Fishery Data Series No. 23-34

Sonar Estimation of Salmon Passage in the Yukon River Near Pilot Station, Alaska, 2021

by

Ryan P. Morrill

and

Jody D. Lozori

November 2023

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

FISHERY DATA SERIES NO. 23-34

SONAR ESTIMATION OF SALMON PASSAGE IN THE YUKON RIVER NEAR PILOT STATION, 2021

by
Ryan P. Morrill and Jody D. Lozori
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, 99518-1565

November 2023

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

Product names used in this publication are included for completeness and do not constitute product endorsement. The Alaska Department of Fish and Game does not endorse or recommend any specific company or their products.

Ryan P. Morrill and Jody D. Lozori
Alaska Department of Fish and Game, Division of Commercial Fisheries,
1300 College Rd., Fairbanks, AK, USA

This document should be cited as follows:
Morrill, R. P., and J. D. Lozori. 2023. Sonar estimation of salmon passage in the Yukon River near Pilot Station, 2021. Alaska Department of Fish and Game, Fishery Data Series No. 23-34, Anchorage.

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act (ADA) of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:
ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526
U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203
Office of Equal Opportunity, U.S. Department of the Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:
(VOICE) 907-465-6077, (Statewide Telecommunication Device for the Deaf) 1-800-478-3648,
(Juneau TDD) 907-465-3646, or (FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact:
ADF&G, Division of Sport Fish, Research and Technical Services, 333 Raspberry Rd, Anchorage AK 99518 (907) 267-2517

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

The Pilot Station sonar project has provided daily passage estimates of Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*) salmon for most years since 1986. Fish passage estimates for each species were generated in 2021 using a 2-component process: (1) estimation of total fish passage with 120 kHz split-beam sonar and an adaptive resolution imaging sonar, and (2) apportionment to species by sampling using a suite of gillnets of various mesh sizes. An estimated 1,040,660 fish passed through the sonar sampling area between May 31 and September 7. Of those fish, 218,819 passed along the right bank, and 821,841 passed along the left bank. Included, with 90% confidence intervals, were 104,267 ± 10,339 large Chinook salmon (>655 mm from middle of the eye to tail fork [METF]), 20,578 ± 3,232 small Chinook salmon (≤655 mm METF), 153,718 ± 16,149 summer chum salmon, 146,197 ± 11,686 fall chum salmon, 37,255 ± 3,879 coho salmon, 22,181 ± 5,832 pink salmon, 195,566 ± 25,264 cisco, 264,160 ± 21,191 humpback whitefish, 23,859 ± 3,971 broad whitefish, 34,820 ± 5,374 sheefish, and 38,059 ± 4,846 other species.

Keywords: Chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta,* coho salmon *O. kisutch*, hydroacoustic, split-beam sonar, riverine, sonar, run strength, species apportionment, net selectivity, adaptive resolution imaging sonar ARIS, Yukon River

INTRODUCTION

BACKGROUND

Chinook (*Oncorhynchus tshawytscha*), chum (*O. keta*), and coho (*O. kisutch*) salmon are managed during the season for harvest by commercial, subsistence, and sport fisheries within the Alaska portion of the Yukon River drainage (Figure 1), as well as to meet treaty obligations made under the U.S./Canada *Yukon River Salmon Agreement*. The diversity and number of fish stocks, combined with the geographic range of user groups, add complexity to management decisions. Escapement estimates and run strength indices are generated by various projects within the drainage, providing stock-specific abundance and timing information; however, much of this information is obtained after the fish have become unavailable to the fisheries. Timely indices of run strength are provided by gillnet test fisheries conducted in the Lower Yukon River, but the functional relationship between catch per unit effort (CPUE) and actual abundance is confounded by varying migration patterns through the multichannel environment, gear selectivity, environmental conditions, and changes in net site characteristics.

The Pilot Station sonar project has provided daily salmon passage estimates, run timing, and biological information to fishery managers for most years since 1986. The project is located at river km 197 in a single-channel environment near the village of Pilot Station. This location is upriver enough to avoid the multiple-channel environment of the Yukon River delta. The project can provide timely abundance information to managers because travel time for salmon from the mouth of the river to the sonar site is 2 to 3 days. The Andreafsky River is the only major salmon spawning tributary downstream of the sonar site (Figure 1); therefore, most migrating salmon in the Yukon River pass the sonar project on their way to the spawning grounds.

The primary role of Alaska Department of Fish and Game (ADF&G) is to manage for sustained yield under Article VIII of the Alaska Constitution, but Alaska is also obligated to manage Yukon River salmon stocks according to precautionary, abundance-based harvest-sharing principals set forth in the *Yukon River Salmon Agreement*. The goal of bi-national, coordinated management of Chinook and chum salmon stocks is to meet escapement requirements that will ensure sufficient fish availability for sustained harvests in both the United States and Canada in the future. Furthermore, managers follow guidelines specified by Alaska regulations through management plans for Yukon River Chinook, summer chum, fall chum, and coho salmon. Accurate daily salmon abundance estimates help managers regulate fishing during the season to meet harvest and escapement objectives and are used postseason to determine whether treaty obligations were met and to judge the effects of management actions.

Prior to 1993, ADF&G used dual-beam sonar equipment that operated at 420 kHz. In 1993, ADF&G changed the existing sonar equipment to operate at a frequency of 120 kHz to allow a greater ensonification range by reducing signal loss, which helped to increase fish detection at longer ranges (Fleischman et al. 1995). The newly configured performance of the equipment was verified using standard acoustic targets in the field.

Until 1995, ADF&G attempted to identify the direction of travel of detected targets by aiming transducers at an upstream or downstream oblique angle relative to fish travel. This technique was discontinued in 1995 in favor of aiming transducers perpendicular to fish travel to maximize fish detection (Maxwell et al. 1997). Due to this change and subsequent changes to counting procedures, data collected from 1995 to 2019 are not directly comparable to previous years. In 2001, the equipment was changed from dual-beam to the current split-beam sonar system configured to operate at 120 kHz (Pfisterer et al. 2002). Reference to the use of dual-beam sonar at the Pilot Station sonar project can be found in (Rich 2001). The split-beam technology can estimate the 3-dimensional position of a target in space, which allows the testing of assumptions about the direction of travel and vertical distribution of fish moving through the acoustic beam (Burwen et al. 1995).

A series of gillnets using different mesh sizes drifted through the acoustic sampling areas to apportion the passage estimates to species. In 2004, the selectivity model used in species apportionment was refined through biometric review and analysis of historical catch data from the project's test fishery. The model that provided the best overall fit to the data was a Pearson model with a tangle parameter (Bromaghin 2004). In 2016, minimum selectivity thresholds were implemented into the model for species apportionment to prevent individual fish from skewing estimates dramatically (Pfisterer et al. 2017). The selectivity parameters used in the species apportionment model were updated using the most current catch data prior to the 2021 field season. Species proportions and passage estimates reported in this document were generated using this apportionment model and are comparable to 1995–2020 estimates because estimates from those years have been regenerated using the most current model.

Early in the 2005 season, the Yukon River experienced high water levels and erosion, which caused the formation of a cut bank and steepened the bottom profile on the left bank. The altered bottom profile allowed fish close to shore to swim under the beam, which compromised detection. On June 9, 2005, a multibeam dual-frequency identification sonar (DIDSON; Belcher et al. 2002) was deployed in this area to verify nearshore fish detection. The wider beam angle, video-like images, and software algorithms that can remove a bottom structure from the image allowed the DIDSON system to detect fish passage within 20 m despite high water levels and problematic erosion and was operated for the remainder of the season, supplanting split-beam counts in this section of the nearshore region. From 2005 until 2014, the DIDSON was integrated into the sampling routine on the left bank and operated side-by-side with the split-beam sonar. The DIDSON sampled the first 20 m of the left bank nearshore strata, and the remainder of the range was sampled by the split-beam sonar. Beginning in 2015, the DIDSON was replaced with an adaptive resolution imaging sonar (ARIS). The ARIS, when equipped with the telephoto lens, is capable of ensonifying the first 50 m of the left bank.

In 2008, electronic charts were tested prior to the switch from paper charts used to count fish traces. Electronic charts were found to provide a number of advantages that include increased threshold levels, better consistency (no ribbons that fade), less downtime related to paper jams, and the ability to easily determine the direction of travel. In 2009, electronic echograms replaced paper charts to count fish traces (Lozori and McIntosh 2013).

For consistency with prior years when paper charts were used, all targets, both up and downstream, were counted from 2010 to 2019 by right clicking the computer mouse on downstream targets and left-clicking on upstream targets. In 2020, a review of 2010–2019 data determined that the overall percentage of downstream targets observed was insignificant compared to the total passage estimates, and counting downstream targets was discontinued (Morrill et al. 2021).

This report presents results from the Lower Yukon River sonar project for the 2021 field season. Included are data from an extension in project operations 1 week prior and past the normal start and end dates through a grant from the U.S. Fish and Wildlife Service Yukon River Salmon Research and Management Assistance fund; with these extensions, the sonar operated from May 31 until September 07, 2021.

OBJECTIVES

The primary goal of this project was to estimate daily fish passage by species during upstream migration past the sonar site.

The primary project objective was as follows:

1. Provide fishery managers with daily and cumulative passage estimates and associated confidence intervals of adult Chinook, chum, and coho salmon.

The secondary project objectives were as follows:

1. Collect biological data from all fish captured in the test fishery, including species, sex, length, and scales, as appropriate.
2. Collect Chinook and chum salmon tissue samples for separate genetic stock identification projects.
3. Collect water temperature data representative of the ensonified areas of the river.

STUDY SITE

Locations in this report are referenced by the proximate bank of the Yukon River relative to a downstream perspective. At the sonar site, the left bank is south of the right bank. Both the village of Pilot Station and the ADF&G sonar camp are located on the right bank.

The Yukon River, at the sonar site, is approximately 1,000 m wide between the left and right bank transducers (Figure 2). The left bank substrate, composed of silt and fine sand, drops off gradually at a vertical angle of approximately 2° to 3°. The right bank has a stable, rocky bottom that drops off uniformly to the thalweg at a vertical angle of approximately 6° (Figure 3). The thalweg is approximately 25 m deep and is located approximately 200 m offshore of the right bank (Figure 4). River discharge, as observed from 2010 to 2020 at the United States Geological Survey (USGS) gauging station located downstream of the project, has ranged from a maximum of 2,643 m^3/s to a minimum of 7,787 m^3/s from June 1 through September 7 (Figure 5).

METHODS

Daily upstream migration of targeted fish species is estimated by multiplying the daily sonar passage of all species by the daily proportions of each targeted fish species that are estimated from the drift gillnet test fishery conducted in the same area as the sonar (Figure 6). Test fishery and sonar sampling were both stratified temporally and physically. Temporal stratification occurs through multiple test fishing and sonar periods per day (Table 1). The physical stratification for test fishery sampling was accomplished using different fishing zones and for sonar sampling by dividing the right bank into 2 range strata (S1 and S2) and dividing the left bank into 3 strata: S3, S4, and S5 (Figure 7).

HYDROACOUSTIC DATA ACQUISITION

Equipment

Left bank sonar equipment included the following:

1. A Hydroacoustic Technology Inc. (HTI) Model 244 echosounder configured to transmit and receive at 120 kHz, controlled via Digital Echo Processing (DEP) software installed on a laptop PC.
2. An HTI 120 kHz split-beam transducer with a 2.8° x 10° nominal beam width.
3. A 250 ft (76.2 m) HTI split-beam transducer cable connecting the sounder to the transducer.
4. An ARIS Explorer 1200 unit equipped with a telephoto lens, configured to transmit and receive at 0.7 MHz, and controlled via software installed on a laptop PC.
5. A 150 m ARIS underwater cable to connect the ARIS to the command module and laptop PC.

Right bank sonar equipment included the following:

1. An HTI Model 244 echosounder configured to operate at 120 kHz, controlled via DEP software installed on a laptop PC.
2. An HTI split-beam 120 kHz transducer with a 6° x 10° nominal beam width.
3. Three 250 ft (228.6 m combined length) HTI split-beam cables to connect the sounder to the transducer.

The HTI Model 244 echosounders were ideal for the project due to configurability and power. The echosounders were set to transmit and receive at 120 kHz, which was necessary to achieve the sampling ranges. The beam heights for each split-beam transducer were chosen to fit the water column between the bottom and surface with minimal interference, and the 10° width provided an adequate field of view. The lengths of cable were necessary for flexibility in the placement of the transducers. Transducers were mounted on metal tripods and remotely aimed with Remote Ocean Systems (ROS) Model PT-25 rotators (Figure 8), which allows precision in aiming, especially at range with the split-beam sonar. Rotator movements were controlled with HTI Model 660-2 rotator controllers with position feedback to the nearest 0.1°. The ARIS was ideal in the left bank nearshore stratum because it was much more robust to bottom and surface interference, and the telephoto lens was used to achieve the sampling range.

After echogram files were recorded, Echotastic software developed by ADF&G staff was used to mark fish traces (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Echograms and associated data were stored on a portable hard drive and transferred onto two 2-terabyte external hard drives.

Equipment settings and thresholds

The split-beam echosounders used a 40 log*R* time-varied gain (TVG) and 0.4 milliseconds (ms) transmit pulse duration during all sampling activities. The receiver bandwidth was automatically determined by the equipment based on the transmit pulse duration. On the left bank, the pulse repetition rate (ping rate) for S4 was set at 3 pings per second (pps), and S5 was set at 1.2 pps. On the right bank, the ping rate for S1 was set at 5 pps, and S2 was set at 3.5 pps (Table 2). On the left bank, S3 was sampled by the ARIS, which operated at an average rate of 4 frames per second with a start range of 0.7 m and an end range of 50 m in low-frequency mode (0.7 MHz). Due to river conditions, the end range in S3 was reduced from 50 m to 40 m (Table 3), and the range in S4 was increased to cover 40–150 m. The digital sampling used by both the split-beam sonar and ARIS eliminated the use of thresholds during raw data collection; however, thresholds were applied to the electronic echogram files when viewed in Echotastic to reduce background noise and improve fish trace detection (Table 4). Thresholds were adjusted throughout the season depending on silt loads and other river conditions.

Aiming

Transducers were deployed on both the left and right banks in an area where the river is approximately 1,000 m wide. The transducers were positioned and aimed to maximize fish detection. Transducers were deployed in an area with the best bottom profile, and the beam was oriented approximately perpendicular to the current so that migrating fish would present the largest possible reflective surface. Because many fish travel close to the substrate, the maximum response angle of the beam was oriented slightly above the river bottom through as much of the range as possible. The right bank transducer was positioned as close to shore as possible depending on the water level, adjusting the aim between S1 (0–40 m) and S2 (40–150 m). The left bank split-beam transducer was positioned as close to shore as possible (depending on the water level) and initially utilized 2 distinct aims to sample S4 (40–150 m) and S5 (150–300 m). The ARIS unit was normally deployed within 2 m of the split-beam transducer and initially ensonified S3 (0.7–40 m; Figure 7). The ARIS's wider beam angle is ideal for the less linear nature of the eroded left bank nearshore stratum, enabling it to detect fish targets throughout more of the water column than the narrower split-beam sonar.

Fluctuating water levels required repositioning of the transducers and subsequent re-aiming of the beams. The transducer was panned horizontally upstream and downstream approximately 15° off perpendicular in 2° increments to establish optimal aim. At each increment, the vertical tilt was adjusted to obtain the best possible bottom picture using an electronic echogram to confirm that the sonar beam was oriented slightly above the river bottom. The left bank transducers were re-aimed more often to compensate for the dynamic bottom conditions and continual changes associated with that bank. Once an optimal aim was obtained, the rotator settings were documented, and the autorotator settings were changed to the new optimal aim. Faulkner and Maxwell (2009) further discuss aiming and sonar site selection protocols to count fish using side-looking sonar systems.

Sampling procedures

Acoustic sampling was conducted simultaneously on both banks during three 3-hour periods each day (Table 1). Sample periods were 0530–0830, 1330–1630, and 2130–0030 hours, alternating sequentially between strata every 30 minutes.

