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Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2003

by

Roger Dunbar

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

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

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518
December 2006

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Roger Dunbar,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Rd., Fairbanks, AK 99701, USA

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ABSTRACT

Hydroacoustic Technology Incorporated (HTI) fixed-location, split-beam sonar was used to estimate chum salmon *Oncorhynchus keta* escapement in the Sheenjek River from August 9 to September 26, 2003. The sonar-estimated escapement of 38,321 chum salmon through September 26 was subsequently expanded to a total abundance estimate of 44,047 using run time data from the Rampart tag recovery fish wheel. This is 12% below the low end of the Sheenjek River biological escapement goal (BEG) of 50,000 to 104,000 chum salmon. Median passage was observed on September 18, about 10 days later than average; peak single day passage was September 23 when 3,321 fish were estimated to have 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 near shore. However, the passage estimate should be considered conservative since it does not include fish migrating beyond the counting range (including along the left bank), or fish present before sonar equipment was in operation, here left and right bank refers to the bank on the left or right side of the river when looking downstream. Only 90 vertebrae samples for age determination were collected because of low salmon passage. Analysis of vertebrae collections showed age-4 fish dominated at 82% and age-5 fish represented 15% of all fish sampled. Age-3 and age-6 fish comprised about 1% each. Male chum salmon comprised 54% of the sample and 46% were female. Due to inadequate conditions for transducer placement on the left bank, only the right bank of the Sheenjek River has historically been used to estimate fish passage. In an effort to estimate fish passage on the left bank, a new dual frequency, multi-beam sonar was deployed on the left bank from September 2 through September 13, 2003. This dual frequency identification sonar (DIDSON™) allows placement in areas not possible with other systems. Using results obtained with the DIDSON™, it is estimated that 33% of the Sheenjek River chum salmon run passed the sonar site on the left bank.

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).

Annual escapement estimates for the Sheenjek River averaged 100,533 spawners for the period 1991–2000 and approximately 32,589 spawners for the most recent 5-year period of 1998–2002 (Table 1). From 1992 to 2000, the Sheenjek River established minimum biological escapement goal (BEG) was 64,000 fall chum salmon, based upon hydroacoustic assessment from 1974 to 1990 (Buklis 1993). In 2001, the Alaska Department of Fish and Game (ADF&G) completed a review of the escapement goal for Yukon River fall chum stocks, of which the Sheenjek River assessment is a component. Based on this review of long term escapement, catch, and age composition data, the BEG for the Sheenjek River was set at a range of 50,000 to 104,000 fall chum salmon (Eggers 2001).

INRIVER FISHERIES

Fall chum salmon are in great demand for commercial and subsistence uses. Commercial harvest is permitted along the entire mainstem of the 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 (Table 2). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s, total catch averaged 535,826 fish from 1979–1983. Harvest peaked in 1979 at 615,000 and in 1981 at 677,000 fish. Since the mid-1980s, management strategies have been implemented to reduce commercial exploitation on fall chum stocks to improve low escapements observed throughout the drainage during the early 1980s. In 1987, the commercial fall chum fishery was completely closed in the Alaskan portion of the drainage. In 1992, commercial fishing in Alaska 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 from 1994 through 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 from 1997 to 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. Although limited, the 2003 season marks the first commercial fishing for fall chum since 1999. Subsistence harvest of fall chum in 2003 was also limited.

ESCAPEMENT ASSESSMENT

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

Department of Fisheries and Oceans Canada (DFO) annually estimated abundance of fall chum salmon crossing the U.S./Canada border in the mainstem river into Yukon Territory since 1982 (excluding 1984) using mark–recapture techniques (JTC 2004; Milligan et al. 1984). DFO has also operated a weir in the Fishing Branch River from 1971 to 1975, and 1985 to present (excluding 1990).

In the Alaskan portion of the drainage, the United States Fish and Wildlife Service (USFWS) estimated annual fall chum salmon escapement to the Chandalar River from 1986 through 1990 using fixed-location, single-beam hydroacoustic techniques (Daum et al. 1992). Results from this project revealed fall chum salmon production was similar to that of the nearby Sheenjek River. Subsequently, in 1994, the USFWS initiated a 5-year study to reassess the population status of fall chum salmon with a newly developed split-beam hydroacoustic system. The initial year, 1994, was used to develop site-specific operational methods, evaluate site characteristics, and describe possible data collection biases (Daum and Osborne 1995). The project was again operated in 1995 and was fully operational from 1996 through 2003. Annual escapement estimates ranged from a low of 65,894 in 2000 to a high of 280,999 in 1995 (JTC 2004; Osborne and Melegari 2002).

ADF&G initiated an experimental main river sonar project near Pilot Station (rivermile 123) in 1978 to estimate salmon passage by species. During the developmental years of 1978 through 1985, data acquisition and sampling designs were investigated using various models of scientific fisheries hydroacoustic systems. The project has operated annually since 1986, except for 1992 when it was operated for experimental purposes with upgraded sonar equipment and 1996 when it was operated for training purposes only. Because of recent improvements in methodologies, historic data are not comparable to improved assessments available since 1995 (JTC 1999). In addition to the Pilot Station sonar project operated by ADF&G, USFWS has conducted a mark–recapture project annually since 1996 at an area known locally as "The Rapids", a narrow canyon near Rampart, which is 1,176 km from the mouth of the Yukon River. The purpose of this project is to provide abundance estimates of adult fall chum salmon bound for the upper Yukon River (Gordon et al. 1998; Underwood et al. 2000).

ADF&G has conducted annual mark–recapture studies in the Tanana River since 1995 to estimate abundance of fall chum salmon bound for the upper river, upstream of the Kantishna River (Cleary and Hamazaki 2004). ADF&G also conducts replicate ground surveys of upper Tanana River drainage fall chum spawning areas in the Delta River. Annual intensive ground surveys cover the major spawning area in the upper Toklat River. Total abundance estimates are derived from the Toklat and Delta surveys, using spawner residence time data collected from the Delta River (Barton 1997; JTC 2004). Hydroacoustic assessment of fall chum salmon escapement in the Toklat River was investigated in 1994, 1995, and 1996 (Barton 1998). The Toklat River sonar project was reinstated in 2001, but in 2002 and 2003 budget constraints and concerns about data quality prevented operation (P. Cleary, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

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 the USFWS reported chum salmon spawning in September. From 1974 to 1981, escapement observations in the Sheenjek River were limited to aerial surveys flown in late September and early October (Barton 1984a). Subsequent to 1980, escapements were monitored annually using fixed location, single-beam, side-looking sonar systems (Dunbar 2004). However, an early segment of the fall chum salmon run was not included by sonar counting operations from 1981 through 1990 because late project startups centered around August 25. By comparison, the average startup during the 1991 through 2000 period was August 8, more than 2 weeks earlier than previous years. The sonar-estimated escapements for the years 1986 through 1990 were subsequently expanded to include fish passing before sonar operations (Barton 1995). Termination of sonar counting was consistent from 1981 through 2003, averaging September

25, except in 2000 when the project was terminated early because of extremely low water (Barton 2002).

The Sheenjek River sonar project used Bendix[1] sonar equipment to estimate migrating chum salmon escapement from 1981 to 2002. Although the Bendix sonar worked well over the years, it is no longer in production and the company provides no support for the system. To continue providing the best possible data to manage the Yukon River fisheries, ADF&G purchased an HTI model 241 split-beam digital hydroacoustic system for use on the Sheenjek River. In 2000 and 2002, the new system was tested for a short time and produced results comparable to the Bendix equipment (Dunbar 2004). In 2003, the new HTI sonar system was used exclusively for the first time to enumerate chum salmon in the Sheenjek River. Due to inadequate conditions for transducer placement on the left bank, only the right bank of the Sheenjek River has been used to estimate fish passage. In an effort to estimate fish passage on the left bank, a new dual frequency, multi-beam sonar was purchased by ADF&G to test on the left bank in 2003. The imaging capabilities of the dual frequency identification sonar (DIDSON™) allows placement in areas not possible with other systems. This report presents results of studies conducted in 2003.

STUDY AREA

The sonar project site is located approximately 10 km upstream from the mouth of the Sheenjek River. Although created by glaciers, the Sheenjek River has numerous clearwater tributaries. Water clarity in the lower river is somewhat unpredictable, but is generally clearest during periods of low water. The water level normally begins to drop in late August and 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.

OBJECTIVES

Goals for the 2003 Sheenjek River fall chum salmon study were to estimate the timing and magnitude of adult salmon escapement, characterize age and sex composition, and to deploy, test, and estimate chum salmon passage with the DIDSON™ on the left bank. To accomplish these tasks, these specific objectives were identified:

- Estimate timing and magnitude of chum salmon escapement using fixed-location, split-beam, and side-looking hydroacoustic techniques.
- Estimate age and sex composition of the spawning chum salmon population from a minimum of 30–35 vertebrae samples per week up to 200 for the season, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 (α=0.05 and d=0.10). Fish ages are combined freshwater and saltwater ages.
- Monitor selected climatological and hydrological parameters daily at the project site for use as baseline data.
- Deploy, test, and estimate chum salmon passage with the DIDSON™ on the left bank.

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

METHODS

HYDROACOUSTIC EQUIPMENT

A fixed-location, split-beam, fisheries hydroacoustic system developed by HTI was used to estimate fall chum salmon abundance in the Sheenjek River in 2003. Fish passage was monitored with a model 241 digital echo sounder (Appendix A1) and a 2° by 10° 200 kHz split-beam transducer deployed from a right-bank point bar at the historic sonar site (Figures 3 and 4). The transducer was attached to an HTI model 662H dual-axis rotator, using a HTI model 660 remote controller to facilitate aiming. The HTI system is capable of distinguishing upstream fish from downstream fish and debris, determining fish velocity, discriminating between random reverberation and fish targets, and providing a less biased estimate of target strength (Hydroacoustic Technology Incorporated 2000).

The HTI digital echo sounder is a state-of-the-art system designed for fisheries research. Accurate time-varied gains (TVGs) and stable transmit and receive sensitivities are possible. Short pulse widths can be used to improve resolution between targets. A Digital Echo Processor (DEP) is integrated into the system. A laptop computer paired with the sounder provides access to all DEP settings and permits saving settings for future use. An oscilloscope can be linked to the sounder for diagnostic use, such as in-situ system calibration or transducer aiming. After all parameters are determined for data acquisition, the system operates 24 hours a day. Digital files are created by the DEP and edited by the field crew to produce an estimate of fish passage. A crew, consisting of 3 technicians, monitors the sonar and interprets the data during three 7 hour shifts per day.

