**Fishery Data Series No. 12-48**

# Sonar Estimation of Fall Chum Salmon Abundance in the Sheenjek River, 2011

**by**

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

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**Weights and measures (metric)**

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

**Weights and measures (English)**

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

**Time and temperature**

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

**Physics and chemistry**

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

**General**

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

**Mathematics, statistics**

| | |
|---|---|
| *all standard mathematical signs, symbols and abbreviations* | |
| alternate hypothesis | $H_A$ |
| base of natural logarithm | *e* |
| catch per unit effort | CPUE |
| coefficient of variation | CV |
| common test statistics | (F, t, $\chi^2$, 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 |

## *FISHERY DATA SERIES NO. 12-48*

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# ABSTRACT

Dual frequency identification sonar was used to estimate chum salmon *Oncorhynchus keta* escapement in the Sheenjek River from August 8 to September 24, 2011. The sonar-estimated escapement through September 24 was 81,980 chum salmon. The estimate was subsequently expanded to a total abundance estimate of 97,976 using run timing data from the Rampart tag recovery fish wheel. For comparison with past years, only the expanded right bank estimate of 61,882 was used to evaluate whether the biological escapement goal was obtained. The right bank estimate was 19% above the low end of the Sheenjek River biological escapement goal of 50,000 to 104,000 chum salmon. Median passage while the sonar was operating was observed on September 12. Peak single day passage was observed on September 22, when an estimated 4,231 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 that passed. The passage estimate should be considered conservative since it does not include fish migrating beyond the counting range or fish present before the sonar equipment was in operation. One hundred eighty vertebrae samples were collected for age determination. The sample comprised 51% female and 49% male chum salmon.

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

# INTRODUCTION

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

## INRIVER FISHERIES

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

Although the Alaska commercial fishery for Yukon River fall chum salmon developed in the early 1960s, annual harvests remained relatively low through the mid-1970s. Estimated total inriver utilization (U.S. and Canada commercial and subsistence) of Yukon River fall chum salmon was below 300,000 fish per year before the mid-1970s (JTC 2011). Inriver commercial fisheries became more fully developed during the late 1970s and early 1980s. Harvest peaked in 1981 at 677,257 fish (JTC 2011). In the mid-1980s, management strategies were implemented to reduce commercial exploitation on fall chum salmon stocks and to improve low escapements observed throughout the drainage during the early 1980s.

Yukon River fall chum salmon runs improved somewhat between 1994 and 1996. Poor salmon runs to Western Alaska between 1997 and 2003 resulted in partial or total closures to commercial and subsistence fishing in the Alaska and Canadian portions of the drainage during those years. Limited commercial fishing for fall chum was allowed from 2003 through 2011, except in 2010 when limited commercial fishing of fall chum salmon was allowed in Canada, and no directed fall chum salmon commercial fishing was allowed in Alaska. Subsistence harvest of fall chum salmon in 2003 was also limited while the subsistence harvest in 2004 was unrestricted except within the Canadian portion of the Porcupine River. There were no restrictions on subsistence harvest from 2005 through 2011, except in 2009 and 2010, when subsistence harvest was limited in Alaska and Canada.

## ESCAPEMENT ASSESSMENT

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

The Sheenjek River is one of the most intensely monitored fall chum salmon spawning streams in Yukon River drainage. Escapement observations date back to 1960 when United States 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 in late September and early October (Barton 1984). Beginning in 1981, escapements were monitored using Bendix[1] fixed-location, single-beam, side-looking sonar systems (Dunbar 2004). However, an early segment of the fall chum salmon run was not measured prior to 1991 because the project typically started around August 25, after that portion of the run had passed. Beginning in 1991, the project startup was changed to start about 2 weeks earlier to include the early segment of the run. The sonar-estimated escapements for 1986 through 1990 have been expanded to include estimated early fish passage (Barton 1995). Termination of sonar counting was consistent between 1981 and 2011, averaging September 24, except in 2000 when the project was terminated early because of extremely low water (Barton 2002).

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

[1] Reference to trade names does not imply endorsement by the Alaska Department of Fish and Game.

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 migrant chum salmon was primarily concentrated on the right bank of the river at the current sonar site, with a small but unknown proportion passing on the left bank (Barton 1985). In 2002, ADF&G began experimenting with a new dual frequency identification sonar (DIDSON), manufactured by Sound Metrics Corporation, for counting salmon in small rivers. This system appeared to be more accurate, easy to use, with the ability to operate across substrate profiles unacceptable for single-beam or split-beam systems (Maxwell and Gove 2004). The uneven substrate on left bank of the Sheenjek River was selected as an ideal candidate for experimenting with this system. In 2003, a DIDSON was deployed on the previously unmonitored left bank. Using DIDSON data it was estimated that approximately 33% of the fish were migrating up the left bank (Dunbar 2006). Given this surprisingly large number, it was proposed that DIDSON be deployed on both banks in the future. In 2004 and 2005, DIDSON and HTI split-beam sonar were deployed side-by-side on the right bank and found that DIDSON estimates were 20% higher than the split-beam estimates (Dunbar and Pfisterer 2009). Since 2005, only DIDSON has been the deployed to estimate chum salmon escapement on both banks of the Sheenjek River. The transition from split-beam to DIDSON has gone smoothly and this equipment should continue to provide accurate escapement estimates in future years.

Escapement estimates averaged 96,055 fall chum salmon from 1981 to 2011 and 70,429 fall chum salmon during the most recent 5-year period of 2006–2010 (Table 1). Escapement estimates range from 14,229 in 1999 to a high of 561,863 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, ADF&G completed a review of the escapement goals for Yukon River fall chum salmon stocks, including the Sheenjek River. Based on this review of long term escapement, catch, and age composition data, the BEG for the Sheenjek River was given a range of 50,000 to 104,000 fall chum salmon on the right bank (Figure 3; Eggers 2001).

It will take several more years of data collection to determine how best to treat the historical estimates that are based only on the right bank. In 2009, 39% of the fish migrated on the formerly unmonitored left bank, compared to 16% in 2008, 40% in 2007, and 39% in 2005 and 2006. The left bank was not monitored in 2010 because of flooding (Dunbar 2010). Only the right bank estimate will be used to evaluate whether the current BEG is obtained, until a new BEG that includes data from both banks is determined.

## STUDY AREA

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

[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 2011 Sheenjek River sonar project were to:

1. Estimate daily passage, seasonal passage, and run timing 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 ($\alpha$=0.05 and d=0.10).
3. Collect selected climatic and hydrologic data daily at the project site.

# METHODS

## HYDROACOUSTIC EQUIPMENT

On August 8, a DIDSON was deployed on the right bank of the Sheenjek River at the historic sonar site (Figures 4 and 5). The left bank DIDSON was deployed almost directly across the river on August 9. The right bank DIDSON (long range) operated at 1.2 MHz, its high frequency option, at a range of 20 m, while the left bank DIDSON (standard) was operated at 1.1 MHz, its low frequency option, at a range of 10 m. Both the low and high frequency modes have a viewing angle of 29° in the horizontal axis and 14° in the vertical axis. Both DIDSON units were mounted on an H-shaped stand equipped with a manual crank-style rotator to facilitate aiming (Figure 6). A 152 m cable on the right bank and a 30 m cable on the left bank carried power and data between the DIDSON units in the water and the topside breakout boxes. A wireless router was used to transfer data between the left bank breakout box and a laptop computer on the right bank. All surface electronics were housed in a small self-supporting tent on the left bank and a 10x12 ft. wall tent on the right bank. All electronics were powered with two portable 1000 W generators (one on each bank) run continuously.

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

## SITE SELECTION AND TRANSDUCER DEPLOYMENT

The gently-sloping river bottom and small cobble at the historic right bank counting location, and the silty cut bank directly across the river, proved 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 1 m increments with a calibrated pole. The transducers and manual crank style rotators were mounted on stands made of aluminum pipe and deployed from each bank. The stands were secured in place with sandbags and designed to permit raising and lowering of the transducer by sliding up or down along two riser pipes that extended above the water. Technicians adjusted the aim by viewing the video image and relaying aiming instructions to a technician at the transducer stand via handheld VHF radio. The transducers were deployed in water ranging from 0.5 to 1.0 m in depth, and aimed perpendicular to the current along the natural substrate. An attempt was made to ensure the transducers were deployed at locations where there was sufficient current, i.e., area without eddies or slack water where fish milling behavior can occur.

Technicians used an artificial acoustic target during deployment to ensure transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beams. The target, an airtight 300 ml weighted plastic bottle, with a volume less than that of a chum salmon, and easily discernible with the DIDSON, was allowed to drift downstream along the river bottom and through the acoustic beams. Drifts were made at multiple ranges in order to verify target detection at all ranges of interest. Beam aim adjustment and target drifts were repeated until a satisfactory result was achieved.

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

## SONAR COUNT ADJUSTMENTS

Data collected by the DIDSONs were transferred to another computer for counting and editing using the echogram viewer program Echotastic (C. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Upstream migrating fish were counted by marking each fish track on the echogram (Figure 7). Upstream direction of travel was verified using the video feature of the program. Counts were saved as text files and recorded on a count form. Brief interruptions in sampling intermittently occurred when routine maintenance (i.e. silt removal) or relocation of the transducer was required. Long-term interruptions may also occur when flooding or hazardous conditions force removal of equipment.

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

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

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

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

If data from one or more complete days $x_d$ were missing, passage for each missing day $y_d$ was estimated using simple linear interpolation, based on the known passage $y_b$ for the day immediately before the missing days and passage $y_a$ for the day immediately after ($x_a$) the missing day(s).

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

As an example, if data from 9 days were missing, for the estimated passage on the third missing day ($d$=3), $x_d$=3, and $x_a$=10.