Operators marked fish traces for both the split-beam sonar and the ARIS on electronic echograms using Echotastic software developed by ADF&G (Figure 9). All personnel were trained to distinguish between fish traces and non-target echoes. Echo traces were counted as a single fish if at least 2 pings in the cluster passed the threshold level and the targets did not resemble inert downstream objects. Valid downstream and upstream split-beam fish targets were marked when computing the total estimate of fish passage for consistency with historical methods. Individuals within groups of fish were distinguishable when the apparent direction of movement of 1 fish trace differed from that of an adjacent trace.

Echograms were reviewed daily by either the project leader or crew leader to monitor the accuracy of the marked fish tracings and reduce individual biases. Each echogram was checked for indications of signal loss and changes to bottom reverberation markings, which could indicate either movement of the transducer or a change in the bottom profile. Data was checked daily for data entry or marking errors and then processed in the statistical software package *R*.

SYSTEM ANALYSES

The performance of the split-beam hydroacoustic system was monitored following many of the procedures first established in 1995 (Maxwell et al. 1997). Monitoring of the ARIS included daily checks of sonar settings prior to each sampling period, routine checks of water level near the transducers, checking aim settings, and periodic cleaning of the transducer lens. System analyses included equipment performance checks, bottom profiles using down-looking sonar, and hydrologic measurements.

Bottom profiles

Bottom profiles were recorded along both banks using a Lowrance LCX15MT recording fathometer with GPS capabilities to locate deployment sites with suitable linear bottom profiles. All bottom profiles were recorded and stored electronically. During the season, the fathometer was used regularly to monitor changing bottom conditions and to watch for the formation of sandbars capable of re-routing fish to unensonified areas.

Hydrological measurements

Water discharge data were sourced from the real-time USGS gauging station located approximately 500 m downstream of Pilot Station and used during the season (Figure 5). HOBO Water Temperature Loggers were deployed to record water temperature on both banks on May 31 and remained submerged until September 8. The data loggers were programmed to record the water temperature once every hour. The daily temperature was calculated as the mean of all recorded temperatures for the day.

SPECIES APPORTIONMENT

A total of 8 different mesh sizes were fished throughout the season to effectively capture all size classes of fish present and detectable by the hydroacoustic equipment (Table 5). All nets were

25 fathoms (45.7 m) long and approximately 8 m deep. All nets were constructed of shade 11 or equivalent, double knot multifilament nylon twine and hung even at a 2:1 ratio of web to cork line.

Test fishing began as soon as practical and continued through the last day of sonar operation. Test fishing was conducted twice daily between sonar periods from 0900 to 1200 hours and 1700 to 2000 hours, except on days when commercial gillnet fishing was scheduled (Table 1). On days of commercial gillnet fishing, only 1 test fishing period was conducted to prevent interference or overlap with the scheduled commercial period or a sonar operation period. During each normal sampling period, 4 different mesh sizes drifted within each of 3 zones for a total of 24 drifts per day, except when only 1 test fishing period was conducted in which all 6 mesh sizes were fished (Table 6). The order of drifts was (1) left bank nearshore zone, (2) right bank zone, and (3) left bank offshore zone, with a minimum of 20 minutes between drifts in the same zone. Each mesh size was fished in all 3 zones before switching to the next mesh size. The shoreward end of the left bank nearshore drift was approximately 5 m to 10 m offshore of the sonar transducers. The left bank offshore drift was approximately 65 m offshore of the transducers to avoid overlap with the nearshore drift. Drifts were approximately 8 minutes in duration but were shortened as necessary to avoid snags or to limit catches during times of high fish passage.

Captured fish were identified to species and length measured to the nearest 1 mm. Salmon species were measured from the middle of the eye to tail fork (METF); nonsalmon species were measured from the tip of the snout to fork of the tail (FL). Nonsalmon species captured and identified included cisco (*Coregonus* spp.), humpback whitefish (*C. pidschian*), broad whitefish (*C. nasus*), sheefish/inconnu (*Stenodus leucichthys*), burbot (*Lota lota*), longnose sucker (*Catostomus catostomus*), Dolly Varden (*Salvelinus malma*), and northern pike (*Esox lucius*). Sex was recorded only for salmon species and was determined by examination of external features. Fish species, length, and sex were recorded on field data sheets. Each drift record included the date, sampling period, zone, drift start and end times, mesh size, length of net, and captain's initials. Handling mortalities among the captured fish were distributed to the local community, and fish dispersal was documented daily.

Four scale samples were collected from each Chinook salmon and mounted on scale cards. Fish and card numbers were recorded on the test fishery data sheets and then entered into a Microsoft Access database. Age, sex, and length (ASL) data are processed, analyzed, and reported annually by ADF&G staff based in Anchorage.

Individual genetic tissue samples from Chinook and chum salmon were also collected in the form of an axillary process clip placed in vials for several stock identification projects in conjunction with the test fishery portion of the project. ASL data were cross referenced with each tissue sample. The ADF&G Gene Conservation Laboratory (e.g., DeCovich and Howard 2011) and the U.S. Fish and Wildlife Service (USFWS) Conservation Genetics Laboratory (Flannery 2020) independently processed and analyzed these tissue samples.

Chinook salmon were classified as either large (>655 mm METF) or small (≤655 mm METF), and small Chinook salmon served as a proxy for jacks. The 655 mm length cutoff was derived from analysis of ASL data when it was determined this was the average length separating 4-year-old and 5-year-old Chinook salmon (Pfisterer and Maxwell 2000). Although there was some temporal overlap between the summer and fall runs of chum salmon, for the purposes of estimating passage, all chum salmon encountered through July 18 were designated as summer chum salmon, and after July 18 were designated as fall chum salmon.

Analytical Methods

Daily estimates were produced from a multicomponent process that involved the following:

1. Hydroacoustic estimates of all fish targets passing the site and species composition derived from test fishery results were applied to the undifferentiated hydroacoustic estimates.
2. CPUE estimates were used as a separate index by the managers and calculated on a subset of the test fishery data.

Catch Per Unit Effort

CPUE estimates used as separate indexes by the managers, and not for species apportionment, were calculated for each day (d) and bank (b) using 2 gillnet suites (g) of specific size mesh sizes (m). Chinook salmon CPUE was calculated on the pooled catch (c) and effort (f) of the large mesh gillnets (7.5 inch and 8.5 inch); chum and coho salmon CPUE was calculated on the pooled catch and effort of the small mesh gillnets (5.25 inch, 5.75 inch, and 6.5 inch).

The duration of the test fishery drift (j) in minutes (t) was calculated as:

$$t_j = SI_j - FO_j + \frac{(FO_j - SO_j)}{2} + \frac{(FI_j - SI_j)}{2}, \tag{1}$$

where:

SO = the time the net is initially set out,

FO = the time the net is fully set out,

SI = the time the net starts back in, and

FI = the time the net is fully retrieved in.

The total fishing effort (in fathom-hours) for each day, bank, and gillnet suite was calculated as:

$$e_{dbg} = \sum_m \frac{25 \cdot t_{dbgm}}{60}, \tag{2}$$

because all nets were 25 fathoms (45.7 m) in length. CPUE estimates (in catch per fathom-hour) for each species (i) were made daily for the right and left banks as:

$$CPUE_{dbig} = \frac{\sum_m c_{dbigm}}{e_{dbg}}. \tag{3}$$

Species composition

Test fishery sampling was conducted on both banks to estimate species proportions. The right bank has 1 zone (Z1), and the left bank has 2 zones (Z2 [0–40 m] and Z3 [40–300 m]). In relation to acoustic sampling, Z1 corresponds to sonar strata S1 and S2, Z2 corresponds to S3, and Z3 corresponds to S4 and S5 (Figure 7). Test fishing was conducted twice daily between sonar periods; P1 was 0900–1200, and P2 was 1700–2000 hours. This was considered 2-stage systematic sampling, in which CPUE of species (i) passing at zone (z), during period (p), of day (d) (C_{dzpi}), was considered the primary sampling unit of measurement.

CPUE of species (i) passing zone (z) during period (p) of day (d) (C_{dzpi}) was calculated by dividing the sum of the number of species (i) of length (l) caught by meshes (m) (c_{dzpilm}) by the sum of length selectivity adjusted efforts by meshes (m) (f_{dzpilm}) and then summed across all lengths:

$$C_{dzpi} = \sum_l \left(\frac{\sum_m c_{dzpilm}}{\sum_m f_{dzpilm}} \right), \tag{4}$$

where length selectivity adjusted effort f_{dzpilm} is calculated as:

$$f_{dzpilm} = S_{ilm} \cdot e_{dzpm}, \tag{5}$$

and S_{ilm} is the net selectivity of the species (i) of length (l) caught by mesh (m), and e_{dzpm} is the effort (in fathom-hours) calculated by multiplying the drift time (t) (in minutes) by 25 fathoms and dividing by 60 minutes per hour (Appendix A1; Bromaghin 2004):

$$e_{dzpm} = \frac{25 \cdot t_{dzpm}}{60}. \tag{6}$$

A threshold to prevent individual fish with extremely low selectivity from unreasonably inflating the CPUE was applied such that:

$$S_{ilm} = \begin{cases} S_{ilm} & S_{ilm} \geq 0.1 \\ 0.1 & \text{otherwise} \end{cases}. \tag{7}$$

The proportion of species (i) passing zone (z) during period (p) of day (d) ($\hat{p}_{dzpi}$) and the proportion for day ($\hat{p}_{dzi}$):

$$\hat{p}_{dzpi} = \frac{C_{dzpi}}{\sum_i C_{dzpi}} \text{ and } \hat{p}_{dzi} = \frac{\sum_p C_{dzpi}}{\sum_p \sum_i C_{dzpi}}. \tag{8}$$

The variance of $\hat{p}_{dzi}$ was estimated from the squared differences between the proportion for each test fishery period within the day ($\hat{p}_{dzpi}$) and the proportion for the day as a whole ($\hat{p}_{dzi}$):

$$\widehat{Var}(\hat{p}_{dzi}) = \frac{\sum_p \left(\hat{p}_{dzi} - \hat{p}_{dzip} \right)^2}{n_p (n_p - 1)}, \tag{9}$$

where n_p is the number of test fishery sampling periods within the day, equation 9 requires n_p to be greater than 1, so days with less than 1 test fishing period were pooled with adjacent days such that there were at least 2 complete test fishery periods.

Sonar passage estimates

Fish passage was estimated separately for each sonar stratum. Let y_{dpsk} be defined as 30-minute subsampling acoustic counts (k) at stratum (s), during periods (p) of day (d). The hourly passage rate per stratum and period was calculated:

$$r_{dps} = \frac{\sum_k y_{dpsk}}{\sum_k h_{dpsk}}, \tag{10}$$

where h_{dpsk} is the fraction of the hour sampled for sample (k). The daily passage was then estimated as:

$$\hat{y}_{ds}=24\ \frac{\sum_p r_{dsp}}{n_p}, \tag{11}$$

where n_p was the number of periods in the day. The variance of $\hat{y}_{ds}$ was estimated as:

$$\hat{V}(\hat{y}_{ds})=24^2\left(\frac{s^2}{n_p}\right)\left(1-\frac{h_{ds}}{24}\right), \tag{12}$$

where s^2 is the variance of the passage rate for the day:

$$s^2=\left(\frac{\sum_p\left(r_{dsp}-\bar{r}_{ds}\right)^2}{n_p-1}\right). \tag{13}$$

Fish passage by species

The final step in the estimation process was combining the sonar estimates with the estimates of species proportions to compute passage by species. To estimate passage by species within each sonar stratum, the passage for each stratum was multiplied by the species proportions for the test fishery zones as follows: test fishery Z1 was applied to the entire counting range of the right bank (sonar strata S1 and S2 approximately 0–150 m). Test fishery Z2 was applied to the counting range corresponding to S3 (approximately 0–50 m on the left bank). Test fishery Z3 was applied to the counting range corresponding to S4 and S5 (approximately 50–150 m and 150–300 m on the left bank, respectively; Figure 7). The passage of species (i) at stratum (s) for each day was estimated by multiplying total passage ($\hat{y}_{ds}$) and proportion ($\hat{p}_{dzi}$):

$$\hat{y}_{dis}=\hat{y}_{ds}\cdot\hat{p}_{dzi}. \tag{14}$$

Except for the timing of sonar and gillnet sampling periods, sonar-derived estimates of total fish passage were independent of gillnet-derived estimates of species proportions. Therefore, the variance of their product was estimated as the variance of the product of 2 independent random variables (Goodman 1960):

$$\widehat{Var}(y_{dis})=\hat{y}_{ds}^2\cdot\widehat{Var}(\hat{p}_{dzi})+\hat{p}_{dzi}^2\cdot\widehat{Var}(\hat{y}_{ds})-\widehat{Var}(\hat{y}_{ds})\cdot\widehat{Var}(\hat{p}_{dzi}). \tag{15}$$

Daily passage and variance of each species are the sum over all sonar strata:

$$\hat{y}_{di}=\sum_s\hat{y}_{dis}\ and\ \widehat{Var}(\hat{y}_{di})=\sum_s\widehat{Var}(\hat{y}_{dis}). \tag{16}$$

Likewise, total passage and variance for the season of each species are the sum of the daily passage:

$$\hat{y}_i=\sum_d\hat{y}_{di}\ and\ \widehat{Var}(\hat{y}_i)=\sum_d\widehat{Var}(\hat{y}_{di}). \tag{17}$$

Assuming normally distributed errors, 90% confidence intervals are calculated as:

$$\hat{y}_i\pm1.645\sqrt{\widehat{Var}(\hat{y}_i)}. \tag{18}$$

R program code (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication) was used to calculate CPUE, passage estimates, and estimates of variance.

RESULTS

The Pilot Station sonar project crew arrived at the sonar site on May 29 and began camp setup. Test fishery drift areas were dragged for snags on May 30, and test fishing began during P2 on May 31. The project was fully operational, beginning with P2 sonar on May 31 and continued operations through September 7. Passage estimates were transmitted to fishery managers daily.

ENVIRONMENTAL AND HYDROLOGICAL CONDITIONS

Ice break-up on the Yukon River at Pilot Station occurred on May 13, which was later than the 10-year average of May 11 (Table 7). The water discharge near Pilot Station during the 2021 season was slightly below the 2011–2020 mean from June 1 through June 20, then rose above the mean through July 21. Water discharge decreased below the previous 10-year high from July 22 to August 25 and rose slightly above average through September 7. (Figure 5). Mean daily water temperatures on the left bank ranged from 10.3°C to 18.3°C and from 10.6°C to 17.8°C on the right bank (Figure 10). Water temperatures also fell below the 10-year averages on both banks, rising above the average shortly in late June and late July.

TEST FISHERY

Drift gillnetting resulted in the capture of 4,681 fish: 761 Chinook salmon (644 large and 117 small), 453 summer chum salmon, 739 fall chum salmon, 411 coho salmon, and 2,317 fish of other species. Of the captured fish, 1,408 (30%) were retained as mortalities and delivered to local users within the nearby community of Pilot Station (Table 8). Of the 761 Chinook salmon captured in the test fishery, scale samples were collected from 761 fish, while 647 of these were ageable.[1] Tissue samples for genetic stock identification were collected from 756 Chinook salmon and 1,195 chum salmon.

HYDROACOUSTIC ESTIMATES

An estimated 1,040,660 fish passed through the sonar sampling areas between June 7 and September 7. Of that total passage, 218,819 (approximately 21%) fish passed along the right bank, and 821,841 (approximately 79%) fish passed along the left bank (Table 9). Total fish passage estimates (with associated errors) by zone were calculated daily (Appendix C1). During both the summer and fall seasons, over 90% of the fish passage occurred within 60 m of the transducers on both banks (Figures 11–12).