The system was configured with a transmit pulse duration of 0.4 milliseconds (ms), ping rate of 14 pulses per second, and attenuation coefficient of 0.0 dB/m. Data collection threshold was set so that only targets larger than -39.8 dB on axis were detected while background noise such as boat wakes, river bottom, and the water surface was minimized. System calibration was confirmed using a 38.1 mm tungsten carbide sphere with nominal target strength of -39.5 dB (MacLennan and Simmonds 1992).

SITE SELECTION AND TRANSDUCER DEPLOYMENT

The relatively gentle-sloping river bottom and small cobble at the historic right-bank counting location has proven adequate for ensonification. A detailed bottom profile was obtained after initial transducer placement at the counting location by stretching a rope across the river and measuring water depth with a pole every 3 m (Figure 5). The transducer and automatic rotator were mounted on a pod made of aluminum pipe and deployed from the right-bank point bar. The pod was secured in place with sandbags and designed to permit raising and lowering the transducer by sliding it up or down along 2 riser pipes that extended above the water. Fine adjustments were made with remote control of the dual-axis rotator attached to the transducer. The transducer was deployed in water ranging from approximately 0.5 m to 1.0 m in depth, and aimed perpendicular to the current along the natural gravel substrate. An attempt was made to ensure the transducer was deployed at locations where minimum surface water velocities did not fall below 30–45 cm/s.

The system operator used an artificial acoustic target during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beam. The target, an airtight 250 ml weighted plastic bottle, was allowed to drift downstream along the river bottom and through the acoustic beams. Several drifts were made with the target in an attempt to pass it through as much of the counting range as possible. Proper transducer aim was verified with visual interpretation (echogram) on a computer screen as well as the oscilloscope. Later in the season, a 38.1 mm tungsten carbide sphere was used to verify how close to the bottom the target could be detected.

As in previous years, a fish lead was constructed shoreward from the transducer to prevent upstream salmon passage inshore of the transducer. The fish lead was constructed using 5 cm by 5 cm by 1.2-m high galvanized chain-link fencing and 2.5 m metal "T" stakes. The lead was constructed to extend beyond the nearfield of the sonar transducer. Whenever the transducer was relocated because of rising or falling water level, the lead was shortened or lengthened as appropriate, and the artificial target used to ensure proper re-aiming.

SONAR COUNT ADJUSTMENTS

At the end of each day, data collected by the DEP in 24 hourly digital text files was transferred to another computer for tracking and editing. To facilitate tracking, echoes from stationary objects were removed using a custom program created in *C* computer language (Dunbar 2004). The data was manually edited to remove spurious tracks such as bottom noise using *Polaris*, an echogram editor developed by Mr. Peter Withler through a cooperative agreement with DFO, ADF&G, and HTI. Fish tracks were then manually counted using *Polaris*. Hourly estimates were exported to a *Microsoft Excel* spreadsheet where expansion or linear interpolation was used for periods of missing data.

STATIONARY BOTTOM REMOVAL

Echoes from stationary objects were removed before tracking by dividing data into range bins (0.2 meters), calculating the moving average (averaging window of 1,000 echoes) of the voltage in each range bin, and then removing the echo if the voltage was within 1.7 standard deviations of the mean and at least 100 echoes were within that range bin. The echo was not removed if the percentage of missed echoes relative to observed echoes was greater than 80. The percentage of missed relative to observed echoes was calculated by summing differences between observed ping numbers minus 1 and then dividing by the total number of echoes in the range bin.

TRACKING

After the data was edited with the bottom removal program, the operator selected groups of echoes considered to be upstream fish based on visual interpretation of the *Polaris* echogram. These echoes grouped into fish tracks can be enumerated to produce an estimate of fish passage. Three times a day the crew saved an hour of tracked data to determine range distribution of the passing fish.

FINAL EDITING

Linear interpretation or expansion was used when data could not be collected due to relocating the transducer, system failure, or other unforeseen circumstances. If data from a complete hour was missing, counts were interpolated by averaging counts from 2 hours before and 2 hours after the missing hour. If 2 complete hours were missing, counts were interpolated by averaging counts from 3 hours before and 3 hours after the missing hours. If 3 hours were missing, counts were interpolated by averaging counts from 4 hours before and 4 hours after the missing hours. If 4 or more hours were missing, counts were interpolated by averaging counts from 5 hours before and 5 hours after the missing hour. When a portion of an hour was missing, passage was estimated by expansion based on the known portion of the hour. Sixty minutes was divided by the known number of minutes counted (if 10 minutes or more) and then multiplied by the number of fish counted in that period. Sonar counts caused by fish other than salmon were assumed insignificant based upon historic test fishing records collected at the site. After editing was complete; data was imported to an Excel spreadsheet where the final estimate of hourly and daily fish passage was produced.

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. Sample size 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).

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

An adult salmon beach seine was periodically fished at different locations between the sonar site and approximately 10–12 km upstream 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). The seine was dyed green, constructed of #18 twine, possessed 3 by 5-inch high-density, non-grommet oval poly floats spaced approximately 45 cm apart, had a 115-120 lb lead line and 1/2 in (1.3 cm) float line. Chum salmon were collected with the beach seine, enumerated by sex using external characteristics, and measured in millimeters from mideye to tail fork (METF). Additionally, 1 vertebra was taken from each fish for age determination.

CLIMATOLOGICAL AND HYDROLOGICAL 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 recording occurrences of precipitation and estimating percent cloud cover. Climatological observations were recorded at approximately 1900 hours daily.

DIDSON™ DEPLOYMENT ON LEFT BANK

DIDSON™ was operated on the left bank of the Sheenjek River directly across from the right-bank sonar site from September 2 through September 13. The DIDSON™ is a dual frequency, multi-beam sonar recently developed by the University of Washington, Applied Physics Laboratory. DIDSON™ produces images that are near video quality, allowing the system operator to distinguish upstream fish from downstream fish and debris. This sonar allows transducer placement in areas that are not possible with other systems, such as areas with large rocks, or submerged vegetation. The DIDSON™ was deployed on the left cutbank using the same type of pod as the HTI sonar. Attached to the transducer was an HTI model 662H dual-axis rotator with HTI model 660 remote controller to facilitate aiming. The electronic equipment was kept in a small tent and powered with a 1000 watt generator. Fish passage estimates were calculated using 15-minute samples from each hour of operation. The system operator visually counted the fish with a tally meter while watching the recorded fish images on a computer monitor.

RESULTS

River and Sonar Counting Conditions

In 2003, the crew deployed the transducer in approximately the same location on the point bar that was used in recent years. The river bottom at the counting location sloped gently from the convex bank (right-bank point bar) at a rate of approximately 9 cm/m (bottom slope ≈ 9%) to the shelf-break that lays approximately two-thirds of the way across the channel on August 10 (Figure 5). River width measured 61 m and much of the nearshore zone along the concave, left cutbank was cluttered with fallen trees and other woody vegetation.

The water level remained relatively high at the project site through 2003, with the highest level recorded on August 30 (Figure 6; Appendix B1). With respect to the initial reading of the water gauge upon deployment on August 7, the water level fell 21.6 cm during the first 6 days then gained 113.0 cm between August 13 and August 30 to 91.4 cm above the initial level recorded on August 7. From September 1 to September 5, the water level dropped slightly then increased again to 90.9 cm above the initial level. During this period of high water, contingency plans were formulated to move the camp to high ground. Fortunately, implementing the plan was not necessary. The water level dropped continuously during the remainder of the project. Final measurement on September 27 was 87.4 cm below the initial level. Water temperature at the project site ranged from 2°C to 14°C based upon instantaneous surface measurements, and averaged 9°C (Appendix B1). The Porcupine and Sheenjek rivers were both beginning to freeze during the final days of operation at the sonar site.

Fluctuations in water level affected placement of the transducer with respect to shore, and in turn affected the proportion of the river ensonified. 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 not collected because of system failures or moving the transducer.

Abundance Estimation

The 2003 sonar-estimated escapement was 38,321 chum salmon for the 49-day period August 9 through September 26 (Table 1). As in the past, only estimates from the HTI sonar on the right bank were used to produce the estimated escapement of fall chum salmon. Although the final day of counting was the second highest passage of the season, the project was terminated due to freezing river conditions. Because of the high passage when the project was terminated, the escapement estimate was subsequently adjusted to 44,047 chum salmon using run timing data from the Rampart tag recovery fish wheel (Table 1; Appendix C1). Daily passage estimates were relayed to the fishery managers in Fairbanks every morning via satellite telephone.

Temporal and Spatial Distribution

Chum salmon were present in the river when sonar counting was initiated on August 9, as evidenced by the 52 fish estimated passing that day. Three distinct pulses of Chum salmon passed the sonar in 2003, the largest passage estimate of 3,321 fish occurring on September 23 (Figure 7). The middle portion of the run was observed from September 6 through September 24, and the median day of passage occurred on September 18. The average passage rate during this period was 1,234 fish per day. An estimated 3,144 chum salmon passed the project site on September 26, the final day of sonar sampling. Factors affecting termination of sonar counting in 2003 included logistics associated with closing down camp and impending winter weather.

The diel migration pattern of Sheenjek River chum salmon typically observed on the right bank in most years (Dunbar 2004) was again manifested in 2003 (Figure 8). Upstream migration was heaviest in periods of darkness or suppressed light, with fish moving in greater numbers close to shore. On average, the period of greatest upstream migration occurred between 1800 hours and 0600 hours the following day (61%); the peak occurred between the hours of 1800 to 2400 (38%). The period of least movement in 2003 was between approximately 0600 and 1600 hours (31%).

Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. Approximately 90% of the fish counted passed through the first half of the counting range, or within 18 m of the transducer. The first few meters had fewer fish due to the placement of the fish lead. While the offshore half of the counting range was 10% of the total, only 0.1% was observed in the outer-most 6 meters (Figure 9).

AGE AND SEX COMPOSITION

Although an attempt was made to sample portions of annual escapement for age and sex composition in 2003, only 90 chum salmon (49 males; 41 females) were obtained due to limited distribution and availability for sampling (Table 3). Twelve seine hauls were made during the period of September 4 through September 23 along gravel bars between river kilometers (rkm) 10 and 16. Although the overall sample goal was not met, sampling was terminated on September 23 because of camp break-down activities, and the late portion of the run was sufficiently sampled. Six of the 90 vertebrae collected were unreadable. From the remaining 84 samples, it was determined that age-4 predominated (82.14%), the proportion of age-5 fish observed was 15.48%, age-2 and age-3 fish was 1.19% each (Appendix D1).

DIDSON™ TEST ON LEFT BANK

The steep uneven substrate, submerged logs and other vegetation posed no problems for detecting fish with the DIDSON™. Results from 160 samples collected from August 2 to September 13 show that 33% of the Sheenjek River chum salmon run may pass the sonar site on the left bank. Ensonification to 20 m was more than adequate to detect fish passing on the left bank. As with the HTI results from the right bank, most fish were observed relatively close to shore. Fish passage on the left bank was greatest during daylight hours (Figure 10).

