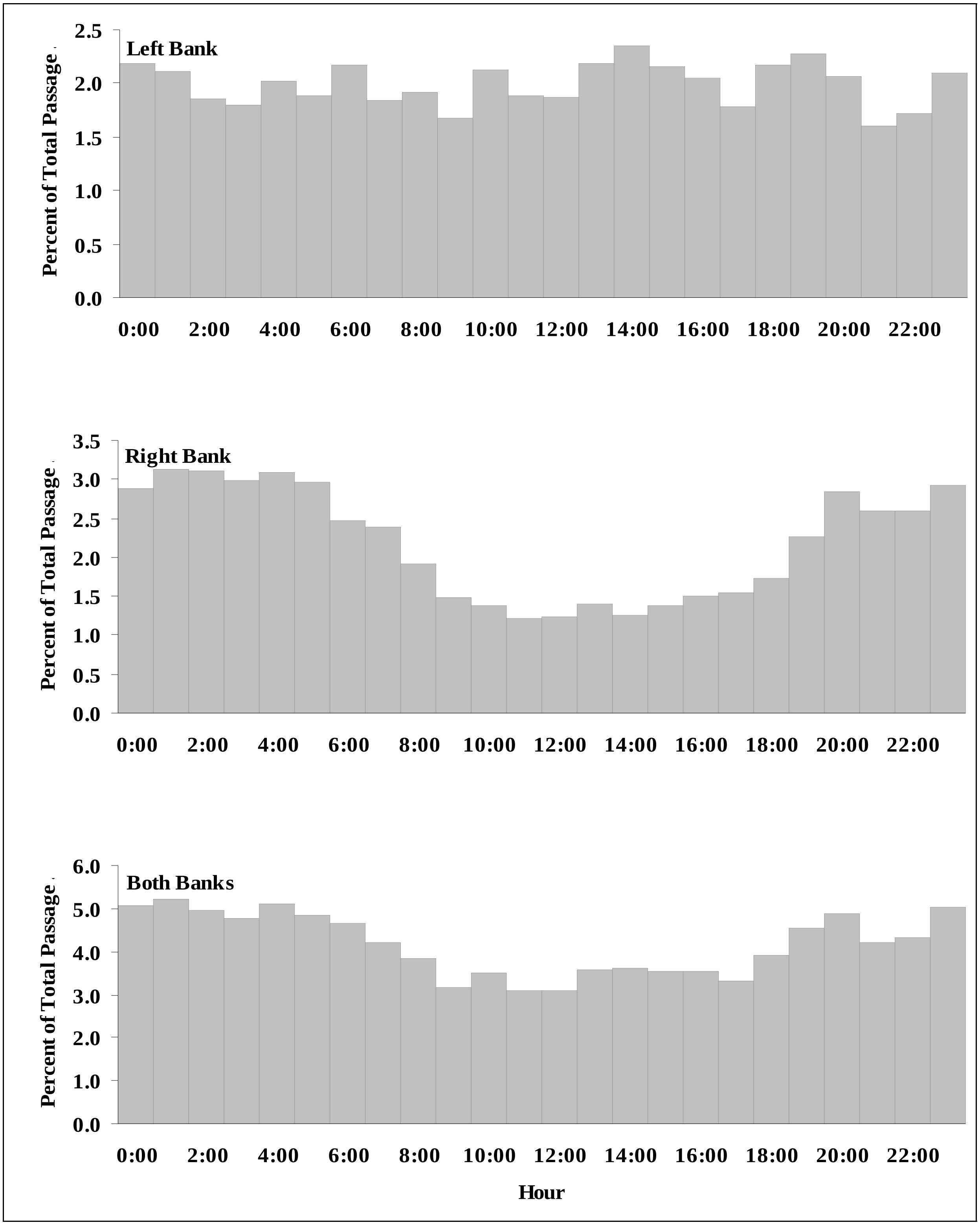

Figure 10.–Diel fall chum salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Sheenjek River, from August 11 through September 24, 2006. Only days with complete data are included.