SPECIES ESTIMATES

Fish passage estimates by species were generated daily and reported to fishery managers each morning (Appendix D1). Chinook salmon cumulative inseason passage estimates, with 90% confidence intervals, were 104,267 ± 10,339 large Chinook salmon (>655 mm METF) and 20,578 ± 3,232 small Chinook salmon (≤655 mm METF). Chum salmon cumulative passage estimates were 153,718 ± 16,149 summer chum salmon and 146,197 ± 11,686 fall chum salmon.

[1] Arctic–Yukon–Kuskokwim Database Management System (AYKDBMS). 2006– . Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, AK. https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx (accessed: May 5, 2022).

Coho salmon cumulative passage estimate was 37,255 ± 3,879 fish, and pink salmon (*O. gorbuscha*) was 22,181 ± 5,832 fish. The cisco cumulative passage estimate was 195,566 ± 25,264 fish, humpback whitefish was 264,160 ± 21,191 fish, broad whitefish was 23,859 ± 3,971, sheefish was 34,820 ± 5,374 fish, and other species (burbot, longnose sucker, Dolly Varden, sockeye salmon, and northern pike) was 38,059 ± 4,846 fish (Table 9).

The initial pulse of Chinook salmon began approximately June 17 (Figure 13); however, the front end of the Chinook run had an unusually long and consistent flow of "tricklers" that lasted for almost 2 weeks before the more distinctive first pulse arrived.[2]

The summer chum salmon estimates this season was the lowest in all the years of project operations (1995–2021). Early fish arrival started on June 4, and no significant pulses were detected until July 18, the last day of the summer chum season. Compared to the 2011–2020 historical mean run timing, the midpoint of the Chinook salmon run occurred 4 days late (June 28) and 8 days late (July 6) for summer chum salmon (Figure 14; Appendices E and F).

There were 5 distinct fall chum salmon pulses that passed the sonar project after July 19. The first pulse was the largest at approximately 33,816 fish. Peak daily passage occurred on July 31, during the first pulse (Figure 15). Inseason mixed stock analysis (MSA) from the Pilot Station sonar project test fishery, utilizing genetic samples, was used to generate stock composition estimates of pulses, which were distributed inseason to assist management decisions. Run timing for both fall chum and coho salmon was restricted to July 19–August 31 to allow more meaningful comparison with years that did not operate into September. The midpoint for the fall chum salmon run was August 7, which was 6 days early compared to the 2011–2020 mean cumulative run timing (Figure 16; Appendices E and F).

There was a relatively steady increase in coho passage until the first significant pulse on August 9 (Figure 15). As in most years, the project ended before the coho salmon run was complete; therefore, estimates were considered conservative, and timing may not reflect the total run. The midpoint for the coho salmon run was August 25, which was 3 days late compared to the 2011–2020 mean cumulative run timing (Figure 16; Appendices E and F).

MISSING DATA

Initially, there were 9 days between May 31 and June 8 that had insufficient catches in at least 1 fishing zone, which made it necessary to pool days to ensure reasonable species apportionment (Table 10). In total, there were 100 days with insufficient catches, primarily in the offshore zone on the left bank (Z3). Unlike other years, there were no commercial fisheries this season that affected the species apportionment test fishery, which would necessitate pooling days.

DISCUSSION

Optimal aiming of the sonar beam is essential for detecting fish on both banks. The rocky substrate found on the right bank is less dynamic than the silty bottom of the left bank and, therefore, has little or no change in profile throughout the season. Upon deployment on the left bank, high water, silt attenuation, and an eroded nearshore substrate hampered ARIS ability to detect fish beyond 40 m. A spreader lens was installed to increase the vertical beam from 3° to approximately 14°.

---

[2] Jallen, D. 2021. 2021 Yukon River Summer Season Summary, Alaska Department of Fish and Game, Division of Commercial Fisheries, Advisory Announcement, Juneau, Alaska. Issued October 26, 2021. Available from: https://www.doi.gov/subsistence/news/general/2021-yukon-river-summer-season-summary (accessed: April 19, 2021).

Additionally, the end range in S3 was reduced from 50 m to 40 m, and the range in S4 was increased to cover 40–150 m. The spreader lens was removed on July 21 due to high waters dropping to average water levels.

Although there were a few problems this season, estimating fish passage on the Yukon River continues to present major technical and logistic challenges. The sampling environment is often demanding due to the extremely dynamic nature of the water level, turbidity, bottom substrate, and range-dependent signal loss. The hydroacoustic systems employed at the Pilot Station sonar project appear to work well for the purpose of detecting migrating salmon, but successful estimation depends on constant attention to the frequent changes and diligent rechecking of every part of the acoustic and environmental system. In 2021, all project goals were met, and passage estimates were given to fisheries managers daily during the season. The information generated at the Pilot Station sonar project was also disseminated weekly through multiagency international teleconferences and data sharing with stakeholders in areas from the Lower Yukon River all the way to the spawning grounds in Canada.

ACKNOWLEDGMENTS

The authors would like to thank the following organizations for their support: the Association of Village Council Presidents (AVCP) for providing a fisheries technician, the U.S. Fish and Wildlife Service for providing funding for genetic analysis and transport of samples, the communities of Pilot Station and St. Mary's as well as Lower Yukon River Tribal government leaders and staff for working with ADF&G to help coordinate permissions to visit the communities and operate the project safely during the COVID-19 pandemic. The U.S. Fish and Wildlife Service also provided funding to extend project operations 1 week prior and past the normal start and end dates through Yukon River Salmon Research and Management Assistance grant F20AP10220.

The authors would also like to thank the following people for their hard work and dedication to the project during the 2021 season: Technicians Kerri Kelly, Jason Norton, Donald Kelly (AVCP technician), Matthew Joseph Jr., Matthew Joseph, Quinn Davis, Jaymes Kelly, and Keela Wiglesworth (Fishery Biologist). Thanks to Carl Pfisterer (ADF&G Commercial Fisheries Sonar Coordinator) for his assistance in the field and careful review of this report, and Toshihide Hamazaki (ADF&G Commercial Fisheries Biometrician) for biometric review.

REFERENCES CITED

Belcher, E. O., W. Hanot, and J. Burch. 2002. Dual-frequency identification sonar. Proceedings of the 2002 International Symposium on underwater technology, April 16–19, 2002, Tokyo, Japan.

Bromaghin, J. F. 2004. An evaluation of candidate net selectivity models for 1990–2003 Yukon River Sonar gill-net catch data. U.S. Fish and Wildlife Service, Alaska Fisheries Technical Report Number 75, Anchorage.

Burwen, D. L., D. E. Bosh, and S. J. Fleischman. 1995. Evaluation of hydroacoustic assessment techniques for Chinook salmon on the Kenai River using split-beam sonar. Alaska Department of Fish and Game, Fishery Data Series No. 95-45, Anchorage.

DeCovich, N. A., and K. G. Howard. 2011. Genetic stock identification of Chinook salmon harvest on the Yukon River 2010. Alaska Department of Fish and Game, Fishery Data Series No. 11-65, Anchorage.

Faulkner, A. V., and S. L. Maxwell. 2009. An aiming protocol for fish-counting sonars using river bottom profiles from a dual-frequency identification sonar (DIDSON). Alaska Department of Fish and Game, Fishery Manuscript No. 09-03, Anchorage.

Flannery, B. G. 2020. Application of mixed-stock analysis for Yukon River chum salmon, 2019. Final Report for Project URE-164-19N, Yukon River Panel, Restoration and Enhancement Fund.

Fleischman S. J., D. C. Mesiar, and P. A. Skvorc II. 1995. Lower Yukon River sonar project report 1993, 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A95-33, Anchorage.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Lozori, J. D., and B. C. McIntosh. 2013. Sonar estimation of salmon passage in the Yukon River near Pilot Station, 2009. Alaska Department of Fish and Game, Fishery Data Series No. 13-28, Anchorage.

Maxwell, S. L., D. C. Huttunen, and P. A. Skvorc II. 1997. Lower Yukon River sonar project report 1995. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A97-24, Anchorage.

Morrill, R. P., K. T. Wiglesworth, and J. D. Lozori. 2021. Sonar estimation of salmon passage in the Yukon River near Pilot Station, 2019. Alaska Department of Fish and Game, Fishery Data Series No. 21-13, Anchorage.

Rich, C. F. 2001. Yukon River project report 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A01-13, Anchorage.

Pfisterer, C. T. 2002. Estimation of Yukon River passage in 2001 using hydroacoustic methodologies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A02-24, Anchorage.

Pfisterer, C. T., T. Hamazaki, and B. C. McIntosh. 2017. Updated passage estimates for the Pilot Station sonar project, 1995–2015. Alaska Department of Fish and Game, Fishery Data Series No. 17-46, Anchorage.

Pfisterer, C. T., and S. L. Maxwell. 2000. Yukon River sonar project report, 1999. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 3A00-11, Anchorage.

TABLES AND FIGURES

Table 1.–Daily sampling schedule for sonar and test fishery at the Pilot Station sonar project on the Yukon River, 2021.

	Sonar by stratum		
Time	Right bank	Left bank	Test fishery
	Period 1		
0530	S1	S3/S4	
0600	S2	S5	
0630	S1	S3/S4	
0700	S2	S5	
0730	S1	S3/S4	
0800	S2	S5	
0830			
0900			Period 1
0930			
1000			
1030			
1100			
1130			
1200			
1230			
1300	Period 2		
1330	S1	S3/S4	
1400	S2	S5	
1430	S1	S3/S4	
1500	S2	S5	
1530	S1	S3/S4	
1600	S2	S5	
1630			
1700			Period 2
1730			
1800			
1830			
1900			
1930			
2000			
2030			
2100	Period 3		
2130	S1	S3/S4	
2200	S2	S5	
2230	S1	S3/S4	
2300	S2	S5	
2330	S1	S3/S4	
0000	S2	S5	

Table 2.–Initial split-beam sonar settings at the Pilot Station sonar project on the Yukon River, 2021.

			Bank	
Component	Setting	Stratum	Left	Right
Transducer	Beam size (h x w)		2.8° x 10°	6° x 10°
Echosounder	Transmit power (dB)	S1		27.0
		S2		27.0
		S4	27.0	
		S5	30.0	
	Receiver gain (dB)	S1		-6.0
		S2		-6.0
		S4	-18.0	
		S5	-12.0	
	Source level (dBµPa @ 1 m)	S1		216.8
		S2		216.8
		S4	222.1	
		S5	223.1	
	Through-system gain (dB)		-161.6	-162.0
	Pulse width (ms)		0.4	0.4
	Blanking range (m)		0	0
	Ping rate (pps)	S1		5.0
		S2		3.5
		S4	3.0	
		S5	1.2	
	Range (m)	S1		0 to 40
		S2		40 to 150
		S4	40 to 150	
		S5	150 to 300	

Note: ms = millisecond, dB = decibel, pps = pings per second.

Table 3.–Technical specifications for the adaptive resolution imaging sonar (ARIS) at the Pilot Station sonar project on the Yukon River, 2021.

Setting	Value
Field of view (h x w)	14° x 14°
Detection frequency (MHz)	0.7
Receiver gain (dB)	20.0
Samples/beam	1456.0
Start range (m)	0.7
Frame rate (f/s)	4.0
End range (m)	40.0

Table 4.–Initial range of lower and upper thresholds used in Echotastic at the Pilot Station sonar project on the Yukon River, 2021.

		Threshold (dB)	
Bank	Stratum	Upper	Lower
Right	S1	-30	-52
	S2	-23	-47
Left	S3	-15	-47
	S4	-30	-53
	S5	-25	-54

Table 5.–Specifications for drift gillnets used for test fishing by season at the Pilot Station sonar project on the Yukon River, 2021.

	Stretch mesh size		Mesh diameter	Meshes deep	Depth
Season	(in)	(mm)	(mm)	(MD)	(m)
Summer	2.75	70	44	131	8.0
(5/31–7/18)	4.00	102	65	90	8.0
	5.25	133	85	69	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0
	8.50	216	137	43	8.1
Fall	2.75	70	44	131	8.0
(7/19–9/7)	4.00	102	65	90	8.0
	5.00	127	81	72	8.0
	5.75	146	93	63	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0

Table 6.–Fishing schedule for drift gillnets used for test fishing by season at the Pilot Station sonar project on the Yukon River, 2021.

Season	Test fishery period	Mesh size (inch)			
		Odd days		Even days	
Summer	1	2.75	5.25	8.50	4.00
(6/7–7/18)		7.50	6.50	7.50	6.50
	2	7.50	6.50	7.50	6.50
		8.50	4.00	2.75	5.25
Fall	1	4.00	5.75	2.75	7.50
(7/19–9/7)		5.00	6.50	5.00	6.50
	2	5.00	6.50	5.00	6.50
		2.75	7.50	4.00	5.75

Table 7.–Yukon River ice break-up dates at Pilot Station, 2001–2021.

Year	Break-up date
2001	5/29
2002	5/18
2003	5/15
2004	5/03
2005	5/11
2006	5/25
2007	5/11
2008	5/19
2009	5/17
2010	5/19
2011	5/17
2012	5/17
2013	5/31
2014	5/03
2015	5/14
2016	4/29
2017	5/05
2018	5/13
2019	5/07
2020	5/11
2021	5/13

Source: National Oceanic and Atmospheric Administration (NOAA). 2021. National Weather Service, Alaska-Pacific River Forecast Center. www.weather.gov/aprfc/breakupDB (accessed: October 27, 2021).

Table 8.–Number of fish caught and retained in the Pilot Station sonar project test fishery on the Yukon River, 2021.

Total catch	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	1	0	0	0	0	0	2	0	0	5	2	10
June	459	142	0	1	0	0	90	54	30	140	80	996
July	298	311	174	18	0	61	507	209	23	50	32	1,683
August	3	0	477	8	316	16	571	292	27	23	13	1,746
September	0	0	88	1	95	0	30	19	7	3	3	246
Total	761	453	739	28	411	77	1,200	574	87	221	130	4,681

Fish retained	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	1	0	0	0	0	0	1	0	0	1	0	3
June	182	106	0	1	0	0	18	0	1	41	0	349
July	117	215	71	5	0	0	155	2	2	12	0	579
August	1	0	179	0	51	0	165	1	2	0	0	399
September	0	0	39	0	23	0	12	1	2	1	0	78
Total	301	321	289	6	74	0	351	4	7	55	0	1,408

Proportion retained	Chinook	S. Chum	F. Chum	Sockeye	Coho	Pink	Whitefish	Cisco	Burbot	Sheefish	Others [a]	Total
May	1.000	0.000	0.000	0.000	0.000	0.000	0.500	0.000	0.000	0.200	0.000	0.300
June	0.397	0.746	0.000	0.000	0.000	0.000	0.200	0.000	0.033	0.293	0.000	0.350
July	0.393	0.691	0.408	0.278	0.000	0.000	0.306	0.010	0.087	0.240	0.000	0.344
August	0.333	0.000	0.375	0.000	0.161	0.000	0.289	0.003	0.074	0.000	0.000	0.229
September	0.000	0.000	0.443	0.000	0.242	0.000	0.400	0.053	0.286	0.333	0.000	0.317
Total	0.396	0.709	0.391	0.214	0.180	0.000	0.293	0.007	0.080	0.249	0.000	0.301

Note: "S. chum" = Summer chum; "F. chum" = Fall chum.

[a] Includes longnose sucker, northern pike, and Dolly Varden.

Table 9.–Cumulative fish passage estimates by zone and species with standard errors (SE) and 90% confidence intervals (CI) at the Pilot Station sonar project on the Yukon River, 2021.