DISCUSSION

ESCAPEMENT ESTIMATE

The 2003 sonar-estimated escapement of chum salmon in the Sheenjek River is considered conservative because fish that passed the site before sonar sampling or passed beyond the range of the acoustic beam (including along the left bank) were not included. Drift gillnetting results during the period 1981–1983 at the historic sonar sampling site demonstrated that distribution of upstream migrant chum salmon was primarily confined to the right side of the river, with only a small (but unknown) proportion passing beyond the sonar counting range (Barton 1982, 1983, 1984b). Barton (1985) also concluded that most upstream-migrant chum salmon orient toward the right bank before reaching the sonar sampling location.

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 collected from the nearby Chandalar River to expand Sheenjek River run size estimates for the years 1986–1988, and 1990 to encompass a comparable time period. The 1989 estimate was expanded from aerial survey observations made before sonar operations in that year (Appendix C1). Barton (2002) used historic run timing data from 1986 to 1999 to expand the estimated escapement for 2000, when sonar operations terminated early. From average run timing data for 1986–2002, approximately 85% of the Sheenjek River fall chum salmon run (through the end of September) materializes subsequent to August 25, with the middle portion of the run passing from August 30 through September 16. The historical median day of passage is September 8. Although fish were present in the river early, the majority arrived later; the median passage day in 2003 was 2 days later than the historical average.

The escapement estimate in 2003 was approximately 38,321 chum salmon for the 49-day period, from August 9 through September 26. Even after expanding this estimate to 44,047 to account for chum salmon that may have passed after counting ceased, this is the eighth lowest escapement recorded at the Sheenjek River, and was not enough to meet the low end of the revised BEG of 50,000 to 104,000 chum salmon (Figure 11). The escapement estimate was not within the acceptable range, although severe restrictions were imposed on the Yukon River commercial fisheries and moderate restrictions imposed on subsistence users. This low run was somewhat expected because the major parent year escapement levels were low at 33,058 in 1998 (returning age-5 fish) and 14,229 in 1999 (returning age-4 fish).

The low 2003 Sheenjek River escapement estimate was inconsistent with most escapement trends for other upper Yukon River areas which received average to above average escapements. The above average Chandalar River escapement was estimated at 214,428 chum salmon for the 49-day period of August 8 through September 25 (B. Osborne, USFWS, Fairbanks; personal communication). Run timing characteristics at the Chandalar were much earlier than those observed in the Sheenjek River. The Chandalar run was slightly bimodal, the median day of passage was recorded on September 3, which was 2 days earlier than the average and 13 days earlier than the Sheenjek River.

Above average numbers of returning fall chum salmon were reported in the Canadian portion of the mainstem Yukon River drainage in 2003. In the Fishing Branch River, 29,519 chum salmon passed the DFO weir during the 57-day period of August 30 through October 25 (JTC 2004). Similar to the Sheenjek River, this escapement was low, above the interim escapement goal of 15,000, but well below the normal escapement goal range of 50,000 to 120,000 fish. The 2003 estimate of spawning escapement for Canadian mainstem Yukon River fall chum salmon was approximately 132,000 fish, 65% above the minimum escapement goal of 80,000 chum salmon.

The 2003 season marked the seventh consecutive year characterized by low salmon runs to some western Alaska river systems. Exact reasons for low fall chum salmon runs are unknown; scientists speculate poor marine survival results from or is accentuated by localized weather conditions in the Bering Sea (Kruse 1998). Although most fall chum salmon BEGs were achieved within the Yukon River drainage in 2003, severe commercial and moderate subsistence restrictions were necessary to achieve these goals.

DIDSON™ ON LEFT BANK

This was the first year it was possible to operate a sonar system directly across from the historic right-bank sonar site. Although the steep left bank with uneven bottom, and submerged logs and vegetation was not conducive to placement of traditional sonar, the DIDSON™ worked very well. In the past, it has been assumed that not many fish pass the sonar site on the left bank.

Results from the DIDSON™ show that 33% of the fish may pass the sonar site on the left bank, which is more than previously thought. In 2002, when the water was low the HTI system on the right bank may have counted some fish following the thalweg near the left bank (Dunbar 2004). The extent of this behavior may not have been noticed during drift net experiments in the 1980s due to the inability to get a drift gillnet close inshore on the left bank where submerged debris hinders sampling. The fish may have been inaccessible amongst the submerged logs and vegetation. Another interesting observation was that some fish apparently shift toward the deeper, darker left bank during daylight hours and back to the shallow right bank at night. This behavior could not be detected with traditional sonar at this location. In the future, it is recommended that the DIDSON™ be used on the left bank to improve the estimate of fall chum salmon escapement in the Sheenjek River.

ACKNOWLEDGMENTS

The author wishes to acknowledge the sonar field camp personnel, Susan Klock and Ian Dickson, for their dedication to the project and collecting most of the data used in this report. Thanks to Heath Sandall, Carl Pfisterer, and Bruce McIntosh for logistical support. Finally, thanks to Toshihide Hamazaki, Carl Pfisterer, Eric Volk, and Renate Riffe 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 NA03NMF4380185.

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TABLES AND FIGURES

Table 1.–Alaskan and Canadian total catch of Yukon River fall chum salmon, 1970–2003.

Year	Canada[a]	Alaska[b]	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[c]	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[d]	148,846
1993	14,090	76,925[c]	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[d]	170,059
1998	7,901	62,869[c]	70,770
1999	19,506	110,369	129,875
2000	9,236	19,307[c]	28,543
2001	9,512	35,154[c]	44,666
2002	8,018	19,393[c]	27,411
2003	11,355	68,174	79,529
Average			
1961–2002 [e]	19,066	257,794	276,860
1979–1983	22,433	513,393	535,826
1993–2002	19,181	126,183	145,363
1998–2002	10,835	49,418	60,253

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

[b] Commercial, subsistence, personal-use, and ADF&G test-fish catches combined. Includes estimated number of salmon harvested for commercial production of salmon roe.

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

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

[e] 1961–1969 data from previous reports (Dunbar 2004).

Table 2.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981–2003.

Year	Starting Date	Ending Date	Project Duration	Sonar Estimate	Expanded Estimate
1981	8/31	9/24	25	74,560	
1982	8/31	9/22	23	31,421	
1983	8/29	9/24	27	49,392	
1984	8/30	9/25	27	27,130	
1985	9/02	9/29	28	152,768	
1986	8/17	9/24	39	83,197 [a]	84,207
1987	8/25	9/24	31	140,086	153,267
1988	8/21	9/27	38	40,866	45,206
1989	8/24	9/25	33	79,116	99,116
1990	8/22	9/28	38	62,200	77,750
1991	8/09	9/24	47	86,496	
1992	8/09	9/20	43	78,808	
1993	8/08	9/28	52	42,922	
1994	8/07	9/28	53	150,565	
1995	8/10	9/25	47	241,855	
1996	7/30	9/24	57	246,889	
1997	8/09	9/23	46	80,423	
1998	8/17	9/30	45	33,058	
1999	8/10	9/23	45	14,229	
2000	8/08	9/12	36	18,652 [b]	30,084
2001	8/11	9/23	44	53,932	
2002	8/09	9/24	47	31,642	
2003	8/09	9/26	49	38,321 [c]	44,047
1981–1985	8/30	9/24	26	67,054	
1986–1990	8/21	9/25	36	81,093	91,909
1991–2000	8/08	9/23	47	99,390	100,533
1998–2002	8/11	9/22	43	30,303	32,589

Source: JTC 2004

[a] The 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.

[b] The 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.

[c] The sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansions for 2003 were based upon run time data from the Rampart tag recovery fish wheel.

Table 3.–Sheenjek River test fishing (beach seine) results, 2003.

Date	Number of Sets	Location (rkm) [a]	Chum Salmon Captured Male		Female		Total	Arctic Grayling
9/04	3	11	1		1		2	1
9/07	6	10 & 11	8		3		11	7
9/08	4	10	1		6		7	0
9/11	4	10 & 11	2		3		5	0
9/16	1	10	0		0		0	0
9/18	2	16	1		0		1	0
9/19	1	16	0		0		0	0
9/22	3	10	14		19		33	0
9/23	3	10	22		9		31	0
Total	27		49	(54%)	41	(46%)	90	8

[a] Locations are river kilometer (rkm).