The proportion of fish other than fall chum salmon in the daily counts was assumed insignificant based upon historic visual counting 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 postseason 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 2011[3]) 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

Regionwide 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 0.10 probability (precision) of not having the true age proportion ($p_i$) within the interval $p_i \pm 0.05$ for all $i$ ages (accuracy).

Vertebrae collections are the preferred method of aging Yukon River fall chum salmon when in close proximity to their natal streams (Clark 1986[4]). 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 $n$=30 chum salmon per week, up to a maximum of $n$=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 (2.5 in stretch measure) is 30 m in length by 67 meshes deep (~3 m) and appropriate for collecting a representative sample. Chum salmon were collected with the beach seine, enumerated by sex using external characteristics, and measured to the nearest 5 mm, from mideye to tail fork. Additionally, 3 vertebrae were taken from each fish and given to ADF&G research staff in Fairbanks for age determination.

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[3] R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, available for download: http://www.R-project.org

[4] 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.

## Climatic and Hydrologic Observations

A water level gauge was installed at the sonar site and monitored daily, with readings made to the nearest centimeter. Surface water temperature was measured approximately 30 cm below the surface daily, with a HOBO U22™ water temperature data logger, and a pocket thermometer. The data logger was suspended from a float tied to the water level gauge and set to record 6 times per day. Minimum and maximum air temperatures, and wind velocity and direction were measured daily with a Weather Wizard III weather station. Other daily observations included occurrence of precipitation and percent cloud cover. Climatic and hydrologic observations were recorded at approximately 1800 hours daily.

# RESULTS

## River and Sonar Counting Conditions

In 2011, the right bank DIDSON was deployed in approximately the same location on the point bar that has been used in recent years, while the cutbank directly across the river continued to work well for the other DIDSON. The river bottom at the counting location dropped abruptly from the left bank at a rate of 21.5 cm/m (bottom slope ≈ 12.1°) to the thalweg approximately 17 m from shore, and then sloped gently up toward the right-bank point bar at a rate of approximately 6.4 cm/m (bottom slope ≈ 3.7°) (Figure 8). River width measured 76 m. Much of the nearshore zone along the left cutbank was silty and cluttered with fallen trees and other woody vegetation, while the right bank consisted of small cobble with no debris.

The water level was relatively high upon arrival at the project site on August 5. With respect to the initial reading of the water gauge upon deployment on August 8, the water level dropped during the first 15 days, climbed slightly for 1 day, and then dropped again for about 6 days. From August 30 to September 1 the water level held steady at the lowest point (87 cm below the initial reading) for the season (Figure 9; Appendix A1). Then on September 2 the water level began to rise slowly. From September 13 to September 17 the water dropped a bit before rising again to 58 cm below the initial reading on September 24. The last 2 days the water level dropped. On the last day, September 26, the water level was 69 cm below the initial reading. Water temperature at the project site ranged from 4.5°C to 12.3°C, and averaged 9.8°C.

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

## Abundance Estimation and Adjustments

The 2011 sonar-estimated escapement was 81,980 fall chum salmon for the 48-day period from August 8 through September 24 (Table 2). A total of 1,252.9 min (20.9 h) on the left bank and 815.7 min (13.6 h) on the right bank of sampling time were missed because of routine maintenance, system diagnostic test, system malfunction, or moving and aiming the transducer (Table 3). Most of the missed time was from the first two days when the transducers were installed mid-day and extrapolations were made to account for full days. Equations used for inseason adjustments are detailed in the methods section of this report. As noted in Table 3, sometimes the collection software from the sonar overruns the sample time, resulting in a sample that is more than an hour long. If at the end of a day the sample time is more than 24 h (1,440 min) then the time in the table may show as negative. In this case, fish may be subtracted from the estimate, resulting in a negative number of fish.

Chum salmon were present in the river when right bank sonar counting was initiated on August 8, as evidenced by the 254 fish estimated passing on the right bank that day. While the sonar was operational, the first quarter point, midpoint, and third quarter point were on September 6, September 12, and September 19, respectively. The largest passage estimate of 4,231 fish occurred on September 22 (Table 2; Figure 10). When sonar operations ceased on September 24 there was relatively high (3,546 fish per day) passage at the project site and projects downriver experienced passage of relatively large numbers of fall chum salmon that would not have reached the sonar site by the time the project terminated. Given these circumstances, the sonar-estimated escapement was expanded to 97,976 to account for chum salmon that were most likely not counted after termination of the project (Table 1) (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). The expansion was calculated by using a second order polynomial equation calculated to October 9. October 9 was chosen as an end date using a 15 day lag time correlated to the end of the run at Rampart Rapids test fish project. The resulting equation for determining the chum salmon passage for each day expanded for after sonar operations ceased was:

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

Where $y_i$ is the *i*th daily passage estimate, $L$ is the count on the last day of sonar operations, $d$ is the total number of days expanding for, and $x_i$ is the day number being estimated (where $i$=1 through 15). Table 4 shows resulting daily counts from September 25 through October 9.

## TEMPORAL AND SPATIAL DISTRIBUTION

The diel pattern of migration of Sheenjek River chum salmon typically observed in most years (Dunbar 2004) was observed again in 2011 (Figure 11). Overall, 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 1900 hours and 0900 hours. The period of minimal passage was 1400 hours, while the highest average passage occurred at 0700 hours.

During the fall chum salmon run, 40% of migrating salmon passed on the left bank and 60% passed on the right bank (Figure 10). The highest proportional passage on the left bank occurred on September 19 (61%), while the lowest occurred on August 21 (13%). Most migrating chum salmon were shore-oriented, passing through the nearshore portion of the acoustic beam. On the right bank approximately 90% of the fish counted were passing through the first 10 m of the counting range (Figure 8). The first few meters had fewer fish due to the placement of the fish lead in relation to the transducer. On the left bank, 97% of the fish were detected within 6 m of the transducer. The unusual bimodal range distribution on the left bank, as seen in Figure 8, was most likely caused by natural diversions such as submerged debris and fallen clumps of riverbank just downstream of the transducer.

## AGE AND SEX COMPOSITION

There were 34 seine hauls made at the sonar site, rkm 10, from September 1 through September 21. A total of 180 chum salmon, 92 (51%) females, and 88 (49%) males were collected for sampling (Table 5). Ten of the samples came from carcasses collected from the camp gravel bar/sonar site. Age, sex, and length compositions estimated from samples collected are on file at the Anchorage ADF&G office (Kyle Schumann, Commercial Fisheries Biologist, Salmon age and sex composition and mean lengths for the Yukon River area, 2011 data, ADF&G; Anchorage).

# DISCUSSION

## ESCAPEMENT ESTIMATE

This was the seventh season that DIDSON was used to estimate fall chum salmon passage in the Sheenjek River, and the sixth season since 1987 that both banks have been fully monitored. The DIDSON systems performed well on both right and left banks over the entire season with no major technical difficulties or failures. The DIDSON, with its viewing angle of 29° in the horizontal axis, and 14° in the vertical axis was the ideal system for the previously unmonitored left bank, where the profile is steep and less linear than the right bank. Procedures used for counting DIDSON files worked well for estimating salmon passage at the site. All data files were processed in a reasonable amount of time. Factors affecting termination of sonar counting in 2011 included logistics associated with closing down camp, and impending winter weather.

The 2011 sonar estimated escapement of 81,980 chum salmon, for the 48-day period August 8 through September 24, was expanded using run timing data from the Rampart tag recovery fish wheel to 97,976 to account for chum salmon that may have passed after sonar operations ceased (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). The expanded right bank estimate of 61,882 chum salmon was 19% above the low end of the BEG of 50,000 to 104,000 chum salmon. Since 1992 the right bank estimate has been used to assess the BEG because it was the only bank monitored. Until more data is collected, the right bank estimate will continue to be used for assessing the BEG. The fact that the DIDSON estimates may be 20% higher than split-beam estimates must also be taken into consideration when evaluating whether or not the BEG has been met. This good escapement was somewhat expected because of good parent year escapements of 160,178 in 2006 (returning age 0.4 fish) and 65,435 in 2007 (returning age 0.3 fish). Timing of the 2011 chum salmon run, while the sonar was operational, was 2 days late based on 1986–1999 and 2001–2010 mean quartile passage dates. This reflects timing while the sonar is operational and not total run timing, which would include the postseason expansion

Drift gillnet studies conducted in the 1980s concluded that only a small proportion of the salmon pass on the left bank. In 2003, preliminary work with the DIDSON on both banks at the sonar site indicated as many as 33% of the fish migrated on the left bank. This season, 40% of the fish migrated on the formerly unmonitored left bank, compared to 39% in 2005, 2006 and 2009, 40% in 2007, and 16% in 2008. Continued estimation of salmon passage on both banks should yield more accurate information on the total escapement to the Sheenjek River.

The 2011 season was characterized by a moderate odd-year fall chum salmon run to the Yukon River. Only minor limitations were placed on commercial fishing. Subsistence and personal use opportunities were not restricted. Most drainages met escapement goals. The Canadian mainstem Yukon River exceeded the spawning escapement goal, whereas the Fishing Branch River fell short of its goal. The Chandalar and Tanana river goals were also met. The Sheenjek River met its spawning escapement goal for the first time since 2006.