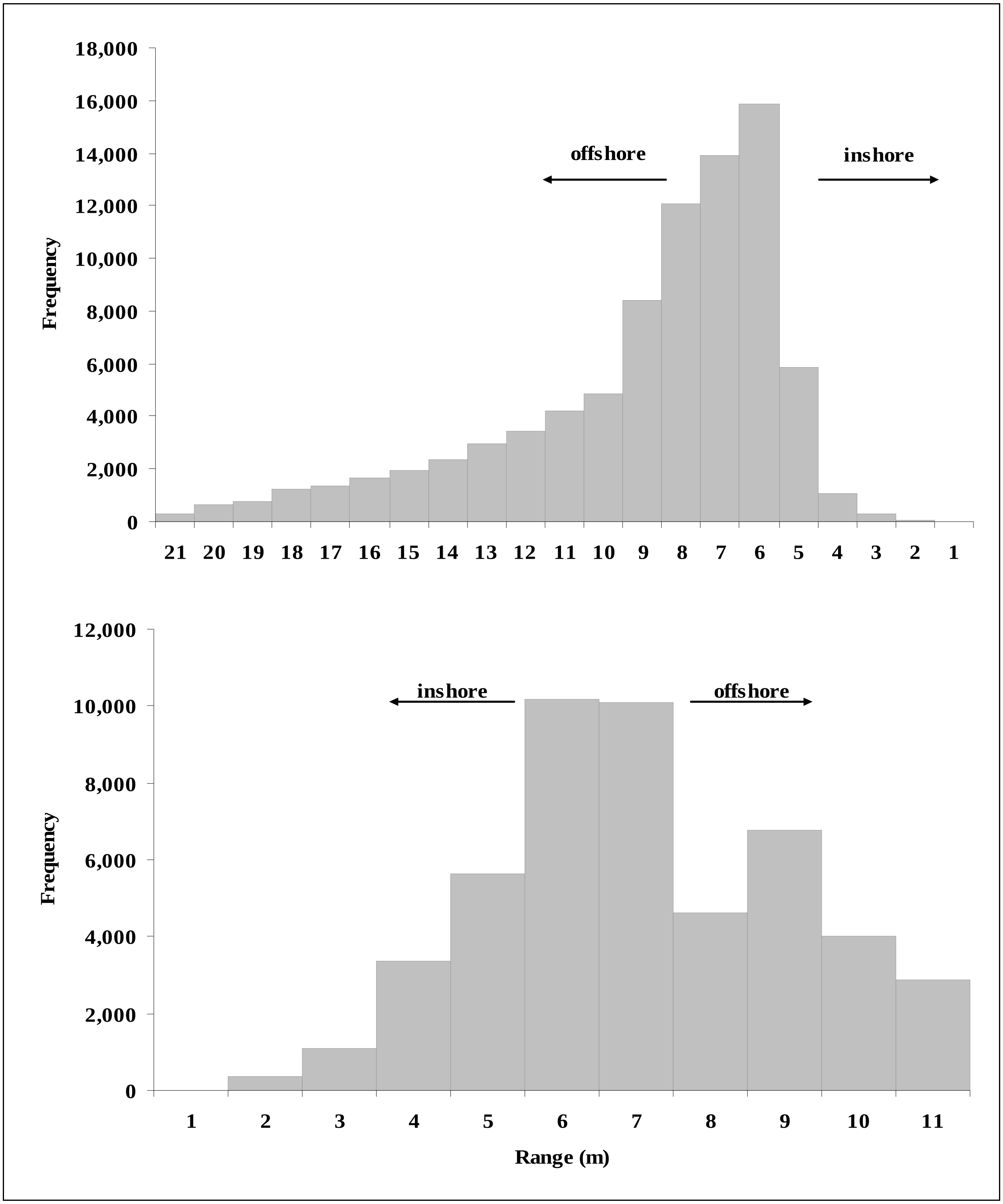

Figure 11.–Right bank (top) and left bank (bottom) horizontal distribution (relative to transducer)of upstream fall chum salmon passage in the Sheenjek River, 2006.