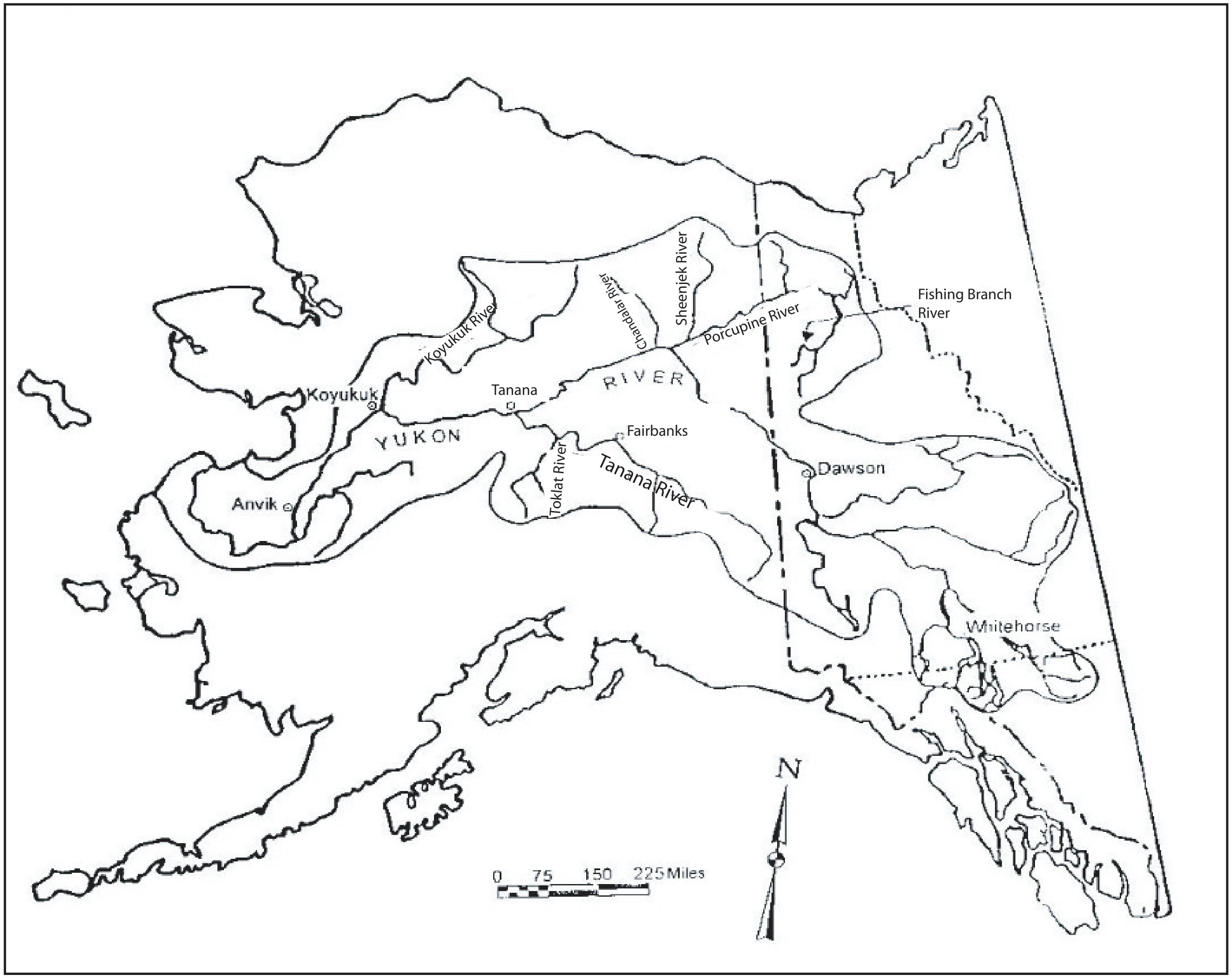

Figure 1.–The Yukon River drainage.

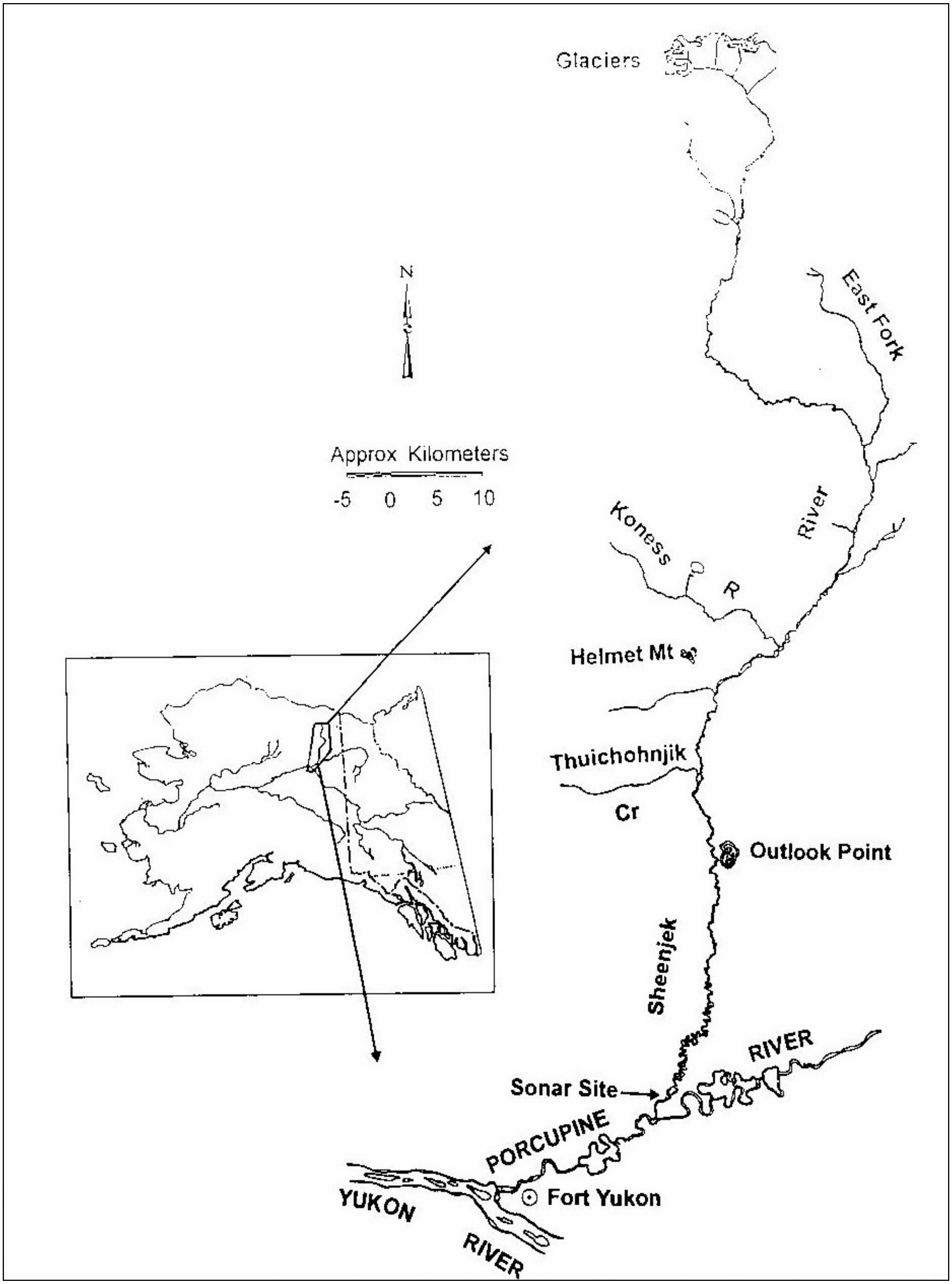

Figure 2.–The Sheenjek River drainage.

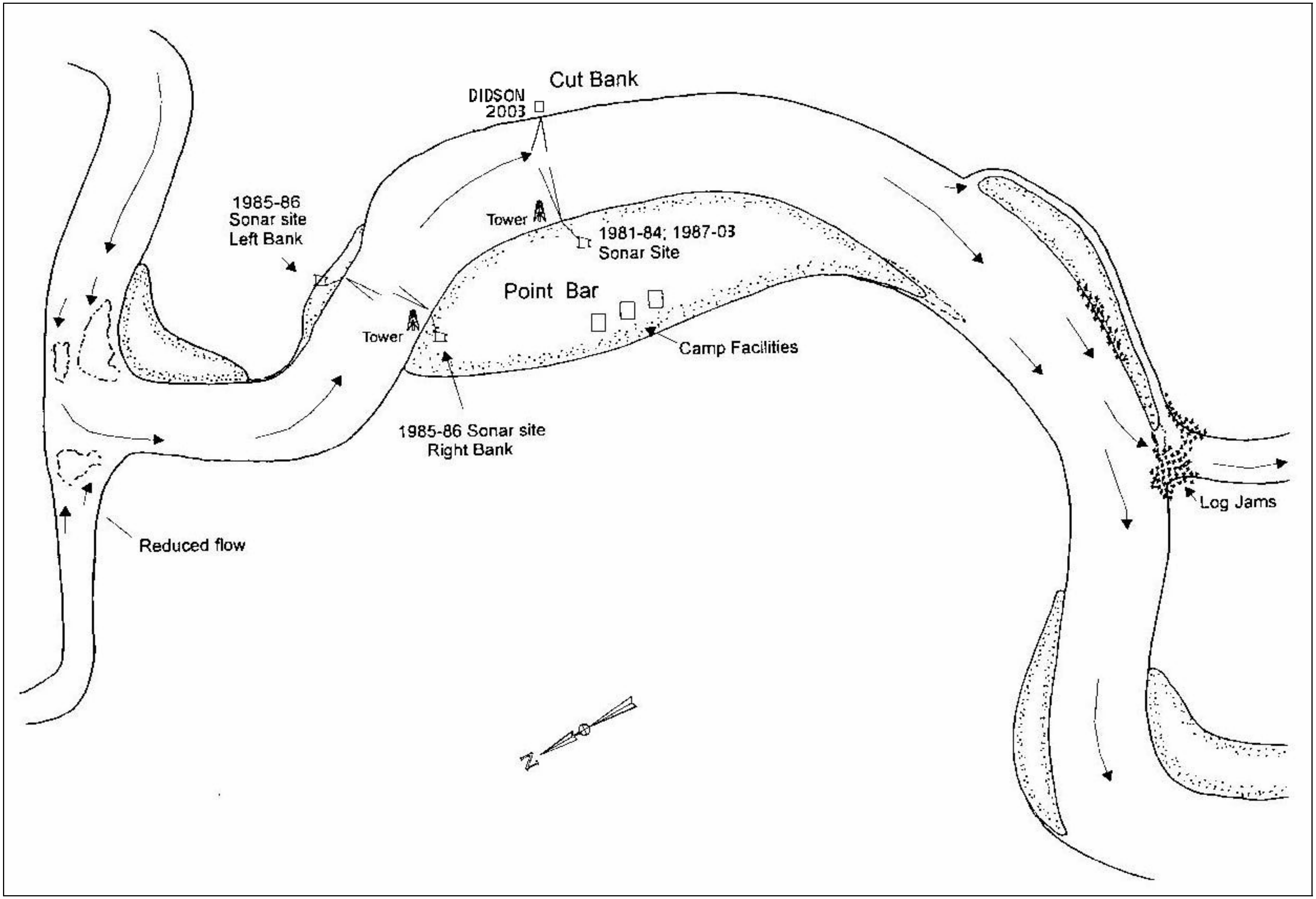

Figure 3.–The Sheenjek River sonar project site.