# ACKNOWLEDGMENTS

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## TABLES AND FIGURES

Table 1.–Operational dates, and escapement estimates of fall chum salmon in the Sheenjek River, 1981–2011.

| 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 [b] | 153,267 |
| 1988 | 21 Aug | 27 Sep | 38 | 40,866 [b] | 45,206 |
| 1989 | 24 Aug | 25 Sep | 33 | 79,116 [b] | 99,116 |
| 1990 | 22 Aug | 28 Sep | 38 | 62,200 [b] | 77,750 |
| 1991 | 09 Aug | 24 Sep | 47 | 86,496 | |
| 1992 | 09 Aug | 20 Sep | 43 | 78,808 | |
| 1993 | 08 Aug | 28 Sep | 52 | 42,922 | |
| 1994 | 07 Aug | 28 Sep | 53 | 150,565 | |
| 1995 | 10 Aug | 25 Sep | 47 | 241,855 | |
| 1996 | 30 Jul | 24 Sep | 57 | 246,889 | |
| 1997 | 09 Aug | 23 Sep | 46 | 80,423 | |
| 1998 | 17 Aug | 30 Sep | 45 | 33,058 | |
| 1999 | 10 Aug | 23 Sep | 45 | 14,229 | |
| 2000 | 08 Aug | 12 Sep | 36 | 18,652 [c] | 30,084 |
| 2001 | 11 Aug | 23 Sep | 44 | 53,932 | |
| 2002 | 09 Aug | 24 Sep | 47 | 31,642 | |
| 2003 | 09 Aug | 26 Sep | 49 | 38,321 [d] | 44,047 |
| 2004 | 08 Aug | 25 Sep | 49 | 37,878 | |
| 2005 [a] | 10 Aug | 24 Sep | 46 | 438,253 [d] | 561,863 |
| 2006 [a] | 09 Aug | 24 Sep | 47 | 160,178 | |
| 2007 [a] | 11 Aug | 24 Sep | 45 | 65,435 | |
| 2008 [a] | 09 Aug | 24 Sep | 47 | 42,842 [d] | 50,353 |
| 2009 [a] | 15 Aug | 24 Sep | 41 | 46,926 [d] | 54,126 |
| 2010 | 18 Aug | 24 Sep | 38 | 22,053 | |
| 2011 [a] | 8 Aug | 24 Sep | 48 | 81,980 [e] | 97,976 |
| 1981-10 | 15 Aug | 24 Sep | 41 | 89,070 | 96,055 |
| 2006-10 | 12 Aug | 24 Sep | 44 | 67,487 | 70,429 |

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

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

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

[d] Sonar-estimated escapement was expanded to include fish passing after sonar operations terminated. Expansions for 2003, 2005, 2008, and 2009 were based upon run timing data from the Rampart Rapids tag recovery fish wheel (Dunbar 2006, Dunbar and Pfisterer 2009, Dunbar 2009, Dunbar 2010).

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

Table 2.–Sonar-estimated passage of fall chum salmon in the Sheenjek River, 2011.

| | Daily | | | Cumulative | | | % of Total |
|---|---|---|---|---|---|---|---|
| Date | Right Bank | Left Bank | Total | Right Bank | Left Bank | Total | Passage |
| 8/8 [a] | 254 | ND | 254 | 254 | ND | 254 | 0.00 |
| 8/9 [b] | 183 | 101 | 284 | 437 | 101 | 538 | 0.01 |
| 8/10 | 178 | 59 | 237 | 615 | 160 | 775 | 0.01 |
| 8/11 | 104 | 63 | 167 | 719 | 223 | 942 | 0.01 |
| 8/12 | 116 | 38 | 154 | 835 | 261 | 1,096 | 0.01 |
| 8/13 | 110 | 47 | 157 | 945 | 308 | 1,253 | 0.02 |
| 8/14 | 115 | 37 | 152 | 1,060 | 345 | 1,405 | 0.02 |
| 8/15 | 54 | 18 | 72 | 1,114 | 363 | 1,477 | 0.02 |
| 8/16 | 62 | 18 | 80 | 1,176 | 381 | 1,557 | 0.02 |
| 8/17 | 71 | 20 | 91 | 1,247 | 401 | 1,648 | 0.02 |
| 8/18 | 87 | 27 | 114 | 1,334 | 428 | 1,762 | 0.02 |
| 8/19 | 50 | 30 | 80 | 1,384 | 458 | 1,842 | 0.02 |
| 8/20 | 106 | 40 | 146 | 1,490 | 498 | 1,988 | 0.02 |
| 8/21 | 142 | 22 | 164 | 1,632 | 520 | 2,152 | 0.03 |
| 8/22 | 122 | 42 | 164 | 1,754 | 562 | 2,316 | 0.03 |
| 8/23 | 130 | 57 | 187 | 1,884 | 619 | 2,503 | 0.03 |
| 8/24 | 124 | 82 | 206 | 2,008 | 701 | 2,709 | 0.03 |
| 8/25 | 94 | 52 | 146 | 2,102 | 753 | 2,855 | 0.03 |
| 8/26 | 52 | 56 | 108 | 2,154 | 809 | 2,963 | 0.04 |
| 8/27 | 63 | 74 | 137 | 2,217 | 883 | 3,100 | 0.04 |
| 8/28 | 110 | 108 | 218 | 2,327 | 991 | 3,318 | 0.04 |
| 8/29 | 206 | 153 | 359 | 2,533 | 1,144 | 3,677 | 0.04 |
| 8/30 | 264 | 376 | 640 | 2,797 | 1,520 | 4,317 | 0.05 |
| 8/31 | 599 | 682 | 1,281 | 3,396 | 2,202 | 5,598 | 0.07 |
| 9/1 | 769 | 972 | 1,741 | 4,165 | 3,174 | 7,339 | 0.09 |
| 9/2 | 1,233 | 1,402 | 2,635 | 5,398 | 4,576 | 9,974 | 0.12 |
| 9/3 | 1,430 | 1,174 | 2,604 | 6,828 | 5,750 | 12,578 | 0.15 |
| 9/4 | 1,030 | 1,537 | 2,567 | 7,858 | 7,287 | 15,145 | 0.18 |
| 9/5 | 1,342 | 1,726 | 3,068 | 9,200 | 9,013 | 18,213 | 0.22 |
| 9/6 | 2,424 | 1,574 | 3,998 | 11,624 | 10,587 | 22,211 | 0.27 [c] |
| 9/7 | 2,438 | 1,258 | 3,696 | 14,062 | 11,845 | 25,907 | 0.32 |
| 9/8 | 1,873 | 1,529 | 3,402 | 15,935 | 13,374 | 29,309 | 0.36 |
| 9/9 | 2,265 | 1,281 | 3,546 | 18,200 | 14,655 | 32,855 | 0.40 |
| 9/10 | 2,841 | 1,135 | 3,976 | 21,041 | 15,790 | 36,831 | 0.45 |
| 9/11 | 2,423 | 1,027 | 3,450 | 23,464 | 16,817 | 40,281 | 0.49 |
| 9/12 | 1.549 | 1.134 | 2.683 | 25.013 | 17.951 | 42.964 | 0.52 |
| 9/13 | 1.530 | 1.351 | 2.881 | 26.543 | 19.302 | 45.845 | 0.56 |
| 9/14 | 1,942 | 1,258 | 3,200 | 28,485 | 20,560 | 49,045 | 0.60 |
| 9/15 | 1,688 | 1,161 | 2,849 | 30,173 | 21,721 | 51,894 | 0.63 |
| 9/16 | 954 | 1,473 | 2,427 | 31,127 | 23,194 | 54,321 | 0.66 |
| 9/17 | 1,258 | 1,099 | 2,357 | 32,385 | 24,293 | 56,678 | 0.69 |
| 9/18 | 1,385 | 1,321 | 2,706 | 33,770 | 25,614 | 59,384 | 0.72 |
| 9/19 | 1,365 | 1,439 | 2,804 | 35,135 | 27,053 | 62,188 | 0.76 |
| 9/20 | 2,688 | 1,342 | 4,030 | 37,823 | 28,395 | 66,218 | 0.81 |
| 9/21 | 2,631 | 1,453 | 4,084 | 40,454 | 29,848 | 70,302 | 0.86 |
| 9/22 | 2,850 | 1,381 | 4,231 | 43,304 | 31,229 | 74,533 | 0.91 |
| 9/23 | 2,938 | 963 | 3,901 | 46,242 | 32,192 | 78,434 | 0.96 |
| 9/24 [d] | 2,838 | 708 | 3,546 | 49,080 | 32,900 | 81,980 | 1.00 |

*Note:* ND = no data.

[a] Right bank DIDSON operational starting at 1200, counts extrapolated to 24 hours based on partial counts.

[b] Left bank DIDSON operational starting at 1400, counts extrapolated to 24 hours based on partial counts.

[c] Single boxed area identifies central half of the observed run, and bold box identifies the observed midpoint.

[d] Last day of sonar operation.