					90% CI	
Species	Right bank	Left bank	Total passage	SE	Lower	Upper
Large Chinook [a]	8,409	95,858	104,267	6,285	93,928	114,606
Small Chinook [b]	3,204	17,374	20,578	1,965	17,346	23,810
Total Chinook	11,613	113,232	124,845	6,584	114,014	135,676
Summer chum	25,090	128,628	153,718	9,817	137,569	169,867
Fall chum [c]	17,569	128,628	146,197	7,104	134,511	157,883
Coho [c]	12,976	24,279	37,255	2,358	33,376	41,134
Pink	5,751	16,430	22,181	3,545	16,349	28,013
Cisco	37,627	157,939	195,566	15,358	170,302	220,830
Humpback whitefish	51,664	212,496	264,160	12,882	242,969	285,351
Broad whitefish	12,288	11,571	23,859	2,414	19,888	27,830
Sheefish	12,556	22,264	34,820	3,267	29,446	40,194
Other [d]	31,685	6,374	38,059	2,946	33,213	42,905
Total	218,819	821,841	1,040,660			

[a] Large Chinook >655 mm.

[b] Small Chinook ≤655 mm.

[c] Because the fall chum salmon migration continued after project operations, estimates are considered incomplete.

[d] Includes sockeye salmon, burbot, longnose sucker, Dolly Varden, and northern pike.

Table 10.–Dates of zones pooled at the Pilot Station sonar project on the Yukon River, 2021.

Date	Right bank (Zone 1)	Left bank Nearshore (Zone 2)	Left bank Offshore (Zone 3)	Reason for pooling
5/31				IC
6/01				
6/02				IC
6/03				
6/04				IC
6/05				
6/06				IC
6/07				
6/08				
6/09				IC
6/10				IC
6/11				
6/12				IC
6/13				
6/14				IC
6/15				
6/16				IC
6/17				
6/18				
6/19				IC
6/20				
6/21				IC
6/22				
6/23				
6/24				IC
6/25				
6/26				
6/27				
6/28				IC
6/29				
6/30				IC
7/01				
7/02				IC
7/03				
7/04				IC
7/05				
7/06				
7/07				IC
7/08				IC
7/09				
7/10				IC
7/11				
7/12				IC
7/13				
7/14				IC
7/15				
7/16				
7/17				
7/18				
7/19				

-continued-

Table 10.–Page 2 of 2.

		Left bank		
Date	Right bank (Zone 1)	Nearshore (Zone 2)	Offshore (Zone 3)	Reason for pooling
7/20				
7/21				
7/22				
7/23				
7/24				
7/25				IC
7/26				IC
7/27				
7/28				IC
7/29				
7/30				
7/31				
8/01				
8/02				
8/03				
8/04				
8/05				
8/06				
8/07				
8/08				
8/09				
8/10				
8/11				
8/12				IC
8/13				
8/14				
8/15				
8/16				
8/17				
8/18				
8/19				IC
8/20				
8/21				
8/22				IC
8/23				
8/24				
8/25				
8/26				IC
8/27				
8/28				
8/29				
8/30				
8/31				IC
9/01				
9/02				
9/03				
9/04				
9/05				IC
9/06				
9/07				

Note: Days with insufficient catches (IC) in at least 1 fishing zone were pooled (boxes) to ensure reasonable species apportionment. There were no commercial fisheries this season that affected the species apportionment test fishery.

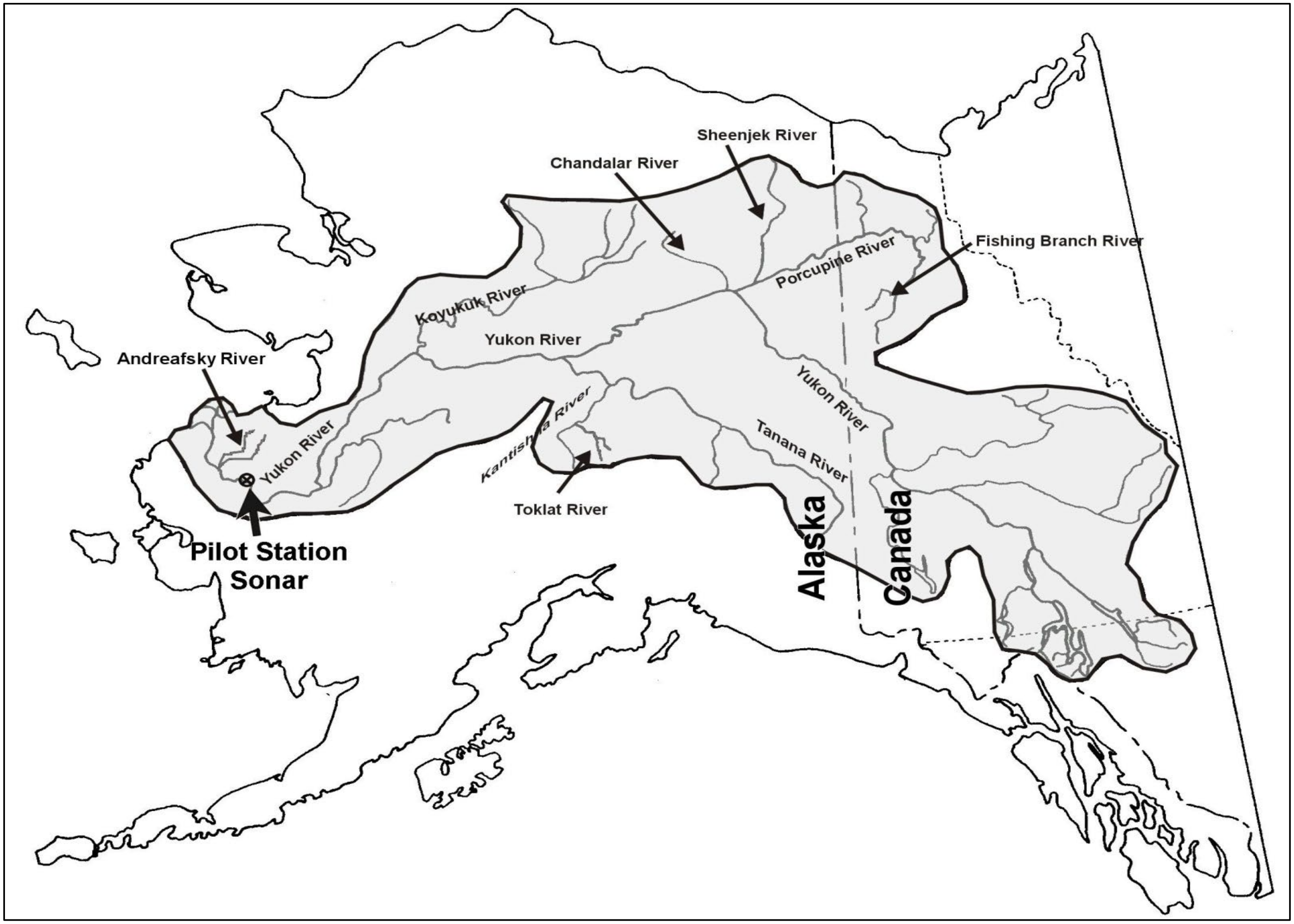

Figure 1.–Fishing districts and communities of the Yukon River drainage.

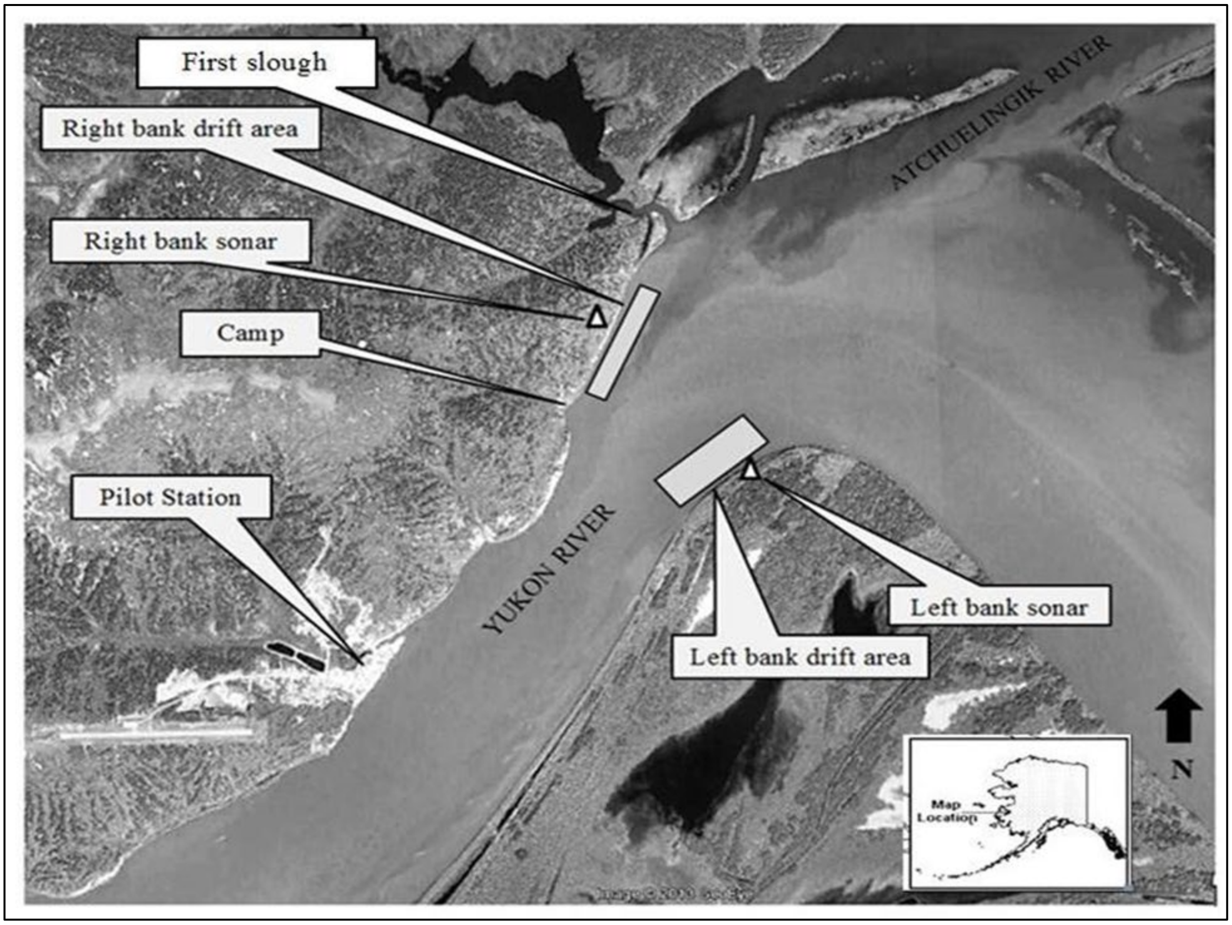

Figure 2.–Location of the Pilot Station sonar project on the Yukon River showing general transducer sites.

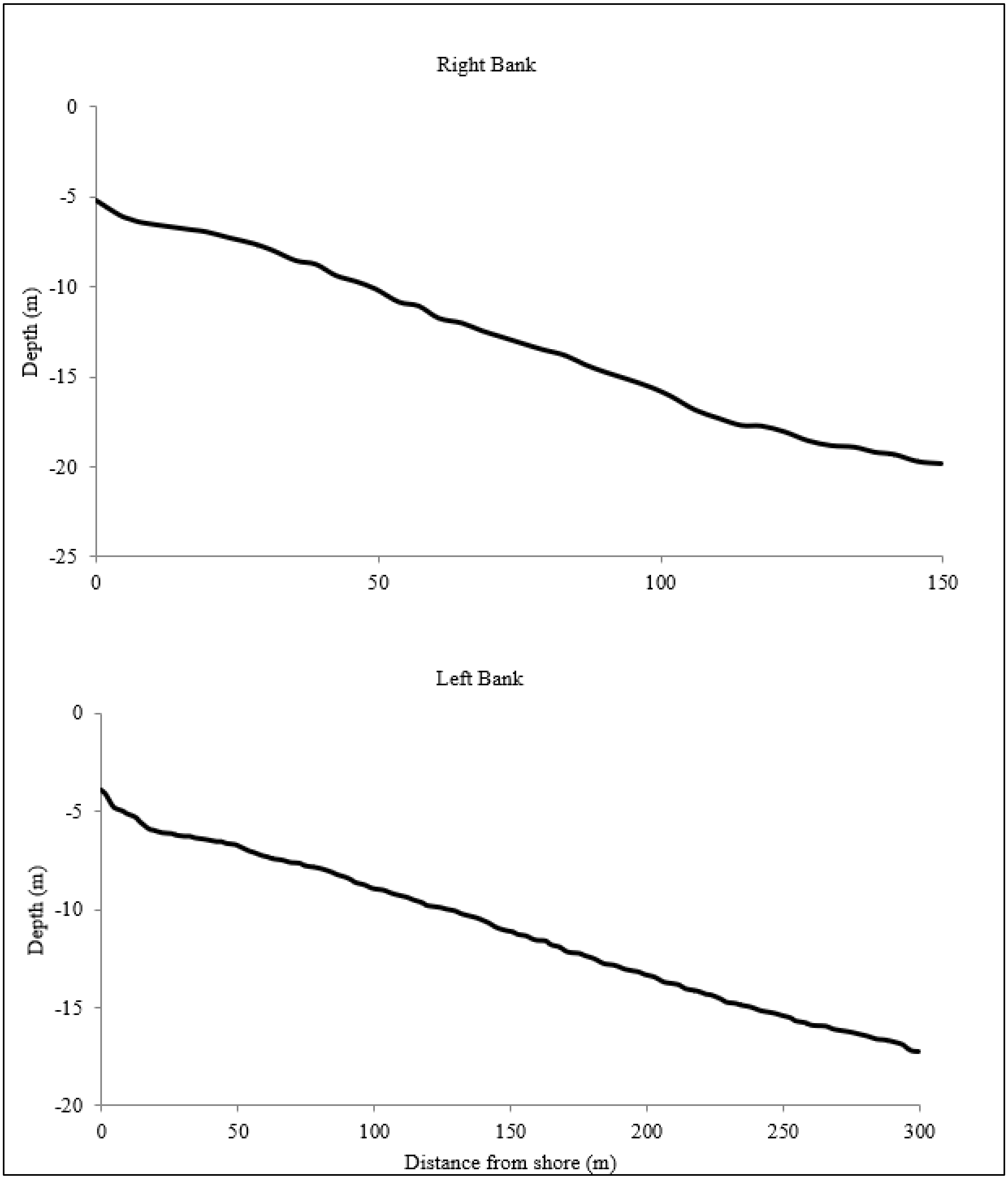

Figure 3.–Bottom profiles for the right bank (top) and left bank (bottom) at the Pilot Station sonar project on the Yukon River, 2021.