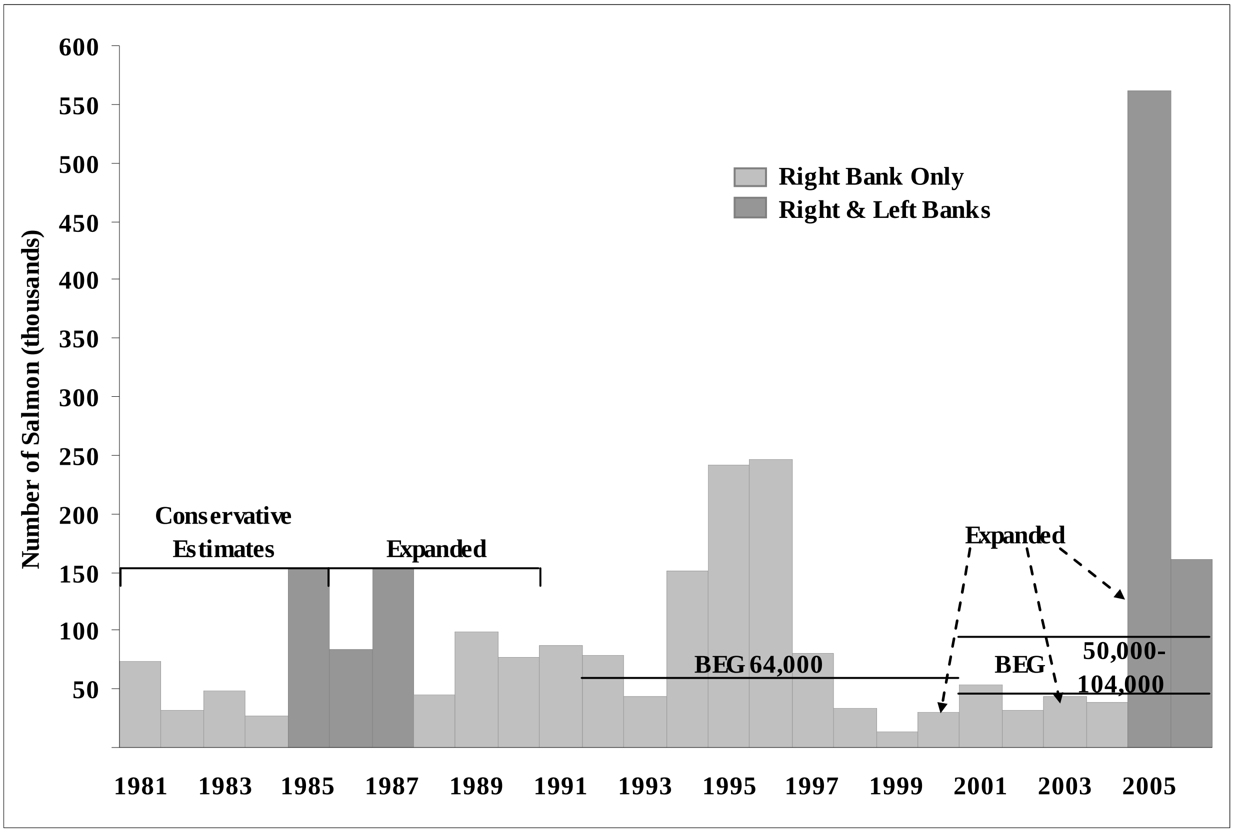

Figure 12.–Sonar-estimated escapement and BEG (horizontal lines) of fall chum salmon in the Sheenjek River, 1981–2006.

APPENDIX A.
HARVEST OF YUKON RIVER FALL CHUM SALMON

Appendix A1.–Alaskan and Canadian total harvest of Yukon River fall chum salmon, 1970–2006.

Year	Canada [a]	Alaska [b,c]	Total
1970	3,711	265,096	268,807
1971	16,911	246,756	263,667
1972	7,532	188,178	195,710
1973	10,135	285,760	295,895
1974	11,646	383,552	395,198
1975	20,600	361,600	382,200
1976	5,200	228,717	233,917
1977	12,479	340,757	353,236
1978	9,566	331,250	340,816
1979	22,084	593,293	615,377
1980	22,218	466,087	488,305
1981	22,281	654,976	677,257
1982	16,091	357,084	373,175
1983	29,490	495,526	525,016
1984	29,267	383,055	412,322
1985	41,265	474,216	515,481
1986	14,543	303,485	318,028
1987	44,480	361,663 [d]	406,143
1988	33,565	319,677	353,242
1989	23,020	518,157	541,177
1990	33,622	316,478	350,100
1991	35,418	403,678	439,096
1992	20,815	128,031 [e]	148,846
1993	14,090	76,925 [d]	91,015
1994	38,008	131,217	169,225
1995	45,600	415,547	461,147
1996	24,354	236,569	260,923
1997	15,580	154,479 [e]	170,059
1998	7,901	62,869 [d]	70,770
1999	19,506	110,369	129,875
2000	9,236	19,307 [d]	28,543
2001	9,512	35,154 [d]	44,666
2002	8,018	19,393 [d]	27,411
2003	11,355	68,174	79,529
2004	9,750	66,167	75,917
2005	18,324	271,933	290,257
2006 [f]	11,796	22,694	239,490
Average			
1971-05	20,385	280,288	300,673
1996-05	13,354	104,441	117,795
2001-05	11,392	92,164	103,556

Source: Modified from JTC 2007.

[a] Catch in number of salmon. Includes commercial, Aboriginal, domestic and sport catches combined.

[b] Catch in number of salmon. Includes estimated number of salmon harvested for commercial production of salmon roe.

[c] Commercial, subsistence, personal-use and ADF&G test fish catches combined.

[d] Commercial fishery did not operate in Alaskan portion of drainage.

[e] Commercial fishery operated only in District 6 (Tanana River).

[f] Data are preliminary.

APPENDIX B.
CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climate and hydrologic observations at the Sheenjek River project site, 2006.