Table 3.–Number of minutes by bank and day that were adjusted, to calculate the hourly or daily chum salmon passage, and the resulting number of fish either added or subtracted from estimate.

| | Right Bank | | Left Bank | |
|---|---|---|---|---|
| Date | Minutes | Fish | Minutes | Fish |
| 8/8 | 725.6 | 128 | ND | ND |
| 8/9 | 2.6 | 0 | 874.8 | 63 |
| 8/10 | 4.0 | 0 | 0.0 | 0 |
| 8/11 | 1.0 | 0 | 8.2 | 0 |
| 8/12 | 1.4 | 0 | 5.5 | 0 |
| 8/13 | 1.0 | 0 | 5.1 | 1 |
| 8/14 | 1.1 | 0 | 66.2 | 1 |
| 8/15 | -1.6 | 0 | 0.7 | 0 |
| 8/16 | 1.4 | 0 | -0.1 | 0 |
| 8/17 | 2.3 | 0 | 9.3 | 0 |
| 8/18 | 0.1 | 0 | 4.9 | 0 |
| 8/19 | -0.1 | 0 | -9.5 | 0 |
| 8/20 | 0.2 | 0 | 8.2 | 0 |
| 8/21 | 0.3 | 0 | -2.5 | 0 |
| 8/22 | 0.2 | 0 | 4.4 | 0 |
| 8/23 | 0.0 | 0 | -1.4 | 0 |
| 8/24 | 0.3 | 0 | -0.1 | 0 |
| 8/25 | -1.4 | 0 | 0.1 | 0 |
| 8/26 | 10.6 | 1 | 0.1 | 0 |
| 8/27 | 2.2 | 0 | 0.2 | 0 |
| 8/28 | 0.1 | 0 | 0.3 | 0 |
| 8/29 | 0.1 | 1 | 0.2 | 0 |
| 8/30 | 0.2 | 0 | -0.1 | 0 |
| 8/31 | 15.9 | 3 | 67.2 | 59 |
| 9/1 | 0.3 | 1 | 0.1 | 3 |
| 9/2 | 0.2 | 3 | 0.4 | 2 |
| 9/3 | 0.1 | 2 | 204.9 | 202 |
| 9/4 | 0.2 | 2 | 0.2 | 3 |
| 9/5 | 0.1 | 3 | 0.2 | 2 |
| 9/6 | 3.5 | 12 | -0.2 | 0 |
| 9/7 | 1.2 | 4 | 0.3 | 1 |
| 9/8 | 0.1 | 2 | 0.0 | 0 |
| 9/9 | 2.4 | 5 | -25.7 | -17 |
| 9/10 | 0.5 | 5 | 25.9 | 32 |
| 9/11 | -0.2 | 2 | 1.3 | -3 |
| 9/12 | 1.1 | 3 | 1.3 | -1 |
| 9/13 | 4.3 | 2 | -1.6 | 1 |
| 9/14 | 33.4 | 45 | 1.6 | 6 |
| 9/15 | -0.9 | 1 | 0.4 | 4 |
| 9/16 | -0.4 | 1 | 0.3 | 0 |
| 9/17 | 1.7 | 1 | 0.4 | 0 |
| 9/18 | 0.0 | 2 | 0.2 | 1 |
| 9/19 | -0.2 | 0 | 0.0 | 2 |
| 9/20 | 0.4 | 7 | 0.4 | 1 |
| 9/21 | 0.1 | 5 | 1.0 | 4 |
| 9/22 | 0.1 | 13 | 0.2 | 4 |
| 9/23 | 0.2 | 10 | 0.0 | 4 |
| 9/24 | 0.1 | 3 | 0.1 | -2 |
| Total | 815.7 (13.6h) | 267 | 1,252.9 (20.9h) | 373 |

*Note:* ND = no data. Negative numbers are result of collection software over running sample period.

Table 4.–Postseason daily expansion.

| Day | Date | Daily Expansion |
|---|---|---|
| 1 | 9/25 | 3,089 |
| 2 | 9/26 | 2,663 |
| 3 | 9/27 | 2,269 |
| 4 | 9/28 | 1,907 |
| 5 | 9/29 | 1,576 |
| 6 | 9/30 | 1,277 |
| 7 | 10/1 | 1,009 |
| 8 | 10/2 | 772 |
| 9 | 10/3 | 567 |
| 10 | 10/4 | 394 |
| 11 | 10/5 | 252 |
| 12 | 10/6 | 142 |
| 13 | 10/7 | 63 |
| 14 | 10/8 | 16 |
| 15 | 10/9 | 0 |
| Sum | | 15,996 |
| Sonar Estimate Through 9/24 | | 81,980 |
| Total Season Estimate | | 97,976 |

Table 5.–Sheenjek River test fishing (beach seine) results, 2011.

| Date | Location (rkm)[a] | Number of Sets | Chum Salmon Captured: Female | Chum Salmon Captured: Male | Chum Salmon Captured: Total | Arctic Grayling | Bourbot | Northern Pike | Longnose Sucker | Whitefish spp. |
|---|---|---|---|---|---|---|---|---|---|---|
| 9/1 | 10 | 2 | 6 | 13 | 19 | 0 | 0 | 0 | 0 | 0 |
| 9/3 | 10 | 3 | 9 | 11 | 20 | 0 | 0 | 0 | 0 | 0 |
| 9/5 | 10 | 3 | 6 | 8 | 14 | 0 | 0 | 0 | 0 | 0 |
| 9/7 | 10 | 1 | 8 | 11 | 19 | 0 | 0 | 0 | 0 | 0 |
| 9/9 [b] | 10 | 4 | 5 | 5 | 10 | 0 | 0 | 1 | 0 | 1 |
| 9/11 | 10 | 3 | 11 | 9 | 20 | 0 | 1 | 2 | 1 | 0 |
| 9/13 | 10 | 4 | 9 | 5 | 14 | 0 | 1 | 0 | 0 | 1 |
| 9/14 [b] | 10 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9/15 | 10 | 4 | 7 | 4 | 11 | 0 | 0 | 1 | 0 | 0 |
| 9/17 [b] | 10 | 3 | 5 | 6 | 11 | 0 | 0 | 0 | 0 | 0 |
| 9/18 [c] | 10 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| 9/19 | 10 | 3 | 8 | 5 | 13 | 1 | 0 | 1 | 2 | 0 |
| 9/20 [c] | 10 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 0 |
| 9/21 | 10 | 4 | 15 | 6 | 21 | 0 | 3 | 2 | 0 | 1 |
| 9/23 [b] | 10 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9/24 [b] | 10 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9/25 [b] | 10 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Total | | 34 | 92 (51%) | 88 (49%) | 180 | 1 | 5 | 7 | 3 | 3 |

[a] Locations are river kilometer (rkm). The sonar site is at rkm 10.

[b] One carcass collected at the sonar site.

[c] Two carcasses collected at the sonar site.

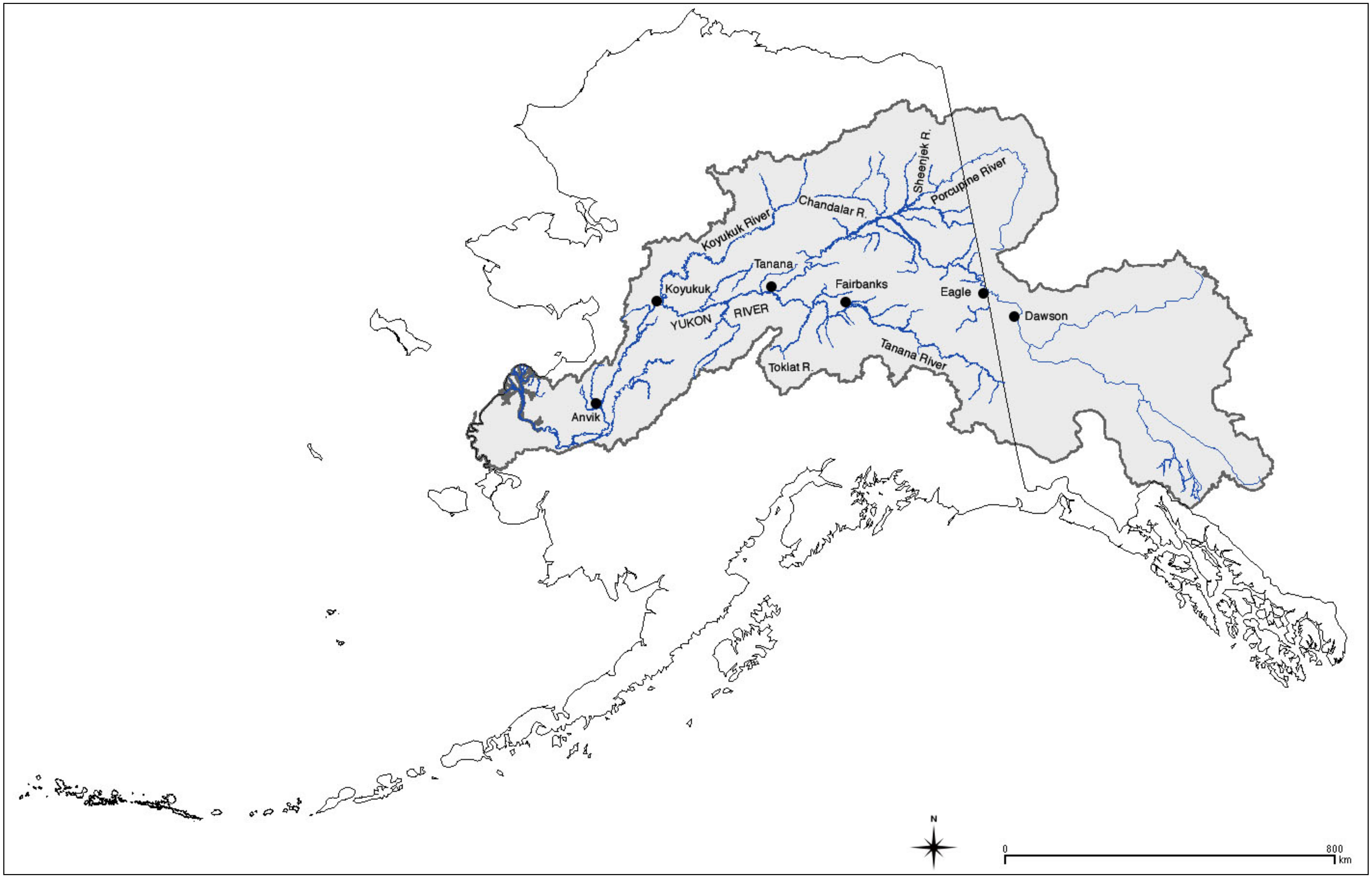



Figure 1.–The Yukon River drainage showing selected locations.