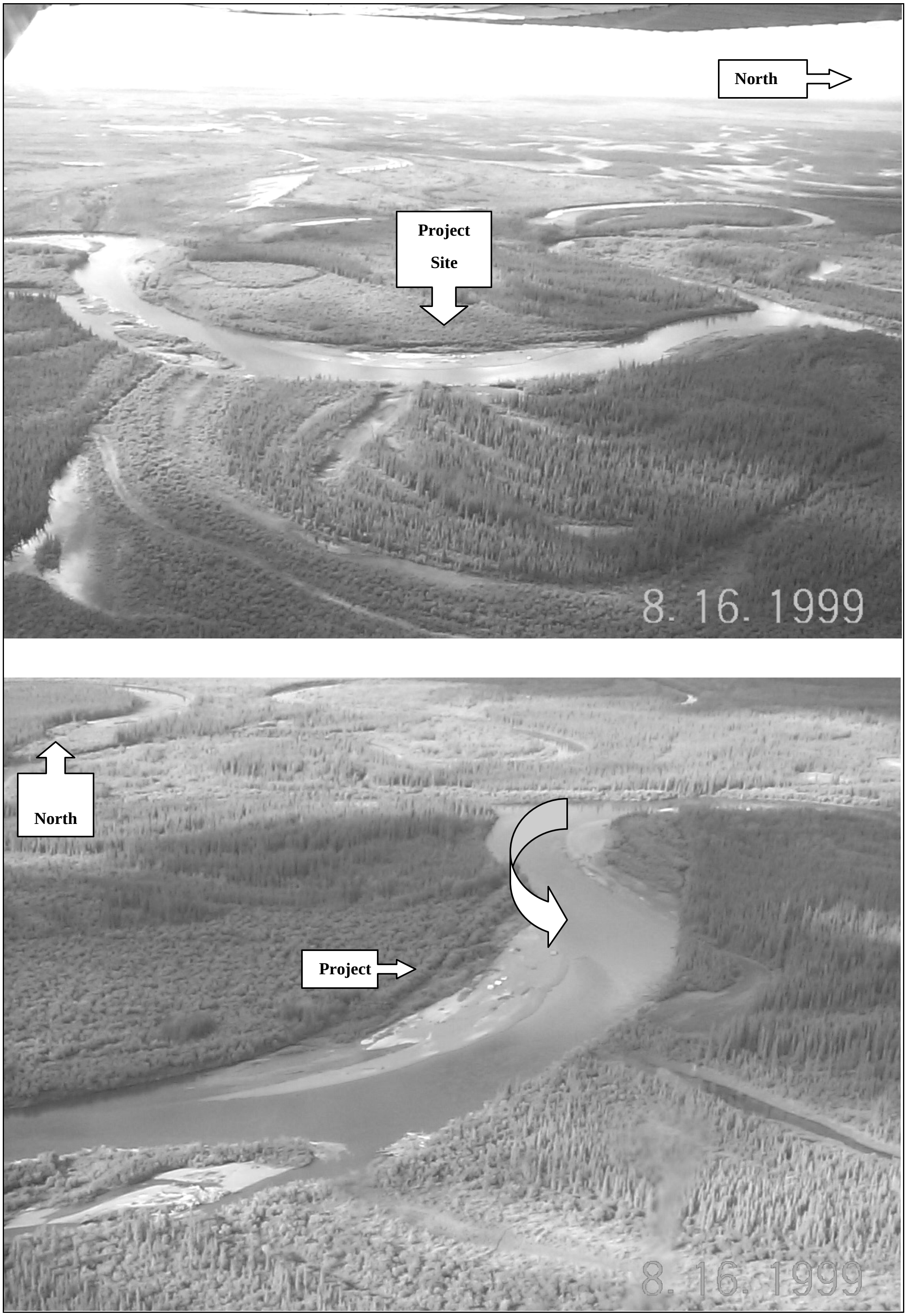

Figure 4.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

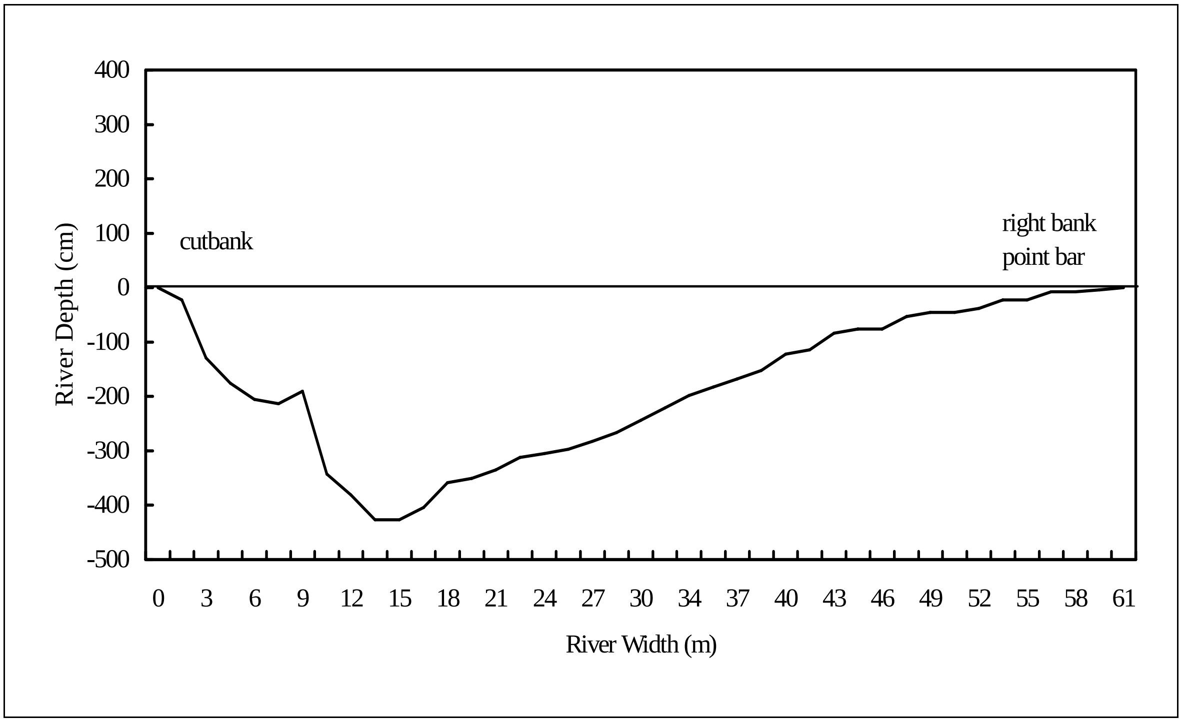

Figure 5.–Depth profile (downstream view) created at the Sheenjek River sonar project site, August 10, 2003.

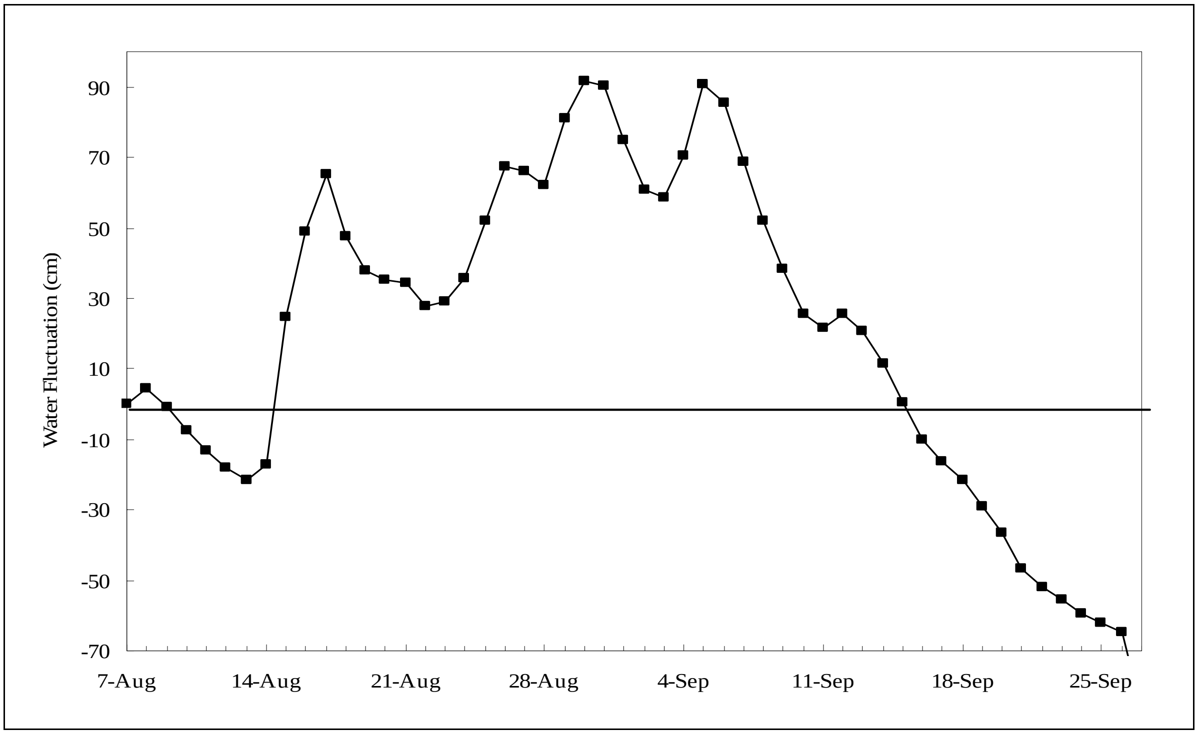

Figure 6.–Changes in daily water elevation measured at the Sheenjek River sonar project site, relative to August 7, 2003.

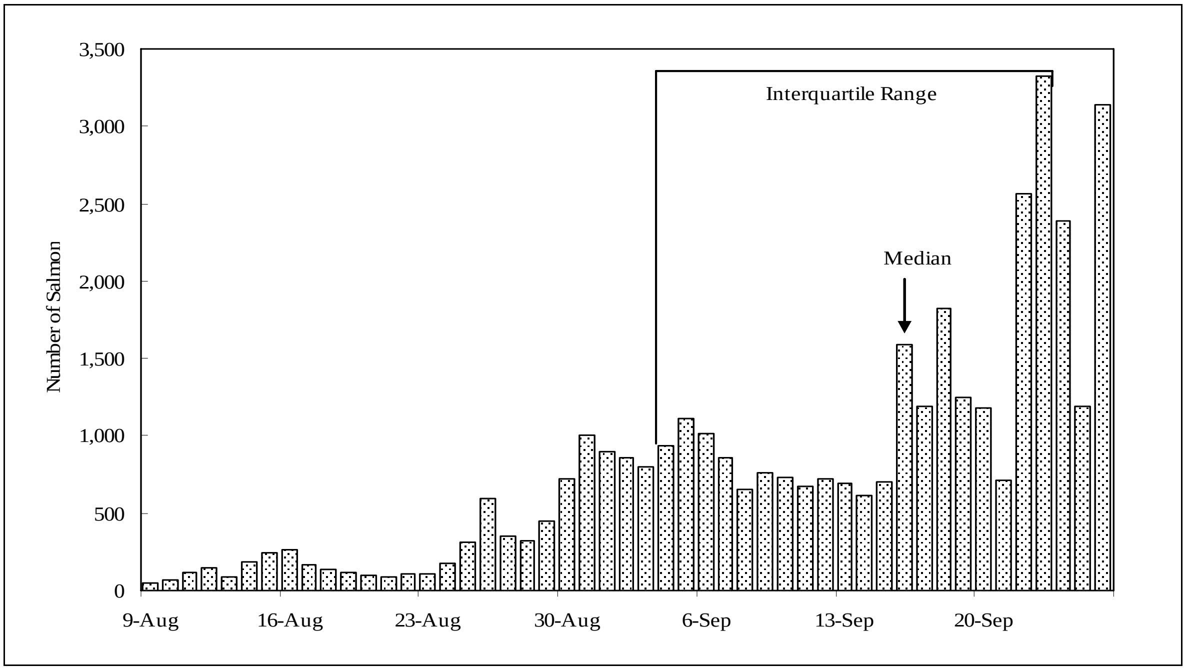

Figure 7.–Adjusted fall chum salmon sonar counts by date, Sheenjek River, 2003.