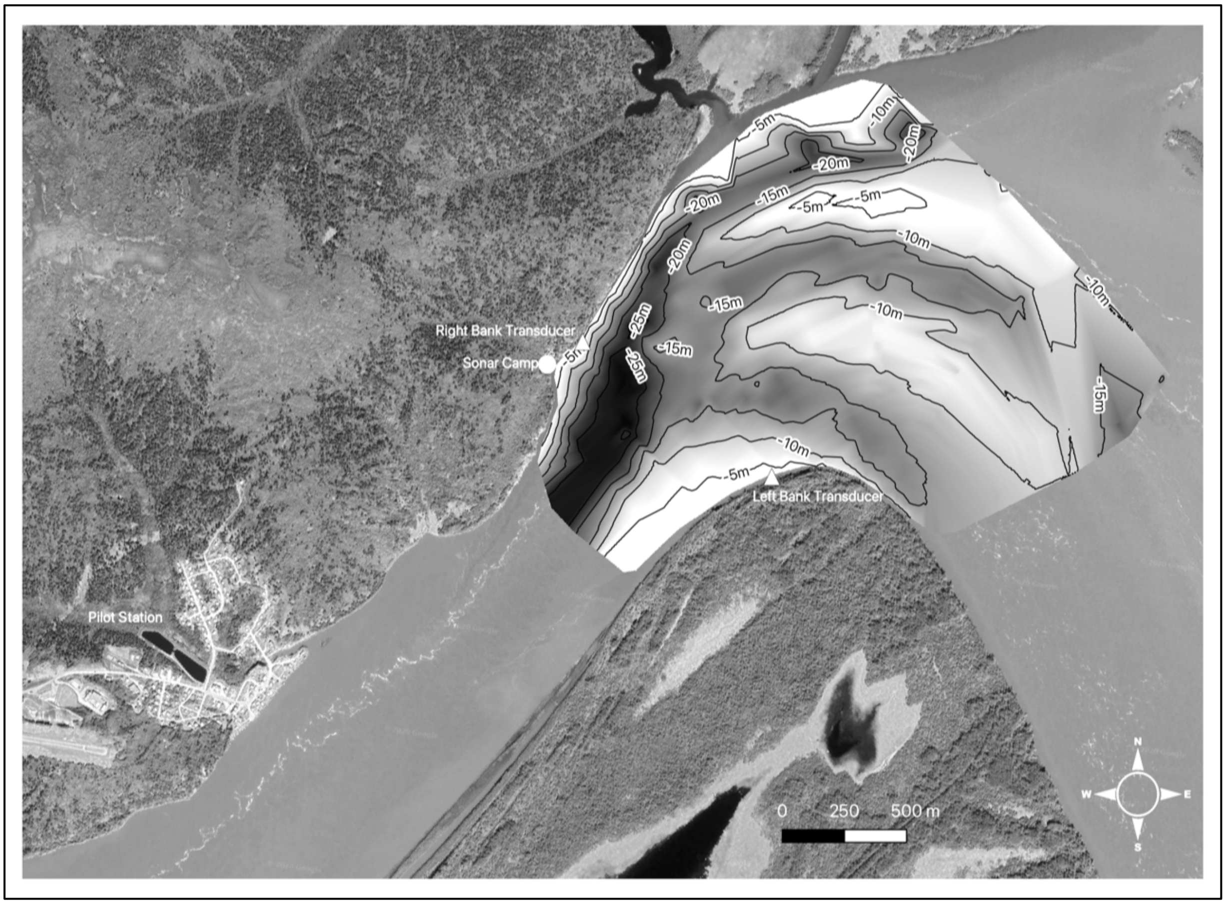

Figure 4.–Bathymetric map of the Yukon River in the vicinity of the Pilot Station sonar project.

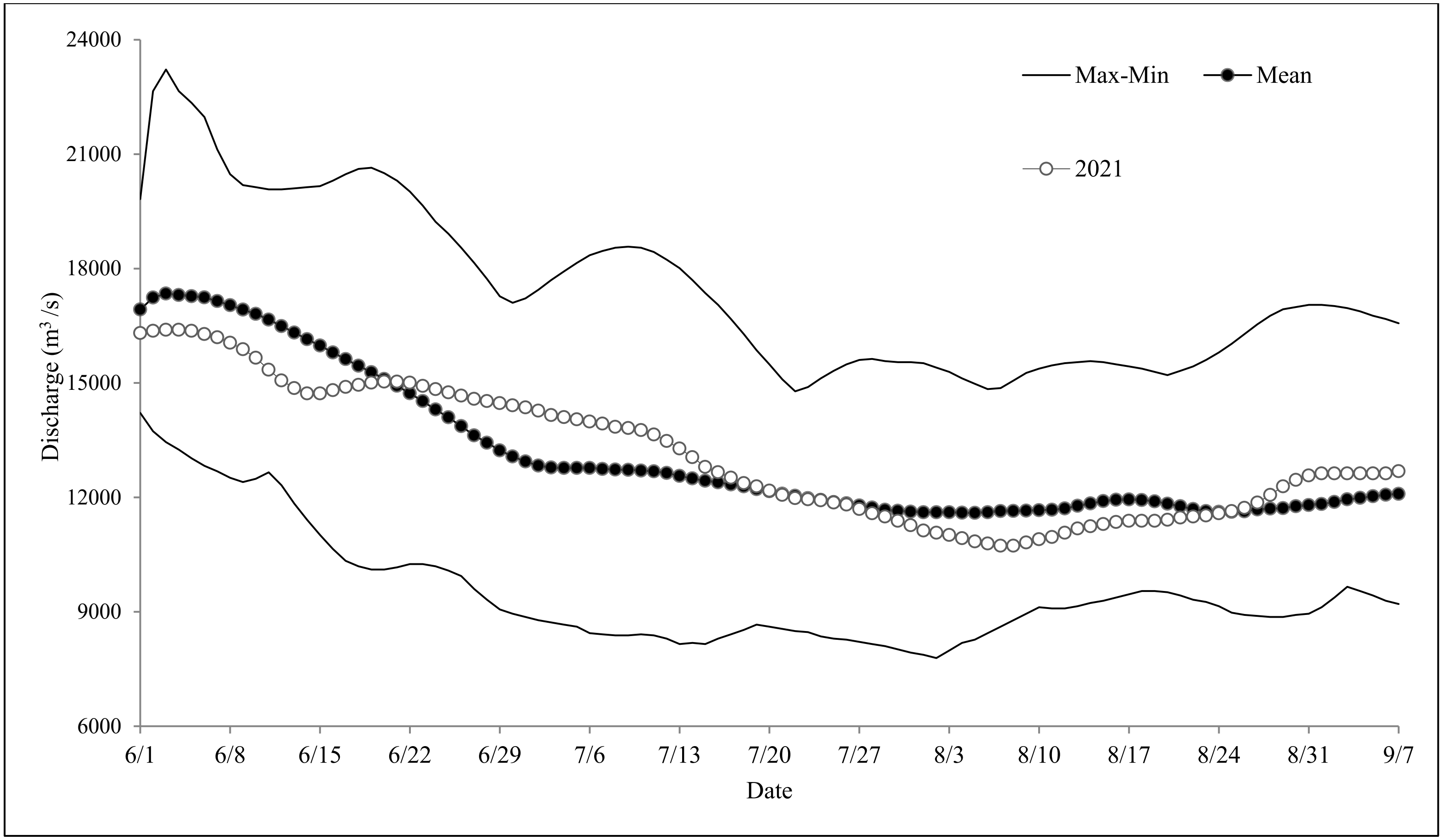

Figure 5.–Yukon River daily water discharge during the 2021 season at Pilot Station water gauge compared to the 2011–2020 minimum, maximum, and mean gauge height.

Source: Water levels were sourced from the real-time United States Geological Survey (USGS) gauging station located downstream of the Pilot Station sonar project. https://dashboard.waterdata.usgs.gov/app/nwd/en/?region=lower48&aoi=default accessed: December 2021.

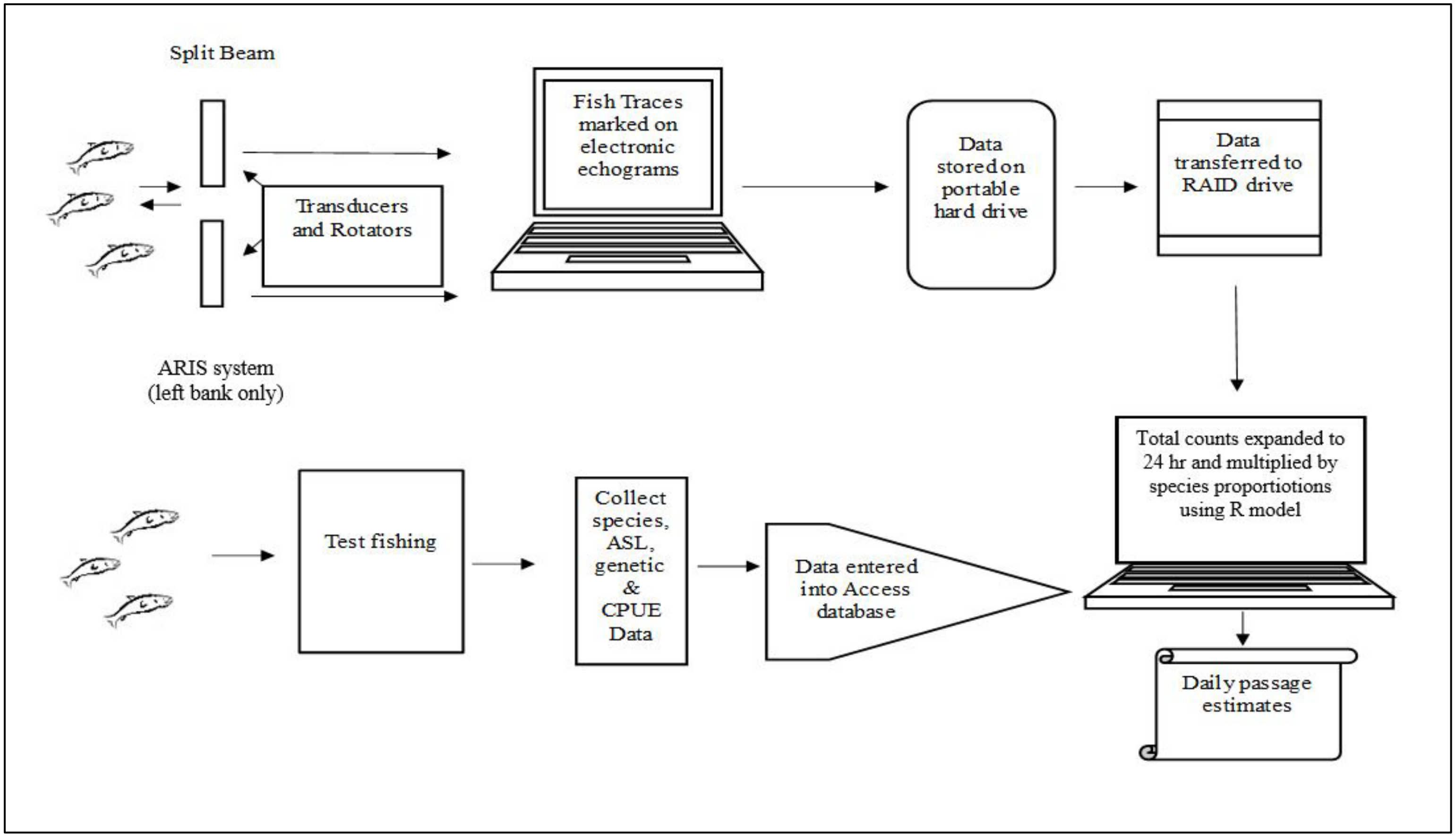

Figure 6.–Flow diagram of data collection and processing at the Pilot Station sonar project on the Yukon River, 2021.

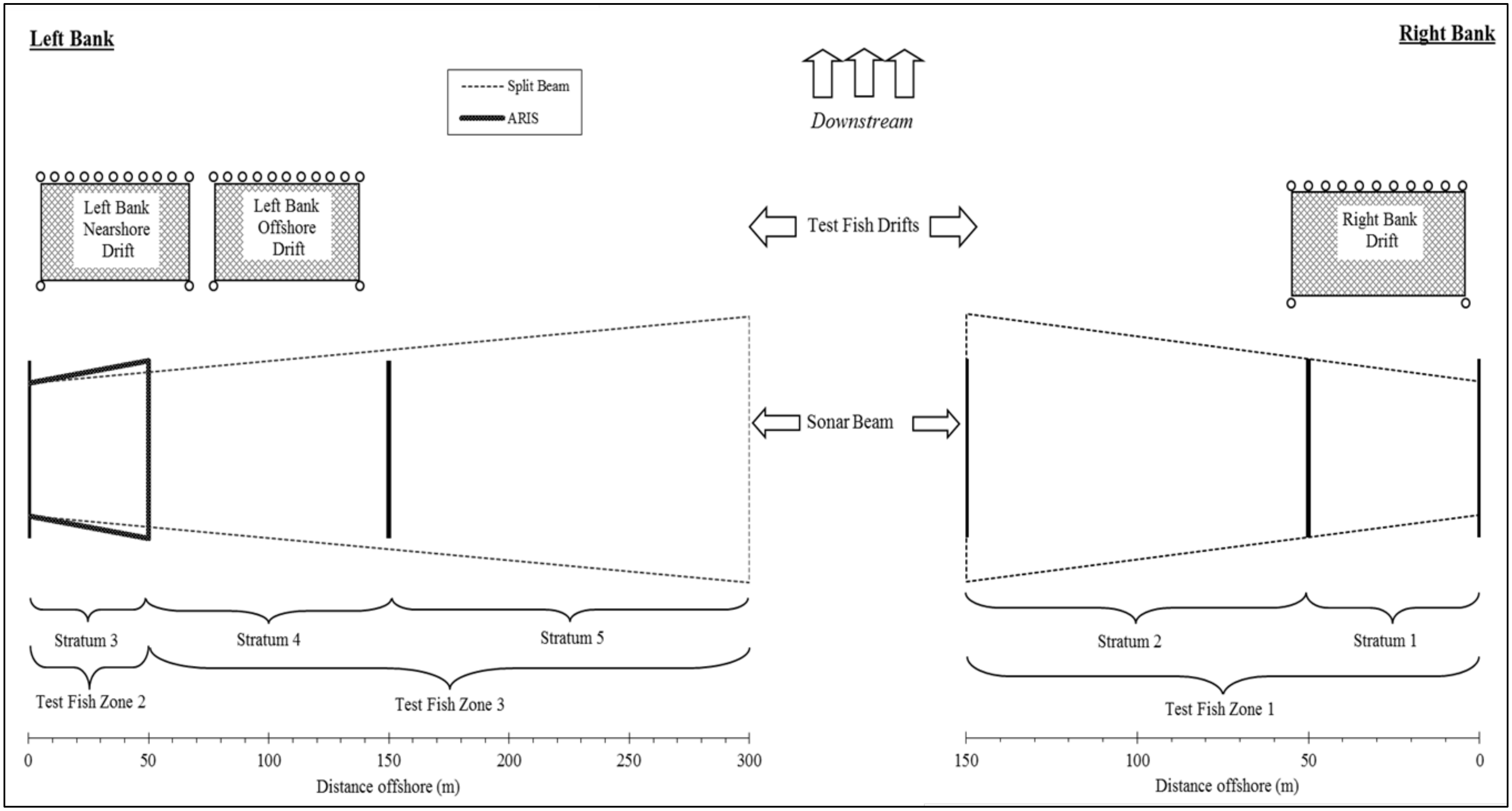

Figure 7.–Illustration of relationships between strata, zones, test fishery drifts, and approximate sonar ranges (not to scale) at the Pilot Station sonar project on the Yukon River, 2021.

Note: Stratum ranges can vary during the season depending on river conditions.

Figure 8.–ARIS with a telephoto lens mounted to a pod with PT-25 rotator (top left), ARIS with a spreader lens installed on the front of the telephoto lens (lower left), and HTI split-beam transducer mounted on the pod with PT-25 rotator (right), at the Pilot Station sonar project on the Yukon River.