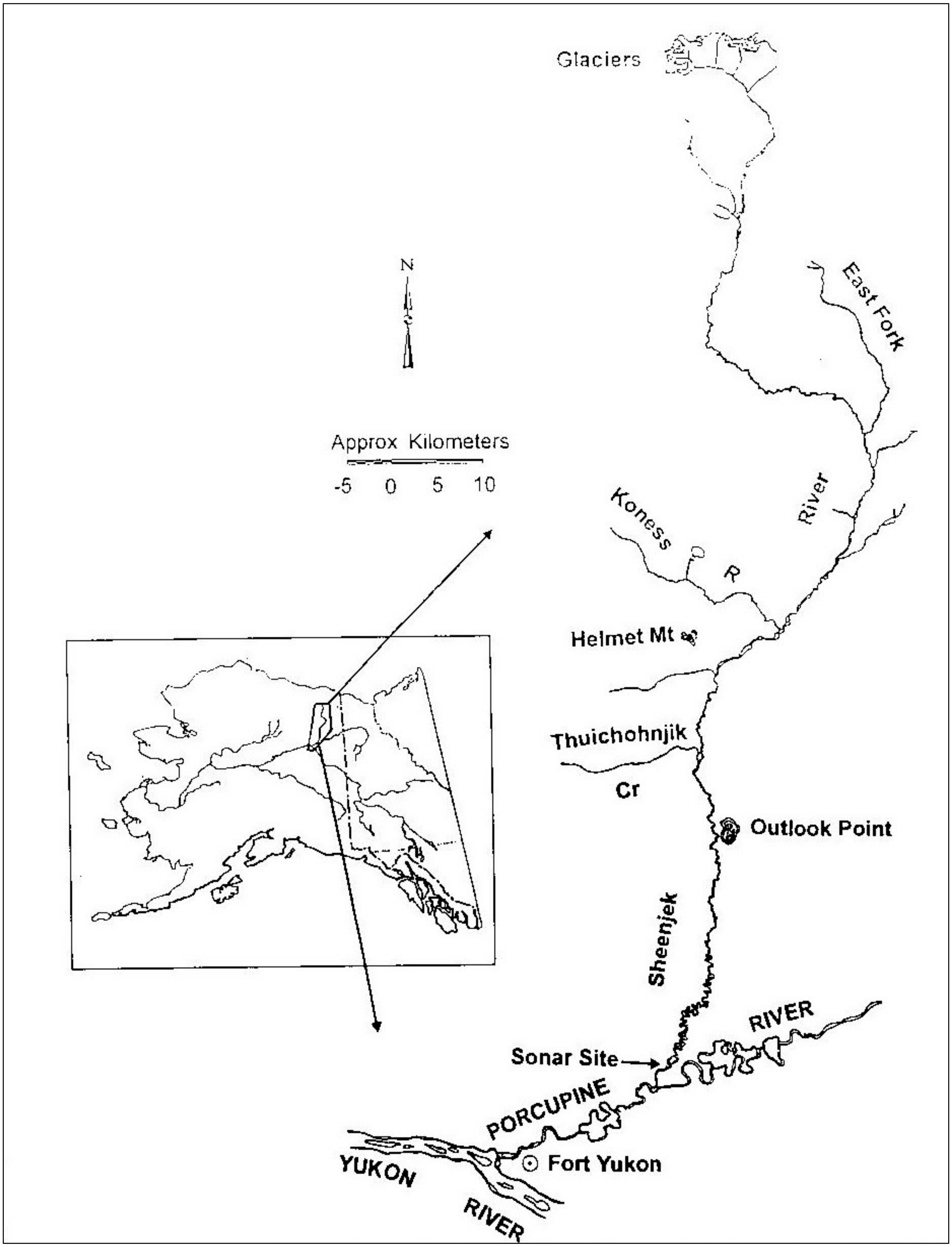
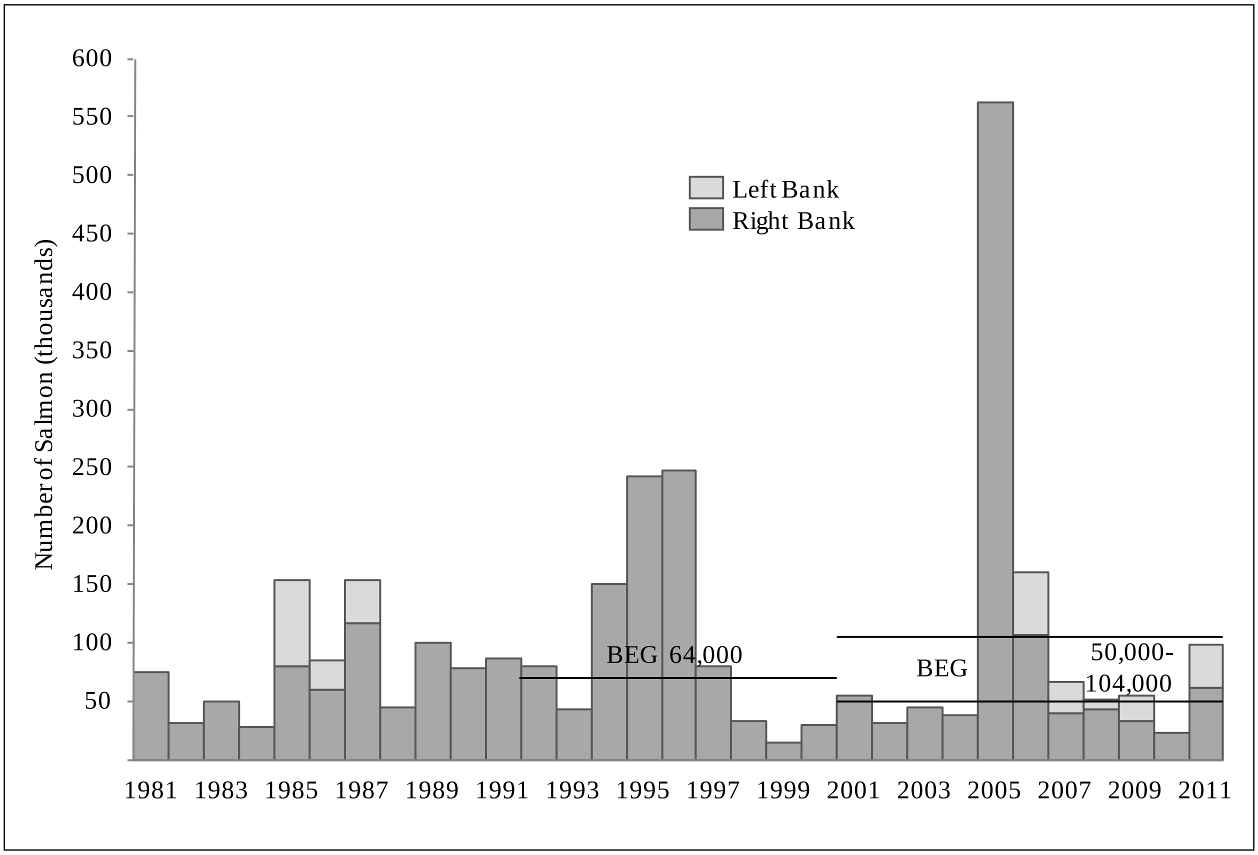



Figure 2.–The Sheenjek River drainage.




*Note*: Although the total escapement estimates for 2007 through 2009 were greater than the low end of the current BEG, the BEG was not achieved because it was based on right bank estimates only. Estimates for 1985-1990, 2000, 2003, 2005, 2008, 2009, and 2011 are expanded estimates.

Figure 3.–Escapement estimates, and BEG (horizontal lines) of fall chum salmon in the Sheenjek River, 1981–2011.