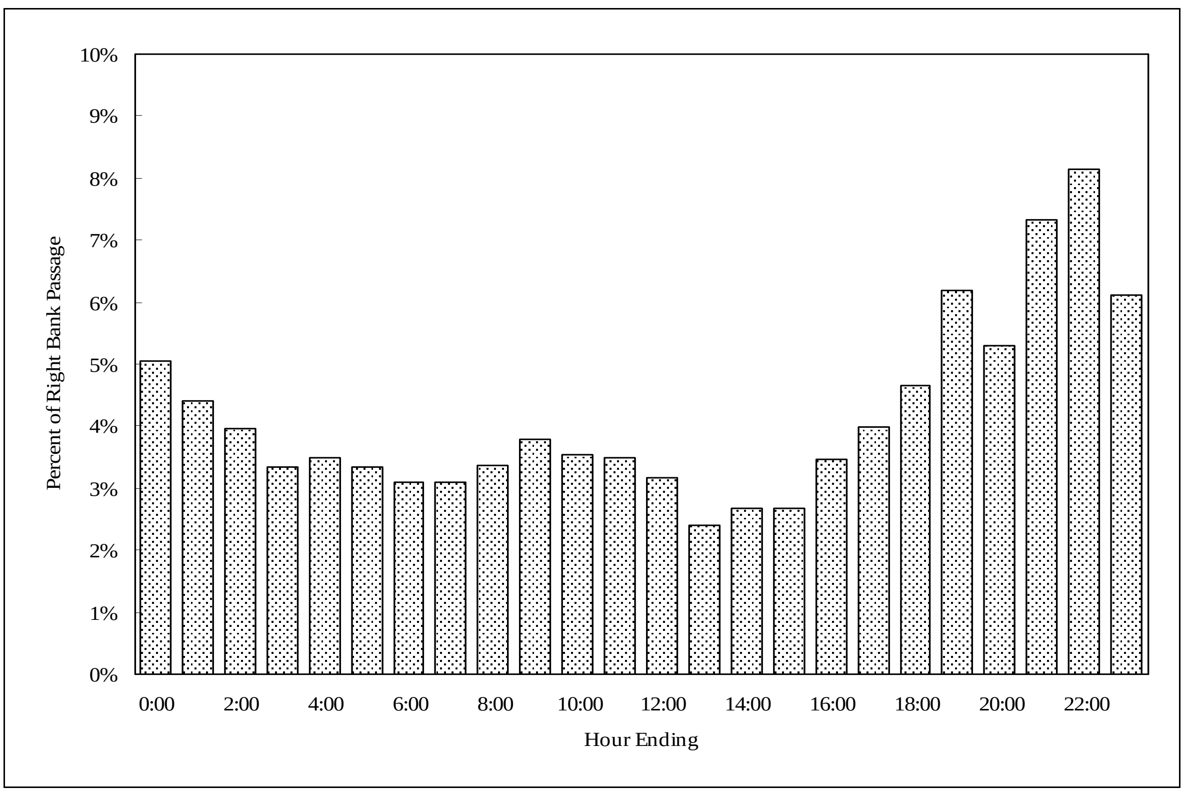

Figure 8.–Diel migration pattern of fall chum salmon observed on the right bank of the Sheenjek River, from August 9 through September 26, 2003.

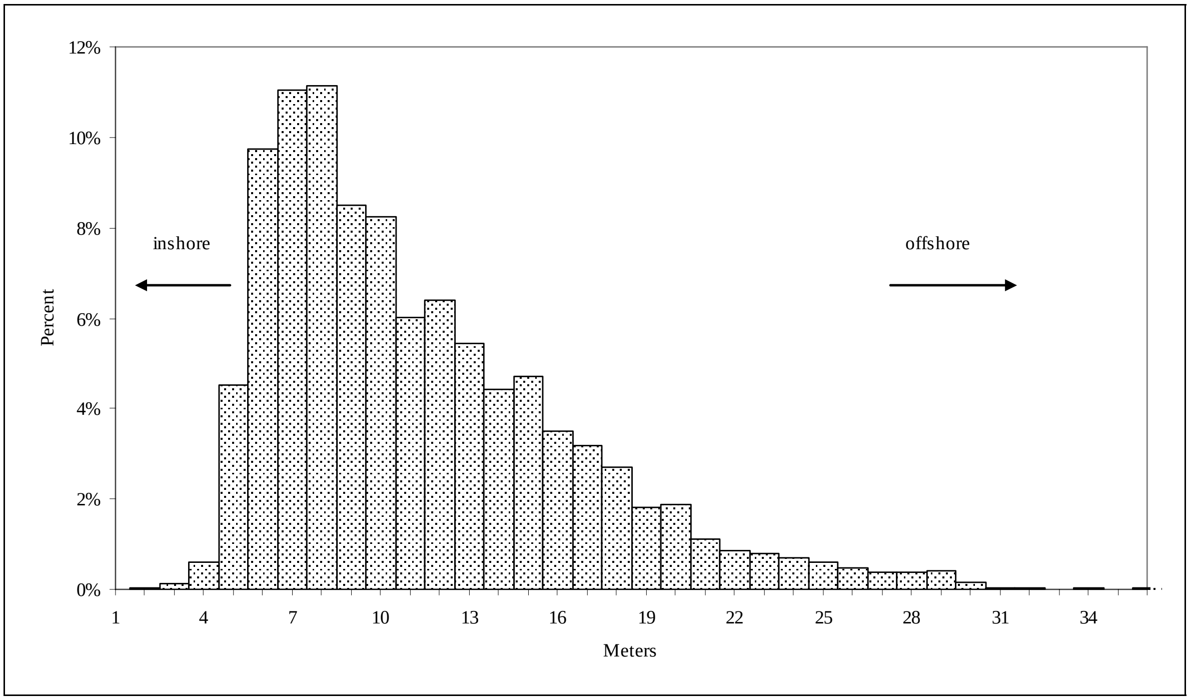

Figure 9.–Right bank, upstream fall chum salmon distribution in the Sheenjek River, 2003.

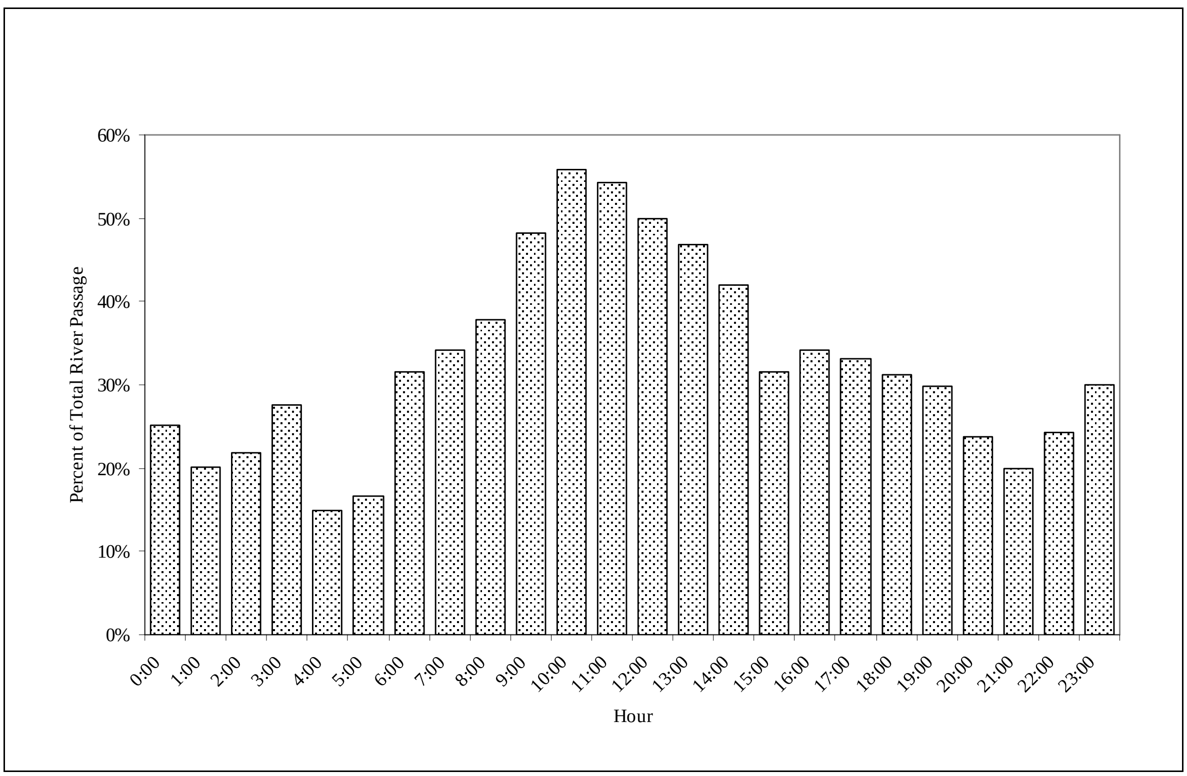

Figure 10.–Left bank chum salmon passage by hour as percentage of total, Sheenjek River, from September 2 through September 13, 2003.