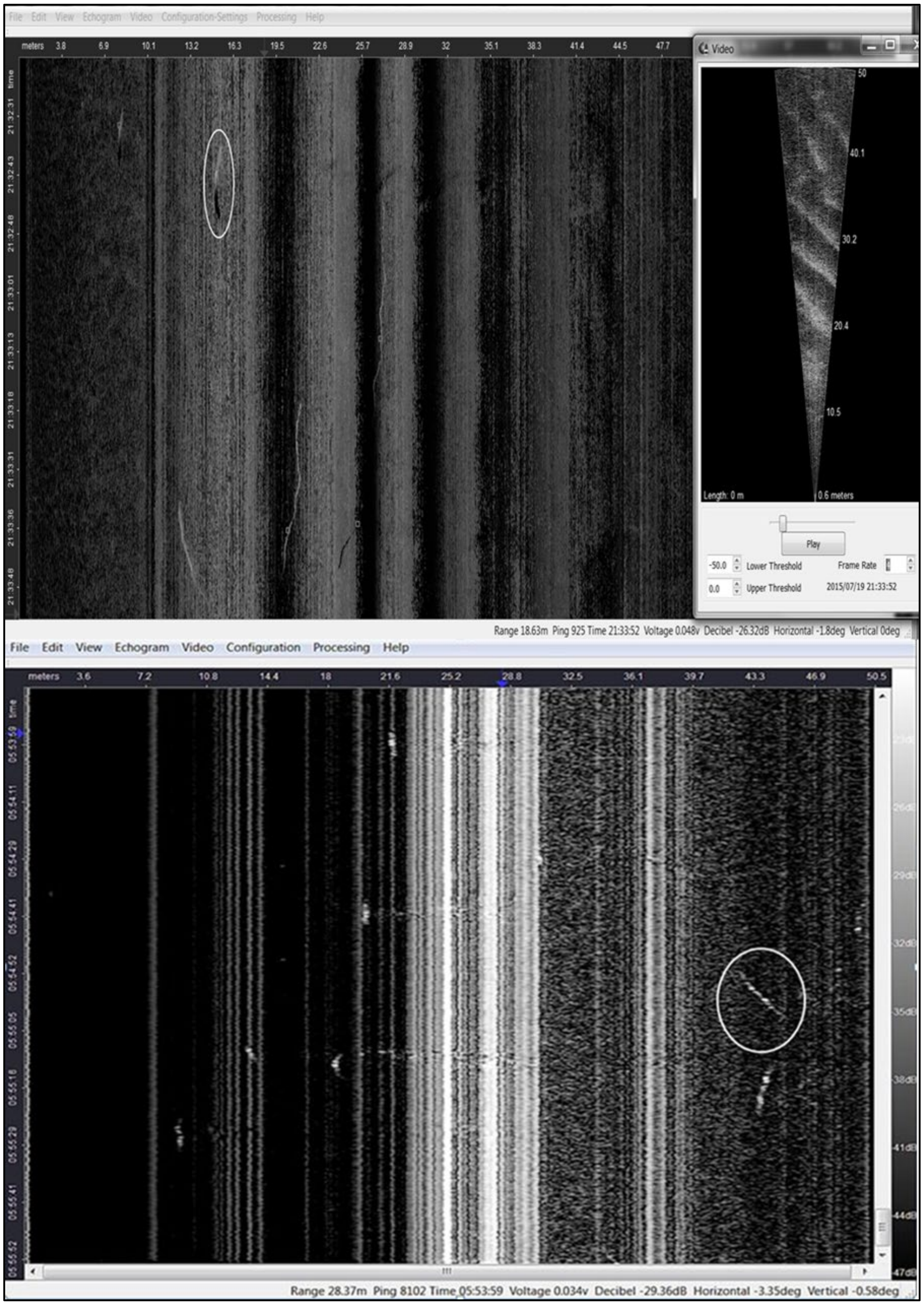

Figure 9.–Echogram of ARIS alongside video image (top) and split-beam sonar (bottom), with an oval around representative fish.

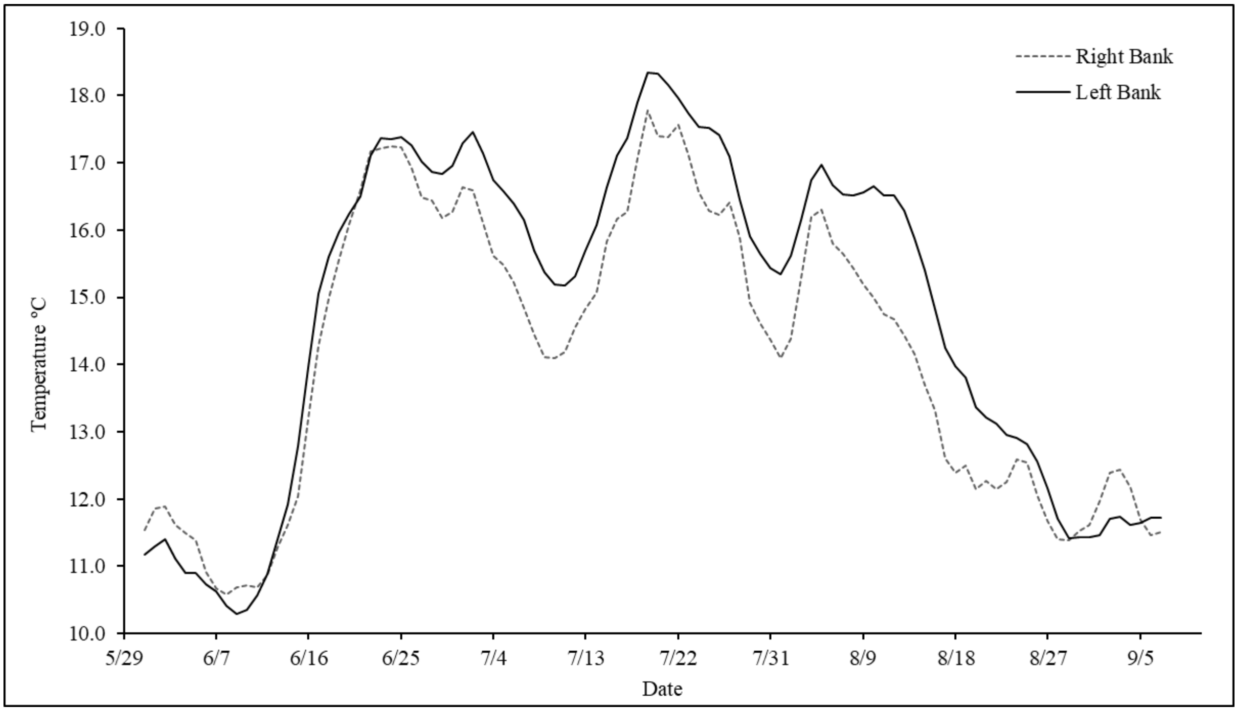

Figure 10.–Mean daily water temperatures recorded at the Pilot Station sonar project on the Yukon River with electronic data loggers by bank, 2021.

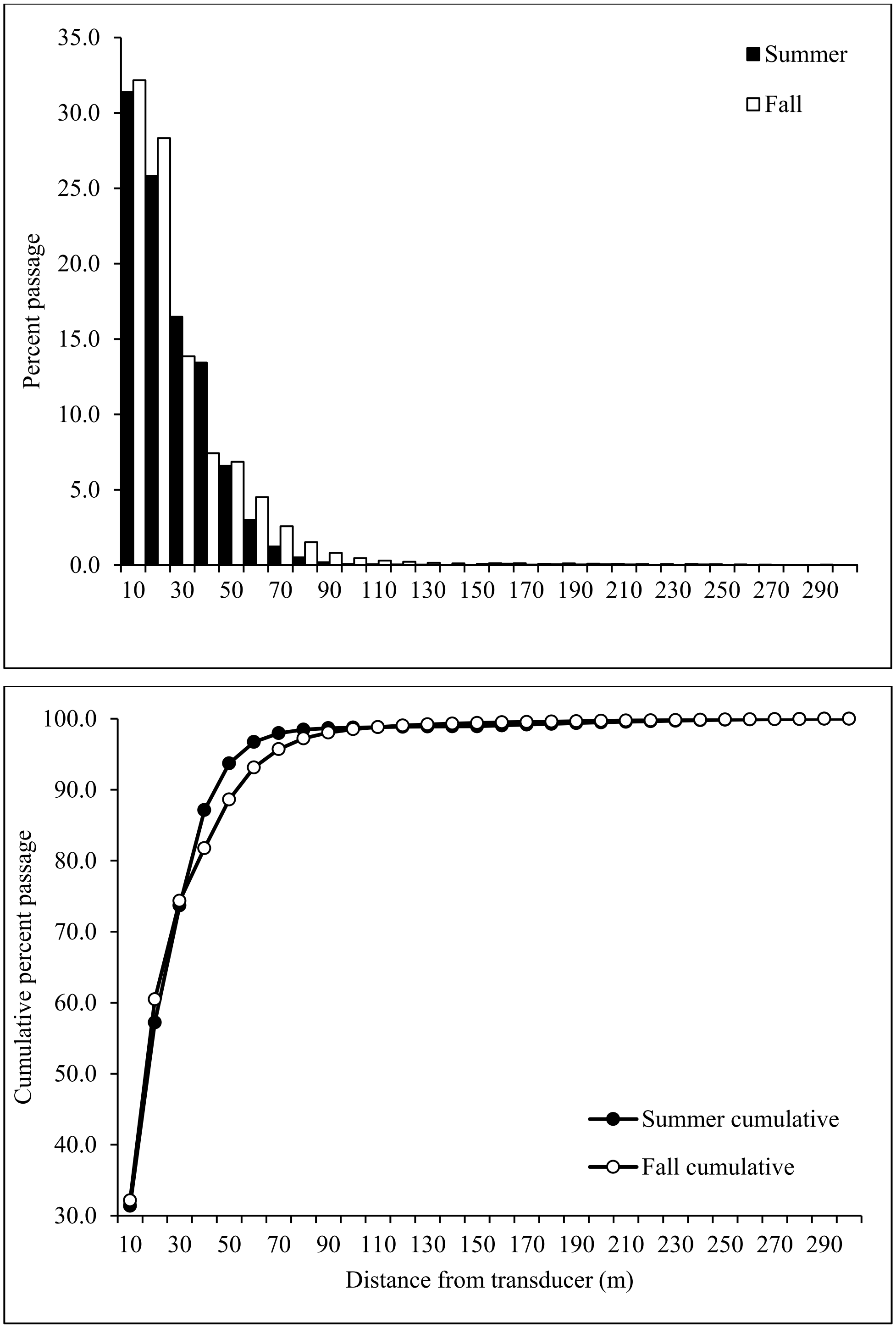

Figure 11.–Distribution of left bank passage (top) and cumulative passage as a function of range (bottom) at the Pilot Station sonar project on the Yukon River, 2021.

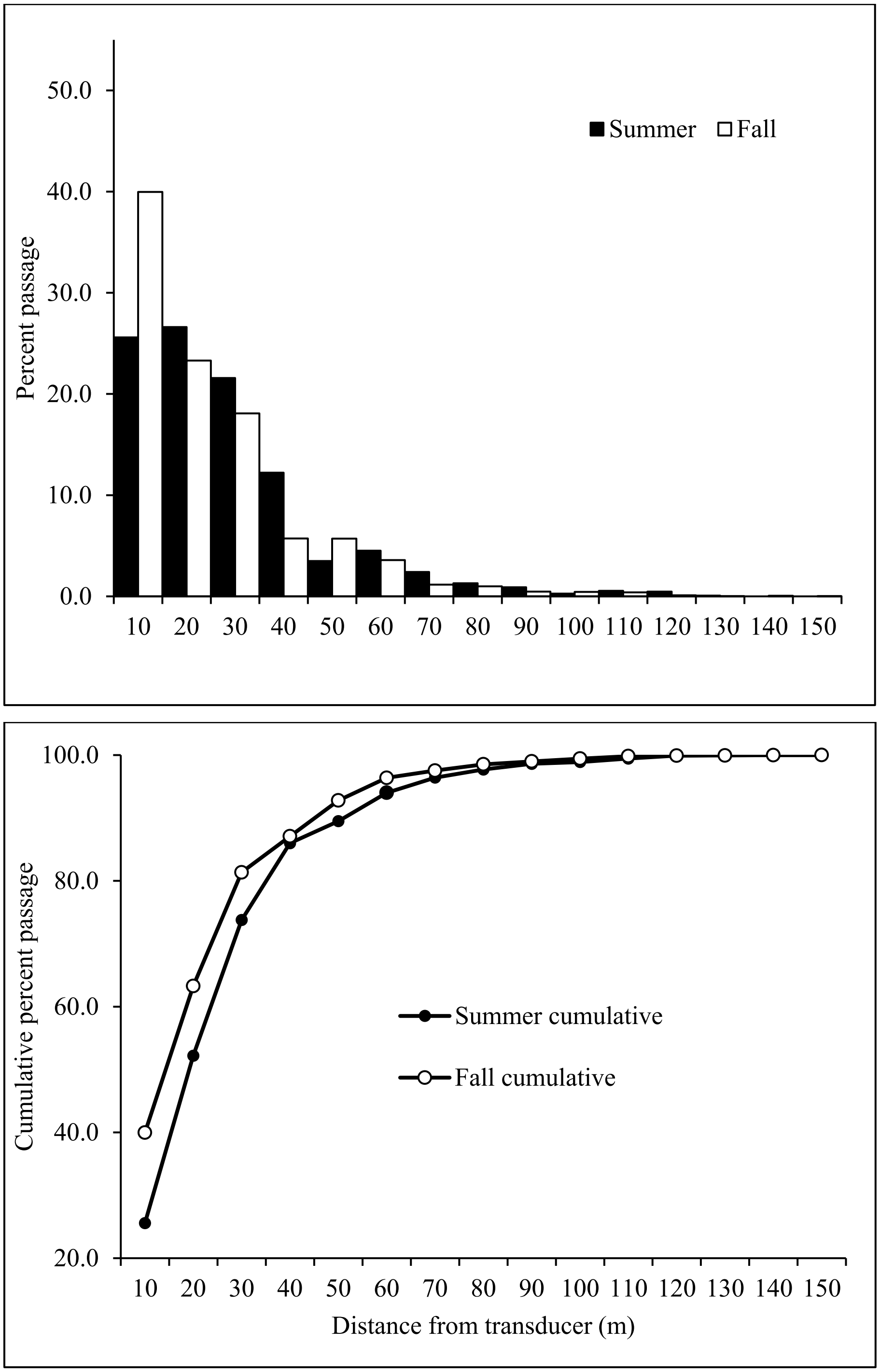

Figure 12.–Distribution of right bank passage (top) and cumulative passage as a function of range (bottom) at the Pilot Station sonar project on the Yukon River, 2021.

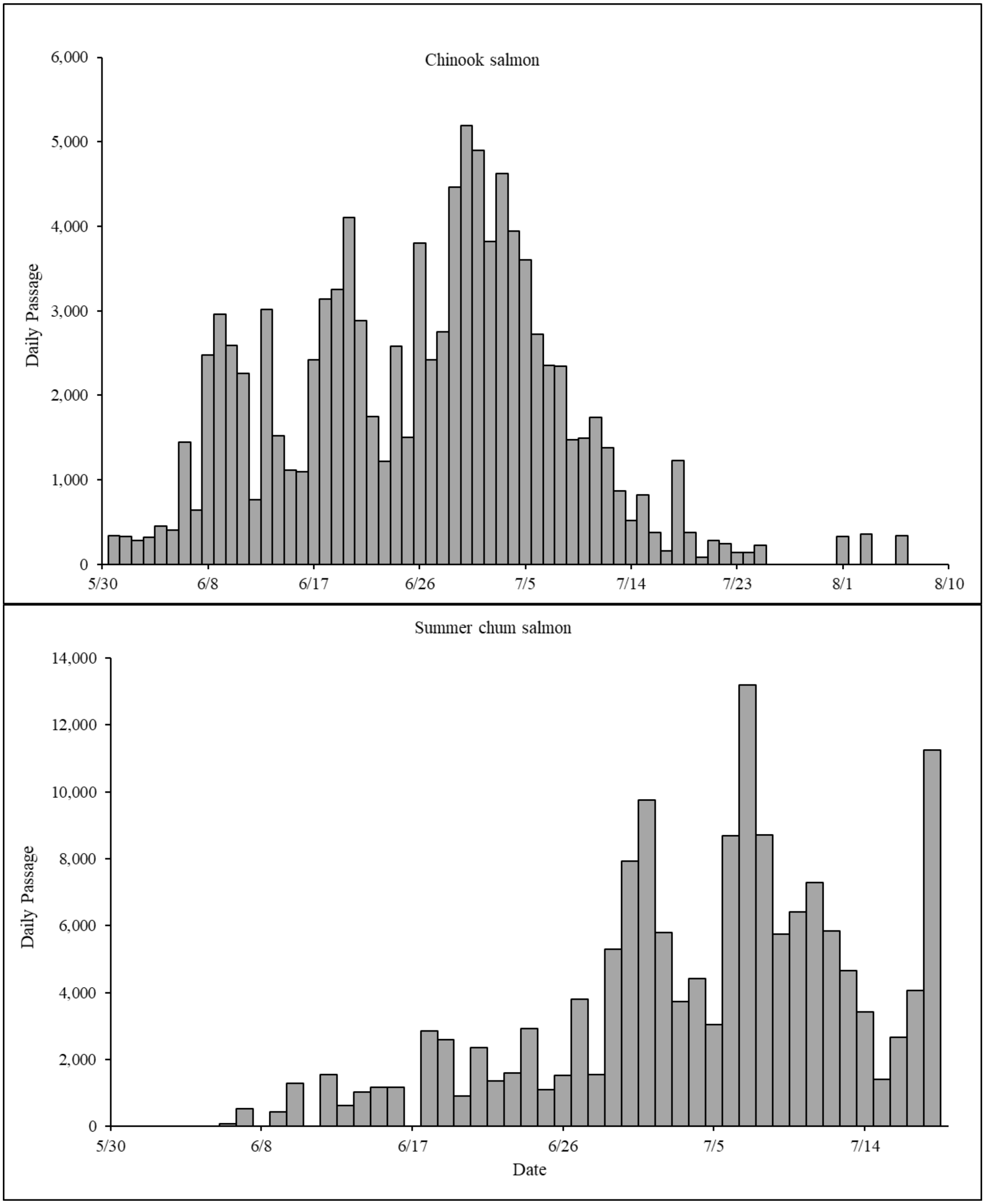

Figure 13.–Chinook (top) and summer chum salmon (bottom) daily passage estimates at the Pilot Station sonar project on the Yukon River, 2021.