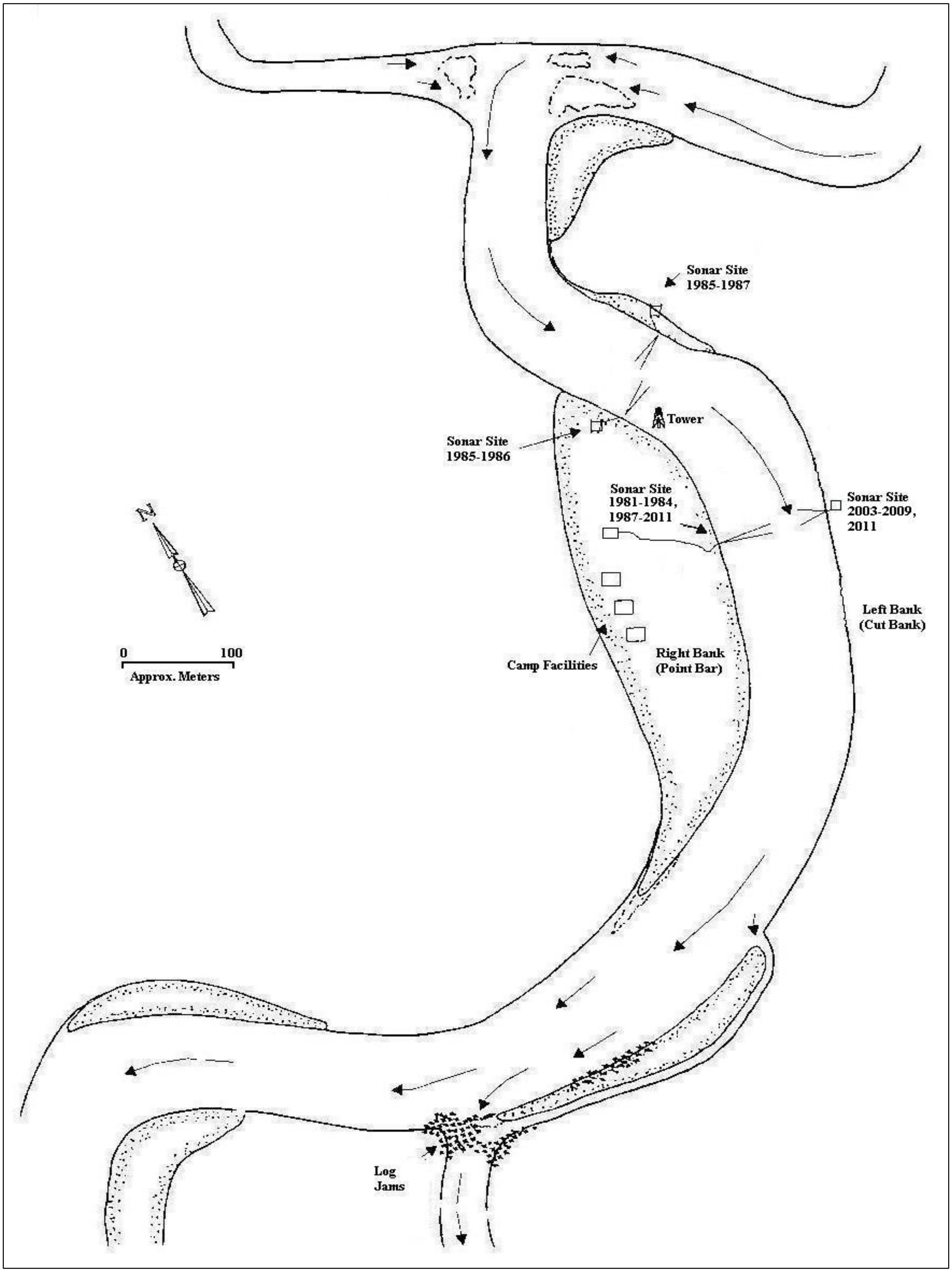



Figure 4.–The Sheenjek River sonar project site.

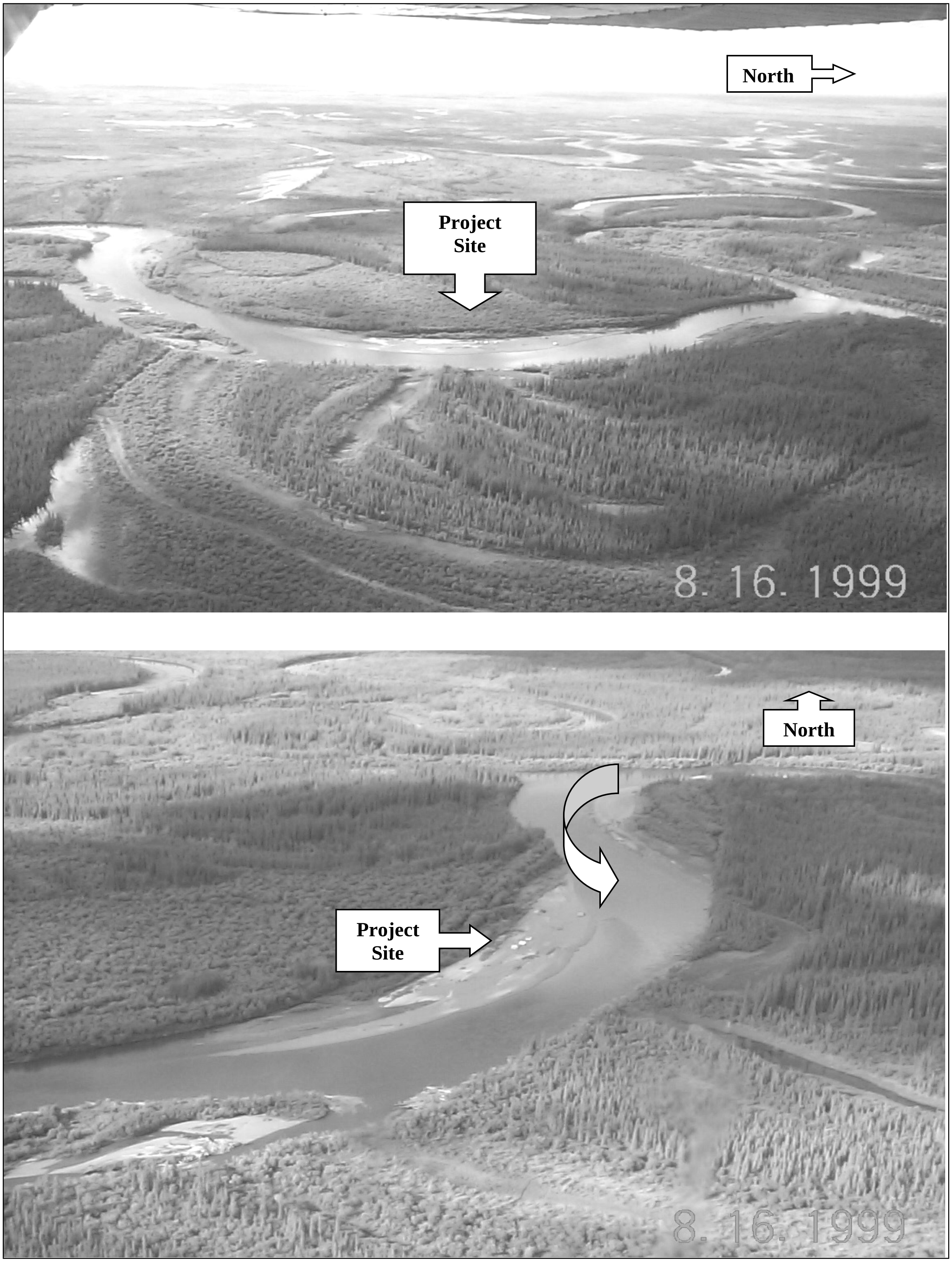



Figure 5.–Aerial photographs of the Sheenjek River sonar project site taken August 16, 1999.

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

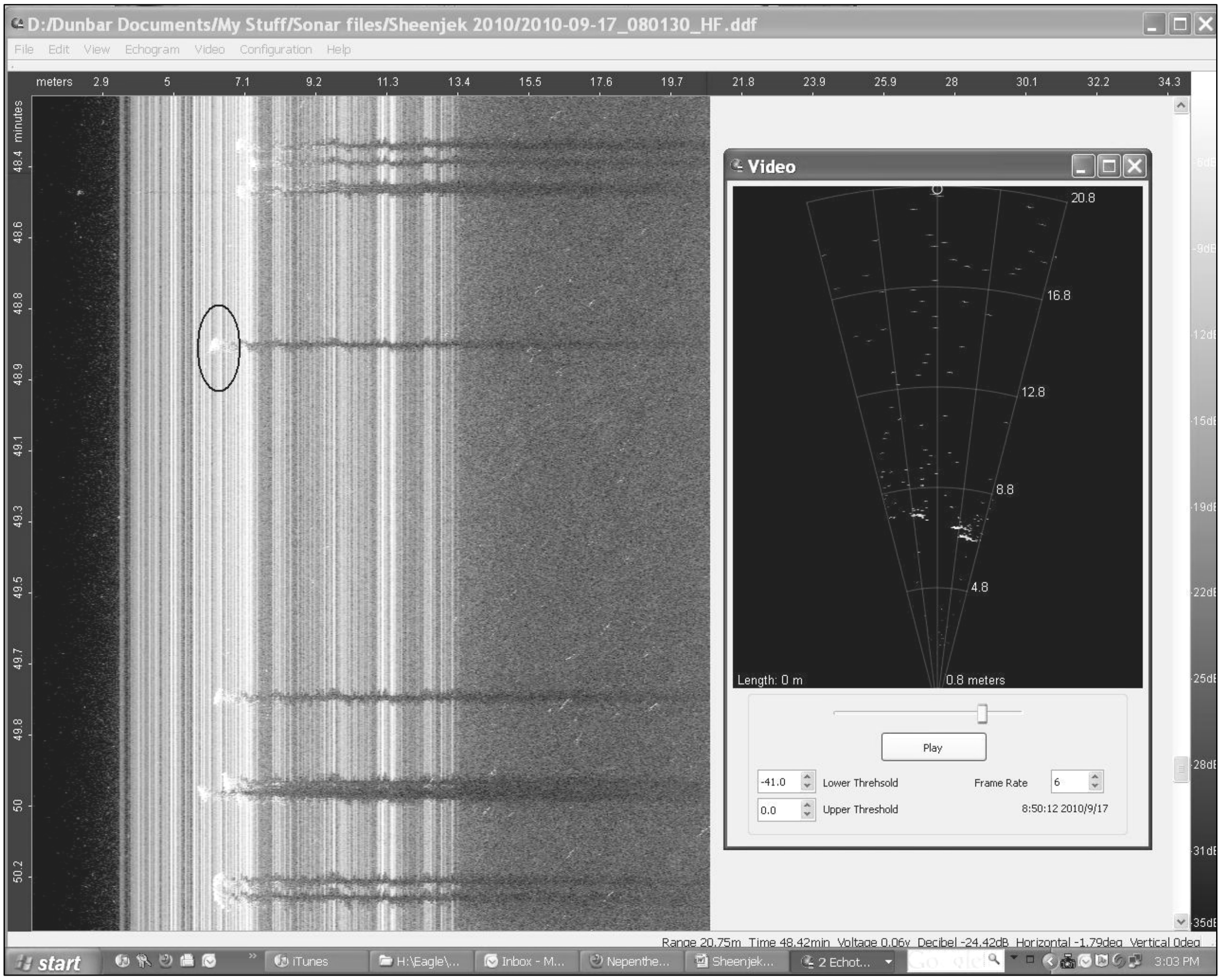
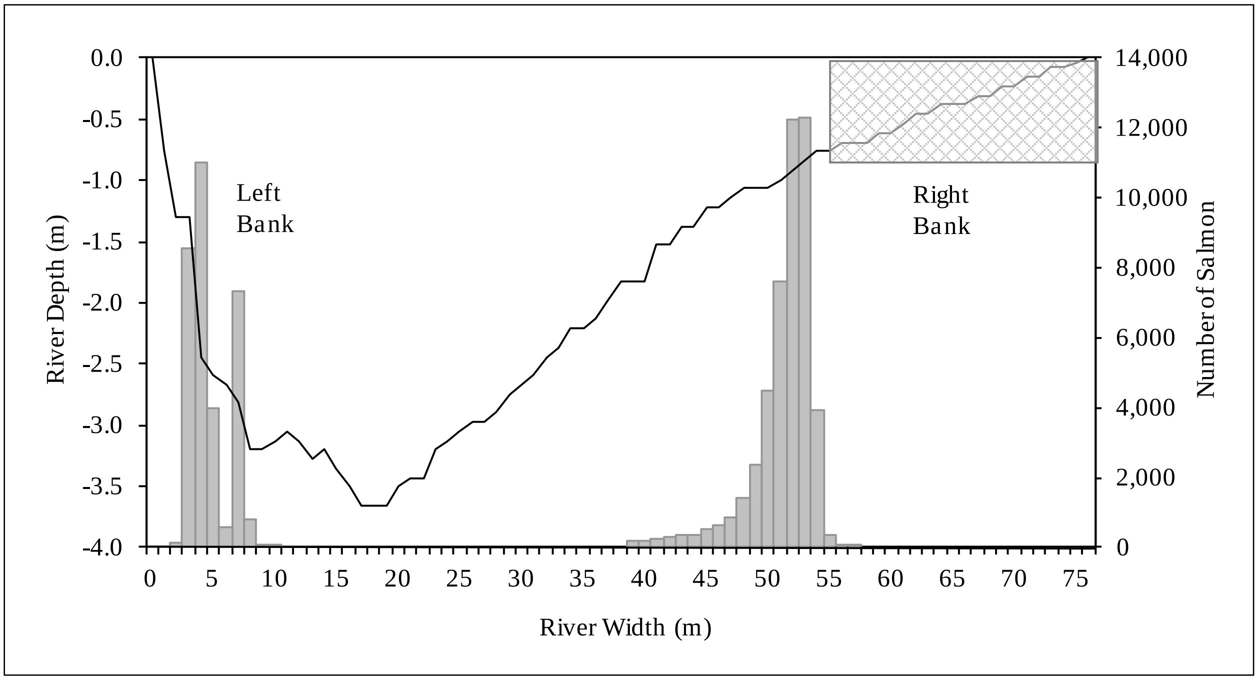