					Temperature (C°)			Water Level (cm)		
	Precipitation	Cloud Cover	Wind		Water	Air		± 24 h	Relative to	Water Color
Date	(code)[a]	(code)[b]	Direction	Velocity (mph)	Surface	Minimum	Maximum	Change	Zero Datum	(code)[c]
8/09	B	S	ND	ND	ND	ND	ND	zero datum	0	B
8/10	B	B	S	3	14.0	ND	ND	2	2	B
8/11	A	C	N	4	14.0	10	30	3	5	B
8/12	B	S	E	5	14.0	12	21	0	5	B
8/13	B	C	S	2	14.0	11	21	-7	-2	B
8/14	A	S	E	2	14.0	5	23	-9	-11	B
8/15	B	S	S	4	13.0	8	23	3	-8	B
8/16	B	S	N	4	13.0	11	18	30	22	C
8/17	B	S	S	4	13.0	9	17	54	76	D
8/18	B	O	NW	6	10.5	6	16	18	94	D
8/19	A	O	NNW	5	9.5	8	17	35	129	D
8/20	B	O	ND	0	9.0	8	20	54	183	D
8/21	B	O	ND	ND	ND	ND	ND	42	225	D
8/22	A	O	ND	ND	ND	ND	ND	30	235	D
8/23	A	O	ND	ND	ND	ND	ND	20	240	D
8/24	A	S	ND	ND	ND	ND	ND	5	255	D
8/25	A	S	NE	15	8.0	ND	12	15	285	D
8/26	A	B	NE	5	8.0	3	14	5	290	D
8/27	A	S	NE	5	8.0	6	13	-15	275	D
8/28	A	S	NE	3	8.0	2	16	-50	225	D
8/29	B	ND	ND	0	8.0	3	15	-60	165	C
8/30	A	C	ND	ND	8.0	4	22	-99	66	C
8/31	A	S	NW	13	9.0	3	15	-16	50	B
9/01	A	B	NE	7	9.0	7	15	-12	38	B
9/02	B	B	ND	0	8.5	1	22	-12	26	B
9/03	A	C	N	3	9.0	3	21	-7	19	B
9/04	A	C	NE	3	9.0	2	20	-7	12	B
9/05	A	B	NE	2	9.5	8	23	-6	6	B
9/06	B	C	SW	3	9.5	9	21	-6	0	B
9/07	A	C	ND	0	10.0	3	24	-5	-5	B

-continued-

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Date	Precipitation (code)[a]	Cloud Cover (code)[b]	Wind Direction	Wind Velocity (mph)	Temperature (C°) Water Surface	Temperature (C°) Air Minimum	Temperature (C°) Air Maximum	Water Level (cm) ± 24 h Change	Water Level (cm) Relative to Zero Datum	Water Color (code)[c]
9/08	A	B	NE	1	9.5	4	24	-5	-10	B
9/09	A	B	ND	0	10.0	2	23	-5	-15	B
9/10	A	O	NE	1	10.0	7	19	-3	-18	B
9/11	A	S	NE	2	10.0	7	22	-3	-21	B
9/12	A	O	ND	0	9.0	1	15	-1	-22	B
9/13	A	B	SW	3	9.0	4	16	-2	-24	B
9/14	A	S	ND	0	9.0	4	21	-2	-26	B
9/15	A	B	NE	3	9.0	4	20	-2	-28	A
9/16	A	B	SW	4	8.0	2	20	-2	-30	A
9/17	A	B	SW	2	9.0	10	21	-2	-32	A
9/18	A	C	NE	3	9.0	5	21	-2	-34	A
9/19	A	B	E	5	9.0	7	20	-2	-36	A
9/20	A	O	ND	0	8.5	7	17	-2	-38	A
9/21	B	B	E	2	8.5	7	15	-1	-39	A
9/22	B	B	ND	0	8.0	7	14	-1	-40	A
9/23	B	C	NW	8	7.0	7	14	-1	-41	A
9/24	A	C	NW	2	7.0	-1	14	-1	-41	A
9/25	A	C	SE	3	6.0	-4	13	0	-41	A
9/26	A	B	E	5	6.0	-1	11	0	-41	A
9/27	ND	ND	ND	ND	ND	ND	ND	-2	-43	A
Average					9.6	5	19			

Note: ND refers to time when no data was collected.

[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] Instantaneous 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 C.
AGE COMPOSITION ESTIMATES

Appendix C1.–Age composition estimates of Sheenjek River fall chum salmon, 1974–2006.

Year[a]	Sample (readable)	Age 3	Age 4	Age 5	Age 6	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[d]	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	0.011	0.229	0.732	0.028	160,178
Avg 1974-05		0.059	0.646	0.285	0.010	94,193
Avg 1996-05		0.024	0.609	0.354	0.021	113,516
Even Years		0.090	0.534	0.367	0.010	65,993
Odd years		0.027	0.758	0.204	0.011	122,394

Note: ND refers to no data collected.

[a] Age determination from scales for years 1974–1985; and from vertebrae 1986–2006.

[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 5–20.

[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.