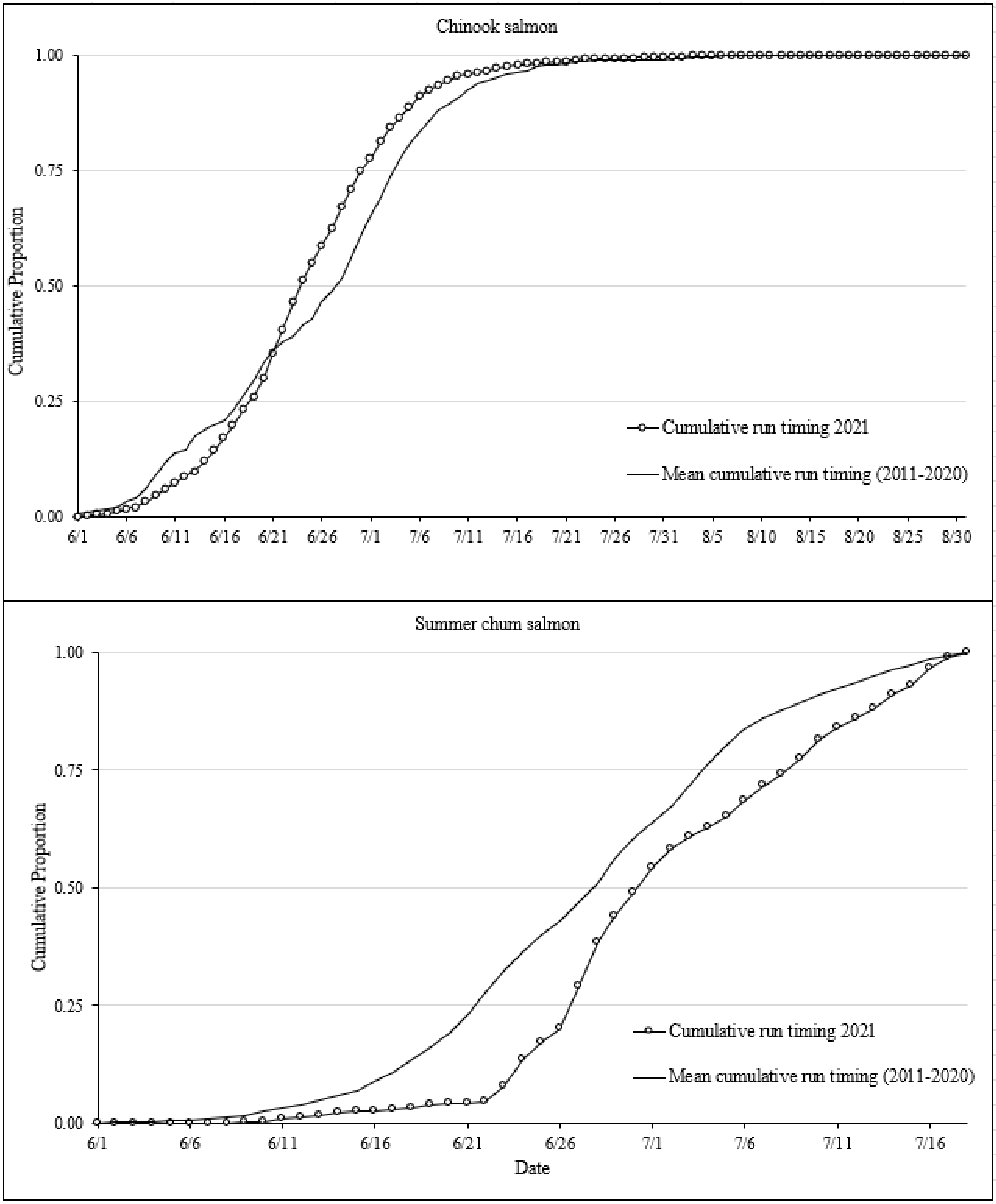

Figure 14.–2021 Chinook (top) and summer chum (bottom) salmon daily cumulative passage timing compared to the 2011–2020 mean passage timing at the Pilot Station sonar project on the Yukon River.

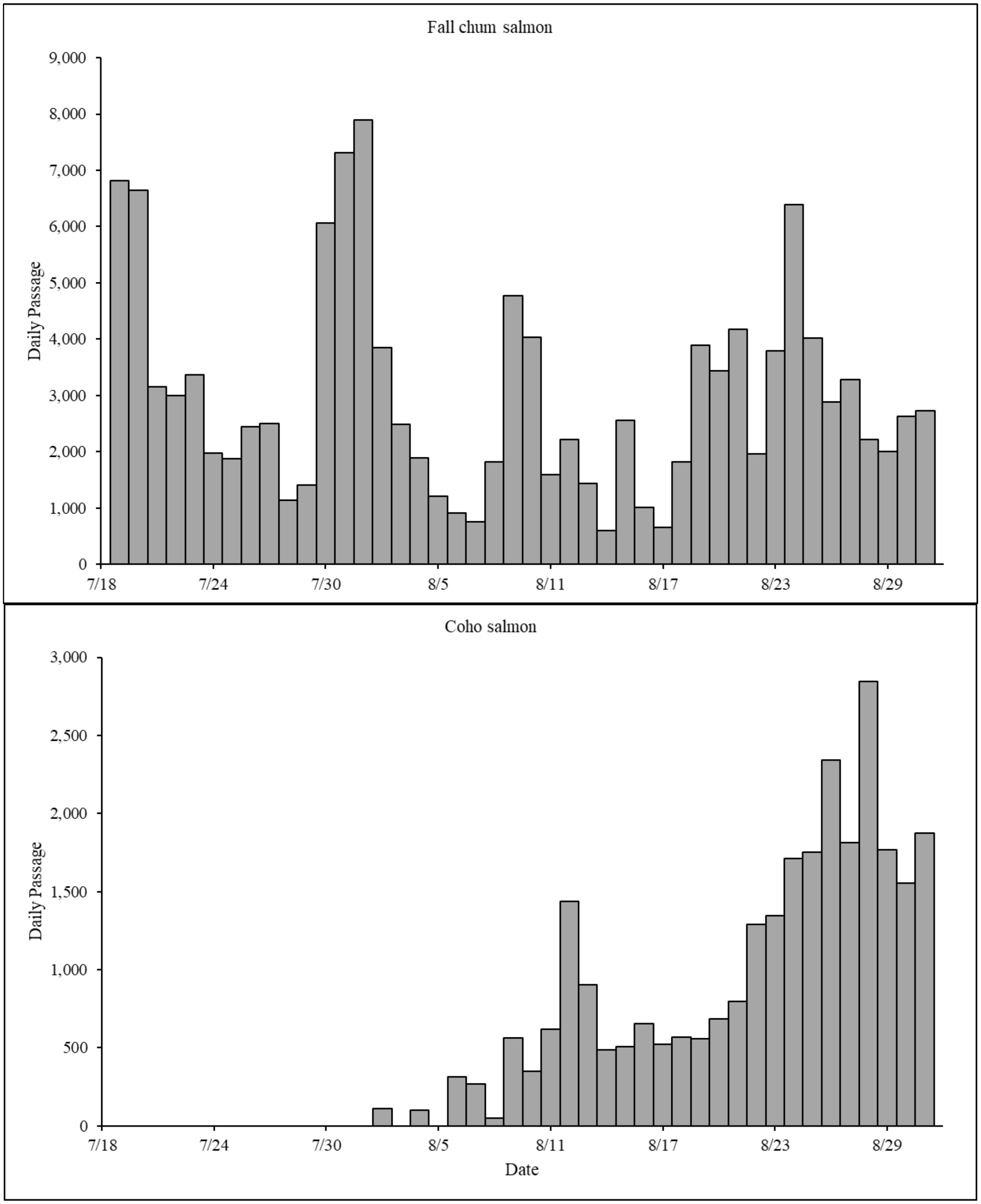

Figure 15.–Fall chum (top) and coho (bottom) salmon daily passage estimates at the Pilot Station sonar project on the Yukon River, 2021.

Note: The mean cumulative run timing for both fall chum and coho salmon was based on run timing from July 19 through August 31 in order to compare timing across years, despite years when the project was in operation until September 7.

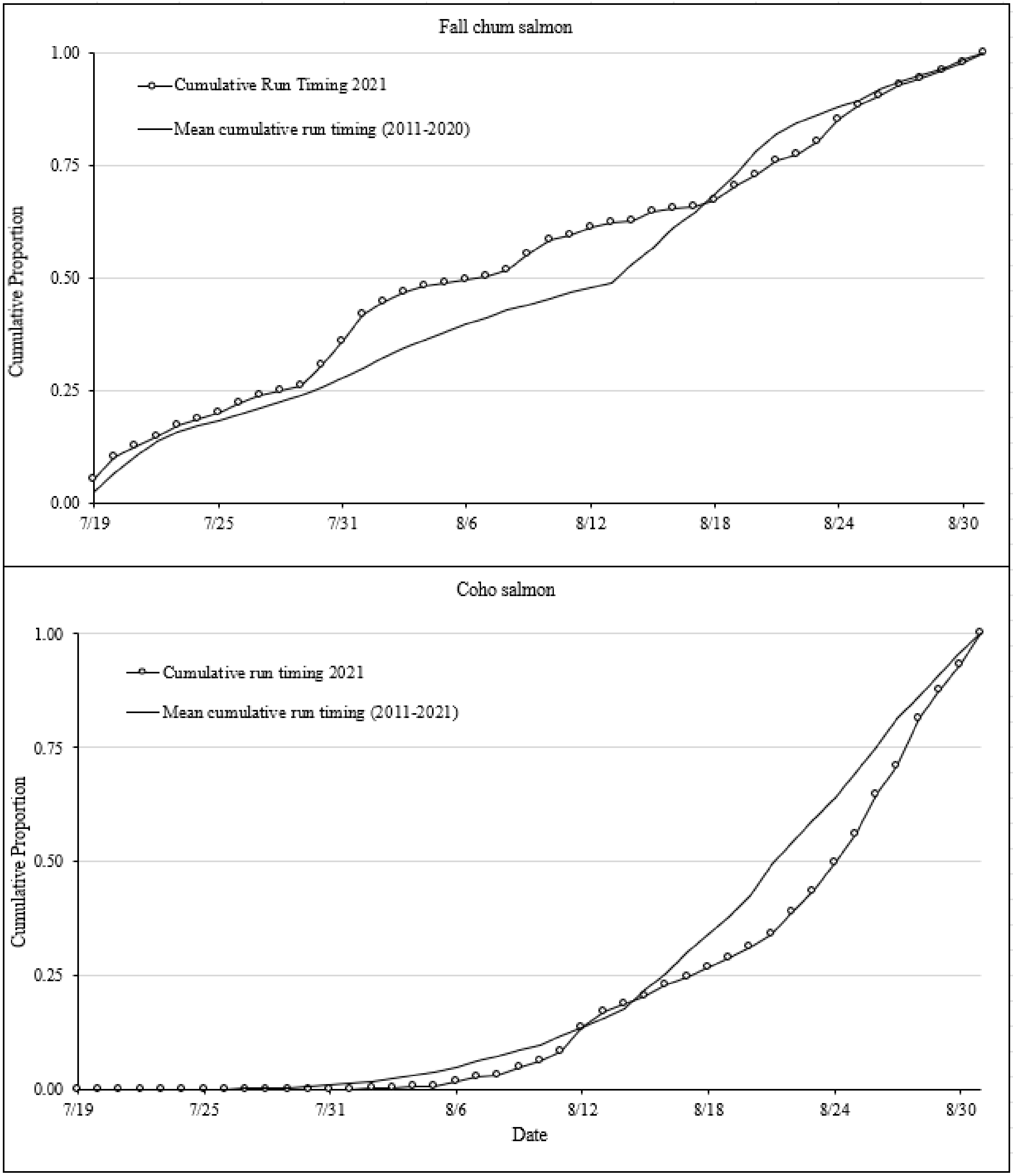

Figure 16.–2021 Fall chum (top) and coho (bottom) salmon daily cumulative passage timing compared to the 2011–2020 mean passage timing at the Pilot Station sonar project on the Yukon River.

Note: The mean cumulative run timing for both fall chum and coho salmon was based on run timing from July 19 through August 31 in order to compare timing across years, despite years when the project was in operation until September 7.

APPENDIX A: NET SELECTIVITY PARAMETERS USED IN FISH SPECIES APPORTIONMENT AT THE PILOT STATION SONAR PROJECT

Appendix A1.–Net selectivity parameters used in species apportionment, at the Pilot Station sonar project on the Yukon River, 2021.

Species	Tau	Sigma	Theta	Lambda	Tangle
Large Chinook [a]	1.9072	0.2177	0.6238	-0.4523	0.0075
Small Chinook [b]	1.9072	0.2177	0.6238	-0.4523	0.0075
Summer chum	1.9675	0.1469	0.7875	-0.4291	0.0416
Fall chum	1.8819	0.2085	1.0548	-0.9855	0.0350
Coho	1.9765	0.2825	0.7764	-1.2320	0.0000
Pink	1.9595	0.3537	2.5556	3.0157	0.1485
Broad whitefish	1.8037	0.2062	1.0548	-1.8365	0.1299
Humpback whitefish	1.9272	0.2581	1.1700	-2.1510	0.1339
Cisco	2.1730	0.2311	0.7922	-1.6967	0.0000
Sheefish	2.1445	0.2875	1.4049	-2.5044	0.2451
Other [c]	2.7002	0.5724	1.0164	-3.7235	0.0100

[a] Chinook salmon >655 mm mid eye to tail fork (METF).

[b] Chinook salmon ≤655 mm METF.