Figure 7.–Screenshot of echogram, and video image, with oval around representative fish.




*Note*: Cross hatch represents portion of river blocked by fish lead and vertical bars represent horizontal distribution of upstream fall chum salmon passage through ensonified zone of the Sheenjek River, 2011.

Figure 8.–Depth profile (downstream view) made August 13, at the project site.

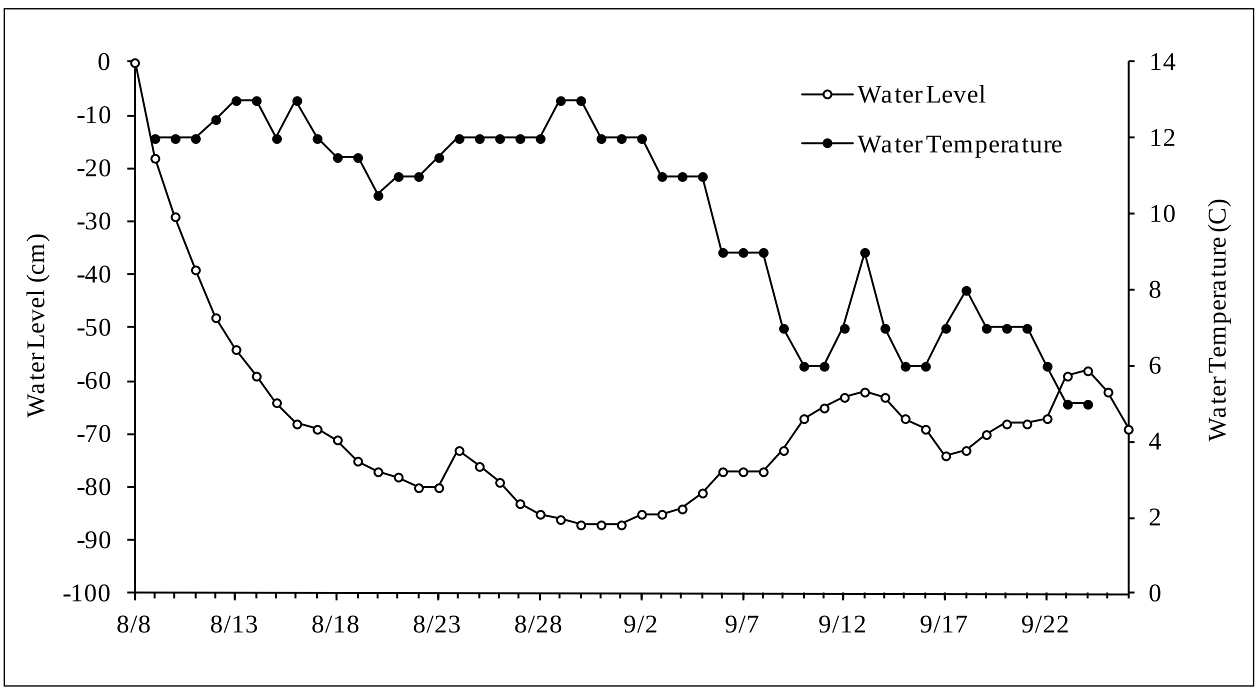



Figure 9.–Changes in daily water level relative to August 8, and water temperature measured at the Sheenjek River sonar project site, 2011.

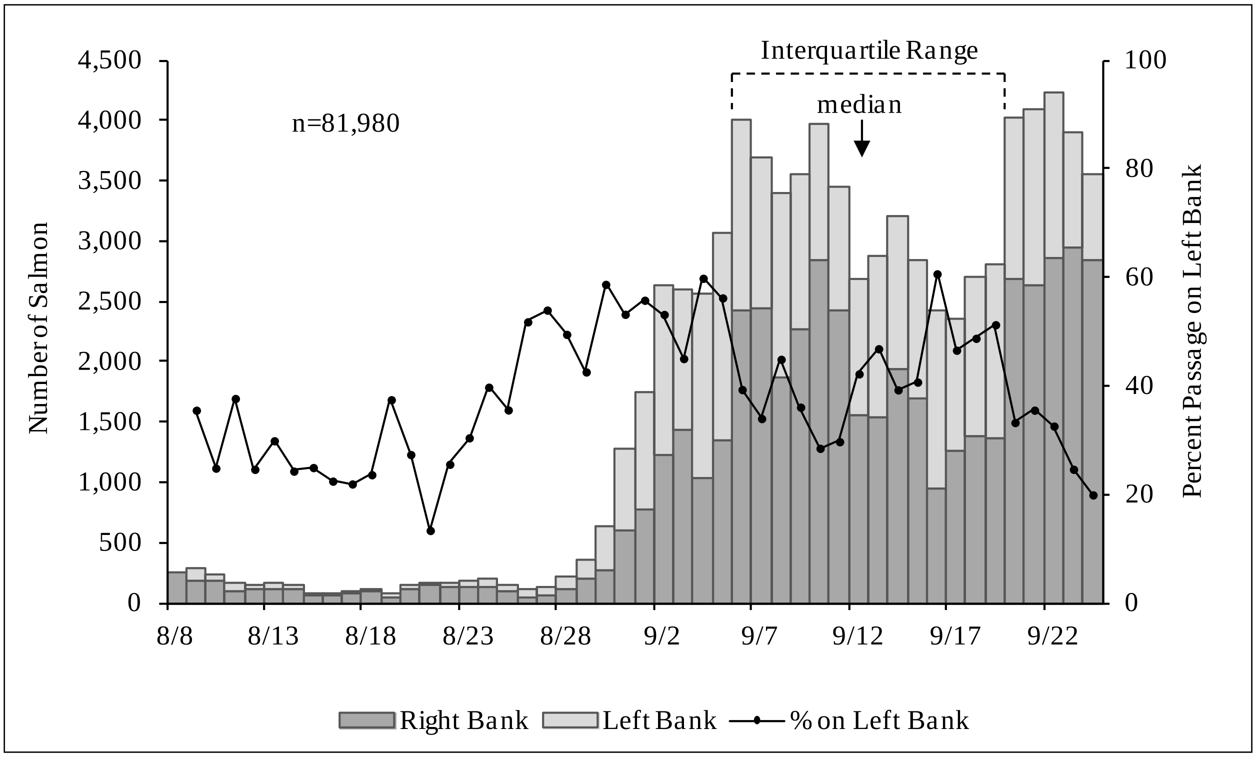



Figure 10.–Fall chum salmon sonar counts by day at Sheenjek River sonar site, August 8 through September 24, 2011.