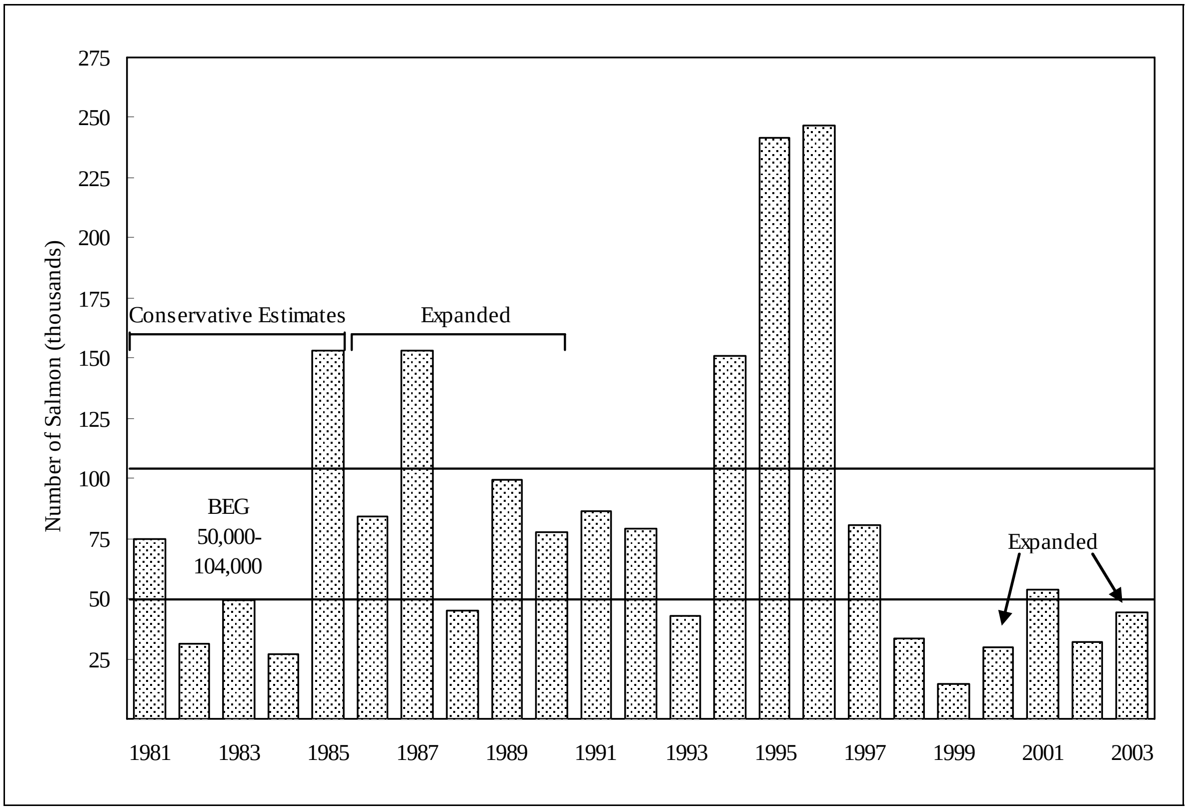

Figure 11.–Sonar-estimated escapement of fall chum salmon in the Sheenjek River, 1981–2003.

APPENDIX A. ECHO SOUNDER SPECIFICATIONS

Appendix A1.–Technical specifications for the Model 241 Portable Split-Beam Digital Echo Sounder.

Size:	10 inches wide x 4.3 high x 17 long, without PC or transducer (254 mm wide x 109 high x 432 long).
Weight:	20 lb. (9 kg) without PC or transducer.
Power Supply:	Nominal 12 VDC standard (120 VAC and 240 VAC optional).
Operating Temperature:	5-50°C (41-122°F).
Power Consumption:	30 watts (120 - 200 kHz), without laptop PC.
Frequency:	200 kHz standard (120 kHz and 420 kHz optional).
Transmit Power:	100 watts standard for 120-200 kHz. 50 watts standard for 420 kHz.
Dynamic Range:	140 dB
Transmitter:	Output power is adjustable in four steps over a 20 dBw range (+2, +8, +14, and 20 dBw).
Pulse Length:	Selectable from 0.1 msec to 1.0 msec in 0.1 msec steps.
Bandwidth:	Receiver bandwidth is automatically adjusted to optimize performance for the selected pulse length.
Receiver Gain:	Overall receiver gain is adjustable in five steps over a 40 dB range (-16, -8, 0, +8, +16 dB).
TVG Functions:	Simultaneous 20 and 40 log(R)+2αr TVG. Spreading loss and alpha are programmable to nearest 0.1 dB. Total TVG range is 80 dB. TVG start is selectable in 1m increments. The minimum TVG start is 1.0 m to maximum of 200 m.
Receiver Blanking:	Start and stop range blanking is selectable in 1m steps.
Undetected Output:	12 kHz, for each formed beam
Detected Output:	10 volts peak
System Synchronization:	Internal or external trigger
Ping Rate:	0.5-40.0 pings/sec
Phase Calculation:	Quadrature demodulation
Angular Resolution:	+/- <0.1° (6° beam width, 200 kHz)
Tape recording:	With Split-Beam Data Tape Interface and optional Digital Audio Tape (DAT) recorder, directly records the digitized split-beam data, permitting complete reconstruction of the raw data output.
Calibrator:	Local receiver calibration check using internal calibration source. Pulse and CW calibration functions provided in step settings.
Positioning:	GPS positioning information (NMEA 0183 format) via serial port of computer

Source: Model 241 operator’s manual.

APPENDIX B. CLIMATOLOGICAL AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climatological and hydrologic observations at the Sheenjek River project site, 2003.

					Temperature (C°)			Water Level (cm)			
			Cloud	Wind	Water	Air		± 24 h	relative to		
		Precipitation	Cover	Direction and						Water	
Date	Time	(code) [a]	(code) [b]	velocity (mph)	Surface	Minimum	Maximum	Change	zero datum	Color (code)	Remarks
8/07	1900	A	S	N15	13.0			zero datum	0.0	B	Beautiful warm sunny weather.
8/08	1900	A	S	Calm	12.0			4.3	4.3	B	Install sonar and fish lead.
8/09	1900	A	C	SW5	13.0			-5.3	-1.0	B	First full day of counts.
8/10	1900	A	S	SSW3	14.0	10	26	-6.6	-7.6	B	Completed river profile.
8/11	1900	B	B	SW8	14.0	17	20	-5.6	-13.2	B	Rainy day.
8/12	1900	B	O	NW1	13.0	8	20	-4.8	-18.0	A	Intermittent rain 0800-1400.
8/13	1900	B	B	WSW4	14.0	11	23	-3.6	-21.6	A	Partly cloudy until 1900; rain1900-1930.
8/14	1900	A	S	E5	13.5	11	25	4.3	-17.3	A	Gorgeous day!
8/15	1900	A	B	ESE6	13.5	no data	no data	42.2	24.9	B	N0 max/min data-dead battery.
8/16	1900	A	B	SSW5	14.0	13	23	24.1	49.0	D	Partly cloudy; hard downpour 1730.
8/17	1900	A	S	W4	14.0	9	20	16.3	65.3	D	
8/18	1900	A	C	SW4	13.0	3	19	-17.8	47.5	D	Gorgeous day!!
8/19	1900	B	B	ENE8	12.0	3	19	-9.4	38.1	C	
8/20	1900	A	B	N3	11.0	9	17	-2.8	35.3	B	Interesting clouds.
8/21	1900	A	B	NNW1	12.0	4	16	-0.8	34.5	B	Best northern lights so far 0200.
8/22	1900	B	B	Calm	10.3	6	16	-6.6	27.9	B	Cold north wind until evening.
8/23	1900	C	O	SSW7	10.1	4	11	1.3	29.2	B	Rain all day.
8/24	1900	C	O	SSW8	10.5	9	15	6.4	35.6	B	Rain all day.
8/25	1900	B	O	NE3	10.6	6	16	16.5	52.1	B	New water gauge level: 25.5, old level: 34.5.
8/26	1900	B	O	Calm	10.8	10	17	15.2	67.3	B	
8/27	1900	A	C	Calm	10.5	8	21	-1.3	66.0	B	Gorgeous day.
8/28	1900	A	C	ESE3	11.7	no data	no data	-3.8	62.2	B	No max/min data-dead battery.
8/29	1900	A	S	E3	11.6	6	24	19.1	81.3	B	New water gauge level: 22, old level: 37.
8/30	1900	A	S	Calm	12.0	12	24	10.2	91.4	C	New water gauge level: 30, old level: 26.
8/31	1900	B	O	NNE1	11.5	11	22	-1.3	90.2	C	Water level =32 at 0700.
9/01	1900	B	O	NNE5	11.0	8	15	-15.2	74.9	B	
9/02	1900	B	B	SSW2	10.6	6	15	-14.0	61.0	B	New water gauge level: 14, old level: 18.
9/03	1900	A	O	SSW4	9.6	no data	no data	-2.5	58.4	B	Sunny am, cloudy windy pm, clear eve.
9/04	1900	A	B	SSW7	9.2	2	15	11.9	70.4	B	Fall is here.
9/05	1900	A	S	SW6	9.0	5	14	20.6	90.9	C	New water gauge level: 29.8, old level: 25.8.
9/06	1900	A	S	SW3	8.4	3	14	-5.3	85.6	B	Partly cloudy cool fall day.
9/07	1900	A	C	SW0	7.8	-3	15	-17.0	68.6	B	Nice fall day!
9/08	1900	A	S	SW3	8.0	-1	16	-16.5	52.1	B	More of the same.
9/09	1900	B	B	SSW4	7.6	no data	no data	-13.7	38.4	A	New water gauge level: 25.0, 0ld level: 9.3.
9/10	1900	B	O	SW3	6.4	-1	10	-12.7	25.7	A	Wind max 22-cold blustery pm.
9/11	1900	A	S	SSW20	6.4	no data	10	-4.1	21.6	A	No min. temp data.
9/12	1900	A	C	NNW2	5.2	1	8	4.1	25.7	A	Clear and cool; wind max 25.
9/13	1900	A	C	NNE3	4.4	-8	6	-5.1	20.6	A	Clear and cold; wind max 14.

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Date	Time	Precipitation (code) [a]	Cloud Cover (code) [b]	Wind Direction and velocity (mph)	Temperature (C°) Water Surface	Air Minimum	Air Maximum	Water Level (cm) ± 24 h Change	relative to zero datum	Water Color (code)	Remarks
9/14	1900	A	S	NNW1	4.2	-6	9	-8.9	11.7	A	
9/15	1900	A	S	SSW2	4.6	-7	9	-11.4	0.3	A	
9/16	1900	F	B	ENE4	4.2	-3	9	-10.2	-9.9	A	Cold wind; wind max 22.
9/17	1900	A	B	NE5	4.2	-5	5	-6.4	-16.3	A	New water gauge level: 28, old level: 3.5.
9/18	1900	A	S	NNE1	2.5	-7	4	-5.1	-21.3	A	
9/19	1900	F	B	NE3	3.6	-8	6	-7.6	-29.0	A	
9/20	1900	A	B	NE8	3.6	-7	6	-7.6	-36.6	A	Cold wind. Max 22.
9/21	1900	A	B	NNE7	2.5	-3	4	-10.2	-46.7	A	Cold wind. Max 24.
9/22	1900	A	B	N5	2.5	-2	4	-5.1	-51.8	A	
9/23	1900	A	B	NE9	2.4	-6	6	-3.8	-55.6	A	
9/24	1900	A	B	ENE8	2.0	no data	4	-3.8	-59.4	A	Batteries died.
9/25	1900	A	B	NNE3	3.0	-4	5	-2.5	-62.0	A	
9/26	1900	A	S	SW4	2.2	-1	6	-2.5	-64.5	A	
9/27	1900							-22.9	-87.4		
	Average				8.8	3	14				

[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] Instantaneous cloud cover code: C = Clear 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. ESCAPEMENT ESTIMATIONS

Appendix C1.–Sonar-estimated escapement of fall chum salmon in the Sheenjek River, 1986–2003.