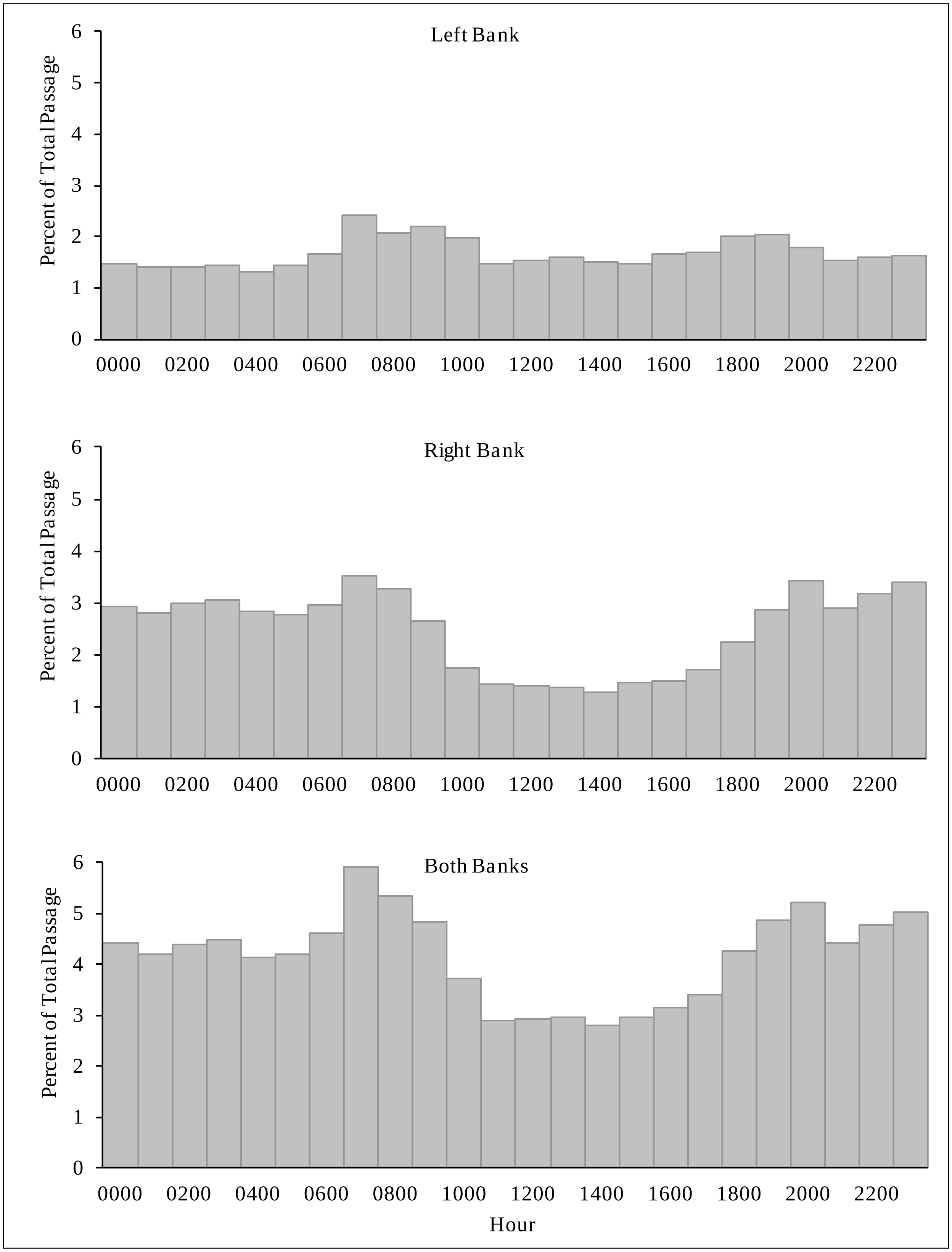



Figure 11.–Diel migration pattern of fall chum salmon on the left bank (top), right bank (middle), and both banks combined (bottom) of the Sheenjek River, from August 10 through September 24, 2011.

# APPENDIX A. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climate and hydrologic observations at the Sheenjek River project site, 2011.

| | | | | | Temperature (C°) | | | Water Level (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cloud | | | | | | | | Water |
| | Precipitation | Cover | Wind | | Water | Air | | ± 24 h | Relative to | Color |
| Date | (code)[a] | (code)[b] | Direction | Velocity (mph) | Surface[c] | Minimum | Maximum | Change | Zero Datum | (code)[d] |
| 8/8 | A | B | S | 3 | ND | ND | ND | zero datum | 0 | C |
| 8/9 | A | S | WNW | 3 | 12 | 6 | 18 | -18 | -18 | C |
| 8/10 | A | O | E | 0 | 12 | 7 | 24 | -11 | -29 | C |
| 8/11 | A | S | N | 6 | 12 | 9 | 28 | -10 | -39 | B |
| 8/12 | A | B | ENE | 4 | 12.3 | 7 | 26 | -9 | -48 | B |
| 8/13 | A | B | WNW | 4 | 12.3 | 10 | 21 | -6 | -54 | B |
| 8/14 | A | B | N | 12 | 12.2 | 10 | 19 | -5 | -59 | B |
| 8/15 | A | S | N | 10 | 12.1 | 10 | 21 | -5 | -64 | B |
| 8/16 | A | S | NNE | 12 | 11.7 | 5 | 25 | -4 | -68 | A |
| 8/17 | A | C | N | 7 | 11.7 | 5 | 18 | -1 | -69 | A |
| 8/18 | A | C | ENE | 3 | 11.3 | 4 | 20 | -2 | -71 | A |
| 8/19 | A | C | NNE | 10 | 11.1 | 4 | 20 | -4 | -75 | A |
| 8/20 | C | O | N | 1 | 10.5 | 4 | 11 | -2 | -77 | A |
| 8/21 | A | S | WSW | 2 | 10.3 | 8 | 16 | -3 | -80 | A |
| 8/22 | A | S | WSW | 0 | 10.3 | 5 | 19 | -2 | -82 | A |
| 8/23 | A | B | E | 7 | 10.6 | 3 | 23 | 0 | -82 | A |
| 8/24 | A | S | WNW | 2 | 11.4 | 10 | 20 | 7 | -75 | A |
| 8/25 | A | C | WNW | 0 | 11.8 | 7 | 24 | -3 | -78 | A |
| 8/26 | A | S | SE | 7 | 11.7 | 6 | 24 | -3 | -81 | A |
| 8/27 | A | C | NE | 2 | 11.8 | 6 | 25 | -4 | -85 | A |
| 8/28 | A | S | WNW | 0 | 12.0 | 8 | 26 | -2 | -87 | A |
| 8/29 | A | C | WNW | 1 | 11.9 | 5 | 23 | -1 | -88 | A |
| 8/30 | A | C | S | 3 | 11.9 | 5 | 25 | -1 | -89 | A |
| 8/31 | A | S | NNW | 1 | 11.5 | 4 | 22 | 0 | -89 | A |
| 9/01 | A | C | S | 3 | 11.5 | 8 | 20 | 0 | -89 | A |
| 9/02 | A | O | N | 2 | 11.5 | 9 | 20 | 2 | -87 | A |
| 9/03 | A | B | SSE | 0 | 11.0 | 9 | 19 | 0 | -87 | A |
| 9/04 | A | S | WNW | 0 | 10.8 | 6 | 20 | 1 | -86 | A |
| 9/05 | A | C | NNE | 14 | 10.3 | 5 | 19 | 3 | -83 | A |
| 9/06 | B | O | N | 4 | 9.5 | 7 | 17 | 4 | -79 | A |
| 9/07 | B | B | NNW | 3 | 9.1 | ND | ND | 0 | -79 | A |

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| | | | Wind | | Temperature (C°) | | | Water Level (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cloud | | | | Air | | | | Water |
| | Precipitation | Cover | | | Water | | | ± 24 h | Relative to | Color |
| Date | (code)[a] | (code)[b] | Direction | Velocity (mph) | Surface[c] | Minimum | Maximum | Change | Zero Datum | (code)[d] |
| 9/08 | A | B | SSE | 0 | 8.8 | 5 | 19 | 0 | -79 | A |
| 9/09 | B | O | SSW | 8 | 8.8 | 5 | 14 | 4 | -75 | A |
| 9/10 | B | O | SSW | 8 | 8.4 | 6 | 10 | 6 | -69 | A |
| 9/11 | A | S | S | 2 | 8.1 | 6 | 14 | 2 | -67 | A |
| 9/12 | A | S | N | 3 | 7.8 | 1 | 20 | 2 | -65 | A |
| 9/13 | A | C | NNE | 0 | 8.1 | 1 | 20 | 1 | -64 | A |
| 9/14 | A | S | S | 0 | 8.4 | 2 | 21 | -1 | -65 | A |
| 9/15 | B | B | N | 1 | 8.5 | 8 | 15 | -4 | -69 | A |
| 9/16 | A | C | N | 1 | 8.3 | 2 | 18 | -2 | -71 | A |
| 9/17 | A | O | N | 6 | 7.9 | 4 | 11 | -5 | -76 | A |
| 9/18 | A | C | N | 2 | 7.7 | 5 | 15 | 1 | -75 | A |
| 9/19 | A | C | N | 3 | 7.2 | 4 | 15 | 3 | -72 | A |
| 9/20 | A | O | NNW | 7 | 7.0 | 6 | 12 | 2 | -70 | A |
| 9/21 | A | C | NNE | 6 | 6.6 | 4 | 14 | 0 | -70 | A |
| 9/22 | A | C | N | 3 | 6.1 | 2 | 11 | 1 | -69 | A |
| 9/23 | A | O | N | 6 | 5.3 | 1 | 8 | 8 | -61 | A |
| 9/24 | A | O | NNE | 5 | 4.5 | 2 | 5 | 1 | -60 | A |
| 9/25 | A | B | NNE | 4 | 5 | -1 | 5 | -4 | -64 | A |
| 9/26 | A | B | N | 3 | ND | -1 | 8 | -7 | -71 | A |
| Average | | | | | 9.8 | 5 | 18 | | | |

*Note:* ND = no data.

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

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

[c] Water temperature collected 30 cm below surface with HOBO data logger from 8/19 through 9/24, and pocket thermometer on 9/25 and 9/26.

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