Date	1986	1987	1988	1989	1990	1991	1992	1993	1994
Jul 30									
Jul 31									
Aug 01									
Aug 02									
Aug 03									
Aug 04									
Aug 05									
Aug 06									
Aug 07									146
Aug 08								45	75
Aug 09	||	||	||	||	||	255	136	95	112
Aug 10	||	||	||	||	||	301	172	256	38
Aug 11	||	||	||	||	||	179	102	143	214
Aug 12	||	||	||	||	||	173	272	217	243
Aug 13	||	||	||	||	||	178	216	227	328
Aug 14	||	||	||	||	||	282	337	175	215
Aug 15	||	||	||	||	||	551	670	291	261
Aug 16	1,010 [a]	||	||	||	||	521	571	346	333
Aug 17	68	||	||	||	||	418	1,100	367	378
Aug 18	345	||	||	||	||	591	1,570	245	524
Aug 19	769	||	||	||	||	668	1,003	316	497
Aug 20	1,576	||	4,340 [a]	||	||	446	2,347	466	257
Aug 21	1,178	||	961	||	15,550 [a]	1,012	1,767	117	594
Aug 22	3,023	||	1,027	||	1,718	1,990	1,353	124	642
Aug 23	1,177	||	884	20,000 [b]	1,825	1,754	1,189	157	1,673
Aug 24	1,733	13,181 [a]	744	2,685	1,940	889	1,390	177	1,035
Aug 25	5,374	168	810	2,321	1,620	1,591	1,147	156	848
Aug 26	4,875	314	1,528	1,392	1,047	1,684	893	248	791
Aug 27	3,712	795	1,203	1,129	1,055	1,846	1,032	208	2,934
Aug 28	4,633	951	1,087	1,009	1,337	1,508	778	296	3,677
Aug 29	5,150	993	756	733	1,605	1,196	463	369	4,082
Aug 30	4,336	1,400	914	1,265	881	905	943	647	4,487
Aug 31	3,889	1,639	1,512	933	1,609	1,676	840	999	5,472
Sep 01	2,101	3,937	1,548	1,598	1,570	2,164	835	1,045	6,912
Sep 02	2,230	3,295	1,492	1,759	1,695	1,749	830	632	7,196
Sep 03	1,819	7,585	2,203	1,739	1,002	1,808	1,217	2,092	5,918

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Date	1986	1987	1988	1989	1990	1991	1992	1993	1994
Sep 04	2,406	11,386	1,991	2,819	1,159	2,026	2,023	2,557	3,666
Sep 05	1,645	10,962	1,309	2,571	955	2,476	2,093	2,097	2,832
Sep 06	2,265	5,439	1,286	2,936	1,339	1,241	3,154	1,673	2,952
Sep 07	2,849	10,182	1,542	4,210	1,259	3,490	4,200	2,414	3,928
Sep 08	2,760	11,122	1,297	3,581	1,071	2,680	3,092	2,720	3,587
Sep 09	2,469	8,487	1,443	4,858	1,411	4,201	4,274	1,300	2,598
Sep 10	1,131	5,561	1,073	4,051	854	3,541	3,209	580	2,341
Sep 11	1,461	4,882	696	3,551	1,746	2,236	3,815	401	3,382
Sep 12	2,500	6,294	340	3,414	1,726	3,136	3,816	465	2,796
Sep 13	1,751	5,831	673	3,227	1,803	3,139	4,047	373	3,066
Sep 14	2,866	4,485	703	2,797	2,196	3,145	6,347	351	3,294
Sep 15	2,290	3,963	1,037	2,027	2,065	4,823	4,289	197	3,522
Sep 16	1,099	4,118	1,275	2,498	2,175	4,240	3,232	407	4,764
Sep 17	1,488	4,763	1,943	3,035	2,867	2,729	2,473	1,176	4,413
Sep 18	1,481	4,326	1,637	2,090	1,909	2,734	2,158	1,053	3,249
Sep 19	1,548	2,635	1,209	1,839	2,020	3,119	2,406	1,359	6,500
Sep 20	679	3,160	1,151	2,321	2,372	3,319	1,007	1,192	7,583
Sep 21	704	3,223	716	1,273	2,444	2,461	**early**	3,382	5,287
Sep 22	577	1,988	743	1,384	2,667	1,924	**freezeup**	2,005	6,520
Sep 23	587	2,878	583	2,434	1,848	2,071		1,803	5,153
Sep 24	653	3,324	522	2,965	1,819	1,430		1,655	4,523
Sep 25			365	2,672	1,923			1,083	3,607
Sep 26			344		1,392			1,158	3,458
Sep 27			319		1,478			568	3,600
Sep 28					798			497	4,062
Sep 29									
Sep 30									
Totals	84,207	153,267	45,206	99,116	77,750	86,496	78,808	42,922	150,565

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Date	1995	1996	1997	1998	1999	2000	2001	2002	2003
Jul 30		670							
Jul 31		706							
Aug 01		541							
Aug 02		793							
Aug 03		685							
Aug 04		577							
Aug 05		469							
Aug 06		724							
Aug 07		918							
Aug 08		1,554				19			
Aug 09		930	114			74		602	52
Aug 10	964	963	248		32	153		756	71
Aug 11	882	479	332		60	160	49	656	115
Aug 12	468	315	306		37	186	78	528	148
Aug 13	344	315	421		76	237	79	381	88
Aug 14	359	903	473		41	179	73	450	188
Aug 15	1,045	762	420		43	205	121	396	242
Aug 16	863	753	534		70	342	126	449	266
Aug 17	891	602	341	56	86	286	90	360	168
Aug 18	1,172	724	307	98	101	487	567	262	138
Aug 19	1,656	753	430	63	290	570	948	395	119
Aug 20	2,105	1,662	354	35	217	407	584	179	96
Aug 21	2,632	1,594	291	23	224	333	313	355	85
Aug 22	2,677	1,178	506	27	59	318	507	243	109
Aug 23	3,525	2,472	688	58	138	341	689	220	112
Aug 24	6,301	11,459	996	43	279	319	884	139	177
Aug 25	4,745	9,966	1,059	95	730	386	1050	370	314
Aug 26	4,445	7,034	1,179	93	395	499	967	300	598
Aug 27	6,358	4,545	2,329	59	645	597	964	244	349
Aug 28	4,839	5,778	2,320	114	676	512	892	488	323
Aug 29	6,842	11,457	1,884	47	410	552	995	892	453
Aug 30	7,436	12,249	2,067	143	247	755	970	573	724
Aug 31	6,517	12,522	2,250	274	207	593	985	733	1,006
Sep 01	8,782	7,597	2,433	248	115	662	1481	774	897
Sep 02	5,856	6,326	2,616	234	164	785	1925	657	861
Sep 03	7,049	6,457	2,799	117	203	726	1374	542	804
Sep 04	4,185	5,113	3,404	301	327	1,023	1235	820	936
Sep 05	4,525	5,214	3,352	118	186	961	1968	429	1,109
Sep 06	6,084	5,763	2,761	277	422	599	2574	838	1,018

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Date	1995	1996	1997	1998	1999	2000	2001	2002	2003
Sep 07	6,852	7,871	2,904	254	416	1,073	1537	543	855
Sep 08	6,318	6,333	4,842	590	742	1,518	3378	406	657
Sep 09	5,403	3,718	2,849	412	555	785	3098	676	757
Sep 10	4,957	4,364	1,995	416	594	856	2575	507	736
Sep 11	6,758	7,409	1,971	594	514	641	3286	376	670
Sep 12	6,597	4,735	2,323	722	470	710	3536	670	719
Sep 13	6,561	6,974	3,602	1,348	589	11,235 [c]	2679	841	694
Sep 14	6,184	5,944	2,983	1,120	343	‖	2130	1353	616
Sep 15	10,161	5,406	3,294	1,201	309	‖	1833	923	705
Sep 16	9,026	7,871	2,376	2,850	303	‖	900	1247	1,590
Sep 17	9,097	11,181	2,379	2,492	430	‖	1482	1124	1,187
Sep 18	8,525	7,850	2,101	2,607	542	‖	430	1588	1,824
Sep 19	8,468	10,474	2,096	2,526	294	‖	1110	2006	1,249
Sep 20	8,065	6,755	1,613	2,692	290	‖	813	1688	1,183
Sep 21	9,590	6,170	1,612	2,756	389	‖	1017	1199	709
Sep 22	5,943	3,924	2,249	2,120	533	‖	1018	816	2,565
Sep 23	6,518	4,486	2,020	1,594	436	‖	622	879	3,321
Sep 24	6,432	1,902		811		‖		769	2,388
Sep 25	6,853			529		‖			1,186
Sep 26				430					3,144
Sep 27				487					5,726 [d]
Sep 28				736					
Sep 29				587					
Sep 30				661					
Totals	241,855	246,889	80,423	33,058	14,229	30,084	53,932	31,642	44,047

Note: Days with no data indicate days when the project was not operational.

[a] For the years 1986 (Aug 9–16). 1987 (Aug 9–24), 1988 (Aug 9–20), and 1990 (Aug 9–21) the early portion of Sheenjek River fall chum salmon run was estimated from run timing and entry pattern observed in the Chandalar River (Barton 1995).

[b] For the year 1989 (Aug 9–23), the early portion of Sheenjek River fall chum salmon run was estimated from aerial survey (Barton 1995).

[c] For the year 2000 (Sep 13–25) the late portion of Sheenjek River fall chum salmon run was estimated from average run time data observed in the Sheenjek River, 1986–1999 (Barton 2002).

[d] For the year 2003 (Sep 27), the late portion of Sheenjek River fall chum salmon run was estimated from 2003 average run time data from the Rampart tag-recovery fish wheel.

APPENDIX D. AGE COMPOSITION ESTIMATES

Appendix D1.–Age composition estimates of Sheenjek River fall chum salmon, 1974–2003.

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	none					91,372
1980	none					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	none					80,423
1998	only 3 fish					33,058
1999	none					14,229
2000	none					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	1.190	82.140	15.480	1.190	44,047
Avg 1974–2002		0.061	0.628	0.302	0.010	80,482
Avg 1974–1985		0.115	0.716	0.168	0.001	68,605
Avg 1986–2002		0.019	0.560	0.405	0.016	94,719
Even Years		0.088	0.527	0.376	0.009	67,867
Odd years		0.031	0.737	0.221	0.010	96,599

[a] Age determination from scales for years 1974–1985; and from vertebrae 1986–2003.
[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] 28 beach seine samples collected at rkm 13 and 1 carcass collected at rkm 10.