[c] Includes sockeye salmon, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX B: SALMON SPECIES CPUE BY DAY AND BANK

Appendix B1.–Left bank catch per unit effort (CPUE), by day and salmon species, at the Pilot Station sonar project on the Yukon River, 2021.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom-hours	Catch	CPUE	fathom-hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
5/31	12.76	1	0.08	5.93	0	0.00	0	0.00	0	0.00
6/01	17.70	1	0.06	19.36	0	0.00	0	0.00	0	0.00
6/02	19.14	1	0.05	19.44	0	0.00	0	0.00	0	0.00
6/03	19.51	3	0.15	18.64	0	0.00	0	0.00	0	0.00
6/04	17.05	2	0.12	16.31	0	0.00	0	0.00	0	0.00
6/05	17.32	1	0.06	17.35	0	0.00	0	0.00	0	0.00
6/06	18.49	3	0.16	18.78	0	0.00	0	0.00	0	0.00
6/07	17.76	2	0.11	17.71	1	0.06	0	0.00	0	0.00
6/08	18.36	9	0.49	17.90	0	0.00	0	0.00	0	0.00
6/09	17.06	9	0.53	18.35	1	0.05	0	0.00	0	0.00
6/10	19.30	5	0.26	18.20	3	0.16	0	0.00	0	0.00
6/11	17.39	7	0.40	17.93	0	0.00	0	0.00	0	0.00
6/12	17.24	2	0.12	16.95	3	0.18	0	0.00	0	0.00
6/13	17.15	9	0.52	18.74	0	0.00	0	0.00	0	0.00
6/14	17.83	9	0.50	17.14	3	0.18	0	0.00	0	0.00
6/15	16.47	4	0.24	17.07	4	0.23	0	0.00	0	0.00
6/16	18.62	2	0.11	17.80	3	0.17	0	0.00	0	0.00
6/17	17.79	10	0.56	18.85	0	0.00	0	0.00	0	0.00
6/18	17.05	7	0.41	18.45	12	0.65	0	0.00	0	0.00
6/19	16.36	6	0.37	17.83	6	0.34	0	0.00	0	0.00
6/20	18.13	10	0.55	17.25	2	0.12	0	0.00	0	0.00
6/21	18.11	11	0.61	17.61	4	0.23	0	0.00	0	0.00
6/22	18.17	5	0.28	18.08	1	0.06	0	0.00	0	0.00
6/23	17.31	6	0.35	17.88	5	0.28	0	0.00	0	0.00
6/24	17.03	9	0.53	17.44	10	0.57	0	0.00	0	0.00
6/25	17.80	6	0.34	16.70	2	0.12	0	0.00	0	0.00
6/26	17.42	9	0.52	17.39	2	0.11	0	0.00	0	0.00
6/27	18.80	7	0.37	18.30	6	0.33	0	0.00	0	0.00
6/28	17.97	9	0.50	18.08	3	0.17	0	0.00	0	0.00
6/29	16.81	14	0.83	18.12	12	0.66	0	0.00	0	0.00
6/30	16.59	20	1.21	16.02	26	1.62	0	0.00	0	0.00
7/01	18.73	11	0.59	16.72	16	0.96	0	0.00	0	0.00
7/02	16.64	13	0.78	16.69	10	0.60	0	0.00	0	0.00
7/03	15.42	14	0.91	16.57	8	0.48	0	0.00	0	0.00

-continued-

Appendix B1.–Page 2 of 3.

Date	Large mesh fathom-hours	Chinook Catch	Chinook CPUE	Small mesh fathom-hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
7/04	17.57	9	0.51	18.72	12	0.64	0	0.00	0	0.00
7/05	17.46	12	0.69	17.15	3	0.17	0	0.00	0	0.00
7/06	17.51	7	0.40	18.10	12	0.66	0	0.00	0	0.00
7/07	16.88	8	0.47	17.31	34	1.96	0	0.00	0	0.00
7/08	16.83	4	0.24	18.67	15	0.80	0	0.00	0	0.00
7/09	11.93	5	0.42	23.26	11	0.47	0	0.00	0	0.00
7/10	17.97	5	0.28	18.35	16	0.87	0	0.00	0	0.00
7/11	16.14	5	0.31	17.68	17	0.96	0	0.00	0	0.00
7/12	17.40	1	0.06	18.49	5	0.27	0	0.00	0	0.00
7/13	16.47	3	0.18	17.77	8	0.45	0	0.00	0	0.00
7/14	18.41	2	0.11	19.65	4	0.20	0	0.00	0	0.00
7/15	18.43	3	0.16	15.12	1	0.07	0	0.00	0	0.00
7/16	17.69	1	0.06	17.89	2	0.11	0	0.00	0	0.00
7/17	15.06	0	0.00	15.43	5	0.32	0	0.00	0	0.00
7/18	17.81	3	0.17	18.10	14	0.77	0	0.00	0	0.00
7/19	5.45	0	0.00	17.67	0	0.00	7	0.40	0	0.00
7/20	6.58	0	0.00	16.84	0	0.00	3	0.18	0	0.00
7/21	5.95	0	0.00	18.22	0	0.00	2	0.11	0	0.00
7/22	5.88	0	0.00	18.07	0	0.00	3	0.17	0	0.00
7/23	6.11	0	0.00	17.15	0	0.00	1	0.06	0	0.00
7/24	6.01	0	0.00	16.80	0	0.00	1	0.06	0	0.00
7/25	5.39	0	0.00	17.03	0	0.00	2	0.12	0	0.00
7/26	6.00	0	0.00	17.94	0	0.00	2	0.11	0	0.00
7/27	6.01	0	0.00	16.33	0	0.00	0	0.00	0	0.00
7/28	5.84	0	0.00	11.05	0	0.00	1	0.09	0	0.00
7/29	5.77	0	0.00	17.73	0	0.00	2	0.11	0	0.00
7/30	5.35	0	0.00	17.66	0	0.00	8	0.45	0	0.00
7/31	5.43	0	0.00	17.37	0	0.00	13	0.75	0	0.00
8/01	5.27	0	0.00	19.18	0	0.00	9	0.47	0	0.00
8/02	6.44	0	0.00	17.61	0	0.00	7	0.40	0	0.00
8/03	5.88	0	0.00	18.70	0	0.00	6	0.32	0	0.00
8/04	6.12	0	0.00	18.17	0	0.00	4	0.22	0	0.00
8/05	6.25	0	0.00	18.09	0	0.00	1	0.06	0	0.00

-continued-

Appendix B1.–Page 3 of 3.

Date	Large mesh fathom-hours	Chinook Catch	Chinook CPUE	Small mesh fathom-hours	Summer chum Catch	Summer chum CPUE	Fall chum Catch	Fall chum CPUE	Coho Catch	Coho CPUE
8/06	6.01	0	0.00	16.92	0	0.00	1	0.06	0	0.00
8/07	5.37	0	0.00	17.32	0	0.00	0	0.00	0	0.00
8/08	5.86	0	0.00	17.34	0	0.00	2	0.12	0	0.00
8/09	5.56	0	0.00	16.93	0	0.00	9	0.53	0	0.00
8/10	5.91	0	0.00	18.49	0	0.00	12	0.65	0	0.00
8/11	5.93	0	0.00	16.93	0	0.00	3	0.18	0	0.00
8/12	6.10	0	0.00	18.49	0	0.00	8	0.43	0	0.00
8/13	5.48	0	0.00	18.68	0	0.00	5	0.27	0	0.00
8/14	5.50	0	0.00	16.66	0	0.00	0	0.00	0	0.00
8/15	5.38	0	0.00	17.07	0	0.00	10	0.59	0	0.00
8/16	5.93	0	0.00	16.98	0	0.00	4	0.24	1	0.06
8/17	5.84	0	0.00	17.10	0	0.00	2	0.12	2	0.12
8/18	5.14	0	0.00	17.20	0	0.00	5	0.29	0	0.00
8/19	6.02	0	0.00	18.52	0	0.00	11	0.59	0	0.00
8/20	5.65	0	0.00	16.92	0	0.00	10	0.59	2	0.12
8/21	5.31	0	0.00	16.41	0	0.00	8	0.49	2	0.12
8/22	5.24	0	0.00	16.40	0	0.00	7	0.43	0	0.00
8/23	5.57	0	0.00	17.48	0	0.00	11	0.63	2	0.11
8/24	5.29	0	0.00	16.41	0	0.00	12	0.73	2	0.12
8/25	5.82	0	0.00	16.35	0	0.00	10	0.61	3	0.18
8/26	5.56	0	0.00	16.85	0	0.00	6	0.36	2	0.12
8/27	5.76	0	0.00	16.89	0	0.00	14	0.83	1	0.06
8/28	5.18	0	0.00	18.52	0	0.00	5	0.27	3	0.16
8/29	5.67	0	0.00	16.78	0	0.00	5	0.30	2	0.12
8/30	4.70	0	0.00	16.95	0	0.00	8	0.47	2	0.12
8/31	5.80	0	0.00	17.25	0	0.00	6	0.35	1	0.06
9/01	5.52	0	0.00	18.50	0	0.00	5	0.27	2	0.11
9/02	4.89	0	0.00	16.94	0	0.00	2	0.12	0	0.00
9/03	5.65	0	0.00	18.07	0	0.00	1	0.06	3	0.17
9/04	5.63	0	0.00	16.25	0	0.00	5	0.31	1	0.06
9/05	5.82	0	0.00	16.63	0	0.00	1	0.06	1	0.06
9/06	5.79	0	0.00	17.47	0	0.00	7	0.40	1	0.06
9/07	5.88	0	0.00	15.99	0	0.00	4	0.25	2	0.13
Total	1,139.33	305	17.73	1,742.57	302	17.05	271	15.68	35	2.06

Appendix B2.–Right bank catch per unit effort (CPUE), by day and salmon species, at the Pilot Station sonar project on the Yukon River, 2021.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom-hours	Catch	CPUE	fathom-hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
5/31	5.94	0	0.00	3.26	0	0.00	0	0.00	0	0.00
6/01	8.32	0	0.00	9.23	0	0.00	0	0.00	0	0.00
6/02	9.34	0	0.00	8.51	0	0.00	0	0.00	0	0.00
6/03	10.16	0	0.00	8.80	0	0.00	0	0.00	0	0.00
6/04	8.33	0	0.00	8.21	0	0.00	0	0.00	0	0.00
6/05	9.02	0	0.00	8.66	0	0.00	0	0.00	0	0.00
6/06	8.41	0	0.00	9.48	0	0.00	0	0.00	0	0.00
6/07	8.76	0	0.00	8.60	1	0.12	0	0.00	0	0.00
6/08	8.78	1	0.11	8.54	0	0.00	0	0.00	0	0.00
6/09	8.60	4	0.47	8.18	0	0.00	0	0.00	0	0.00
6/10	8.76	2	0.23	9.05	0	0.00	0	0.00	0	0.00
6/11	8.42	0	0.00	8.47	0	0.00	0	0.00	0	0.00
6/12	8.59	0	0.00	7.44	1	0.13	0	0.00	0	0.00
6/13	8.01	0	0.00	7.84	0	0.00	0	0.00	0	0.00
6/14	8.57	0	0.00	8.65	0	0.00	0	0.00	0	0.00
6/15	8.11	0	0.00	7.97	0	0.00	0	0.00	0	0.00
6/16	8.34	0	0.00	8.94	0	0.00	0	0.00	0	0.00
6/17	8.14	0	0.00	8.96	0	0.00	0	0.00	0	0.00
6/18	8.70	1	0.11	8.65	0	0.00	0	0.00	0	0.00
6/19	8.12	1	0.12	8.32	1	0.12	0	0.00	0	0.00
6/20	9.53	4	0.42	7.88	0	0.00	0	0.00	0	0.00
6/21	8.60	3	0.35	8.81	1	0.11	0	0.00	0	0.00
6/22	8.61	0	0.00	8.53	0	0.00	0	0.00	0	0.00
6/23	7.76	0	0.00	7.10	0	0.00	0	0.00	0	0.00
6/24	7.75	1	0.13	8.66	2	0.23	0	0.00	0	0.00
6/25	8.13	0	0.00	7.89	0	0.00	0	0.00	0	0.00
6/26	8.47	0	0.00	8.36	1	0.12	0	0.00	0	0.00
6/27	8.03	1	0.12	8.22	2	0.24	0	0.00	0	0.00
6/28	8.49	1	0.12	8.65	1	0.12	0	0.00	0	0.00
6/29	7.37	0	0.00	8.10	0	0.00	0	0.00	0	0.00
6/30	8.65	1	0.12	8.43	2	0.24	0	0.00	0	0.00
7/01	9.09	3	0.33	7.90	0	0.00	0	0.00	0	0.00
7/02	8.40	1	0.12	8.64	3	0.35	0	0.00	0	0.00
7/03	8.12	3	0.37	8.16	2	0.25	0	0.00	0	0.00

-continued-

Appendix B2.–Page 2 of 3.

	Large mesh	Chinook		Small mesh	Summer chum		Fall chum		Coho	
Date	fathom-hours	Catch	CPUE	fathom-hours	Catch	CPUE	Catch	CPUE	Catch	CPUE
7/04	8.80	2	0.23	8.32	3	0.36	0	0.00	0	0.00
7/05	8.61	0	0.00	7.82	4	0.51	0	0.00	0	0.00
7/06	7.93	1	0.13	8.00	4	0.50	0	0.00	0	0.00
7/07	7.97	1	0.13	8.14	14	1.72	0	0.00	0	0.00
7/08	8.22	0	0.00	8.83	7	0.79	0	0.00	0	0.00
7/09	5.60	0	0.00	11.34	7	0.62	0	0.00	0	0.00
7/10	8.11	2	0.25	8.60	2	0.23	0	0.00	0	0.00
7/11	8.77	10	0.11	8.27	5	0.60	0	0.00	0	0.00
7/12	7.80	2	0.26	8.87	2	0.23	0	0.00	0	0.00
7/13	8.34	0	0.00	8.27	3	0.36	0	0.00	0	0.00
7/14	8.19	0	0.00	8.51	1	0.12	0	0.00	0	0.00
7/15	8.48	0	0.00	8.43	1	0.12	0	0.00	0	0.00
7/16	8.80	0	0.00	8.71	2	0.23	0	0.00	0	0.00
7/17	8.14	0	0.00	8.60	2	0.23	0	0.00	0	0.00
7/18	8.56	0	0.00	8.86	11	1.24	0	0.00	0	0.00
7/19	2.63	0	0.00	8.25	0	0.00	2	0.24	0	0.00
7/20	2.59	0	0.00	8.68	0	0.00	2	0.23	0	0.00
7/21	2.68	0	0.00	8.60	0	0.00	1	0.12	0	0.00
7/22	2.89	0	0.00	8.97	0	0.00	0	0.00	0	0.00
7/23	2.79	0	0.00	8.64	0	0.00	0	0.00	0	0.00
7/24	2.80	0	0.00	8.64	0	0.00	1	0.12	0	0.00
7/25	2.62	0	0.00	8.82	0	0.00	0	0.00	0	0.00
7/26	2.73	0	0.00	8.29	0	0.00	0	0.00	0	0.00
7/27	3.05	0	0.00	7.98	0	0.00	2	0.25	0	0.00
7/28	2.89	0	0.00	5.19	0	0.00	0	0.00	0	0.00
7/29	2.97	0	0.00	8.26	0	0.00	0	0.00	0	0.00
7/30	2.91	0	0.00	8.12	0	0.00	0	0.00	0	0.00
7/31	2.65	0	0.00	8.68	0	0.00	4	0.46	0	0.00
8/01	2.72	0	0.00	8.64	0	0.00	4	0.46	0	0.00
8/02	2.65	0	0.00	8.61	0	0.00	1	0.12	0	0.00
8/03	2.92	0	0.00	8.32	0	0.00	1	0.12	0	0.00
8/04	2.78	0	0.00	8.86	0	0.00	1	0.11	0	0.00
8/05	2.75	0	0.00	8.64	0	0.00	0	0.00	0	0.00

-continued-

Appendix B2.–Page 3 of 3.

Date	Large mesh fathom-hours	Chinook		Small mesh fathom-hours	Summer chum		Fall chum		Coho	
		Catch	CPUE		Catch	CPUE	Catch	CPUE	Catch	CPUE
8/06	2.87	0	0.00	8.72	0	0.00	0	0.00	0	0.00
8/07	2.75	0	0.00	8.64	0	0.00	0	0.00	0	0.00
8/08	2.81	0	0.00	8.45	0	0.00	2	0.24	0	0.00
8/09	3.01	0	0.00	8.06	0	0.00	4	0.50	1	0.12
8/10	2.65	0	0.00	8.57	0	0.00	4	0.47	0	0.00
8/11	2.83	0	0.00	8.65	0	0.00	3	0.35	1	0.12
8/12	2.89	0	0.00	8.40	0	0.00	5	0.60	0	0.00
8/13	2.78	0	0.00	8.46	0	0.00	2	0.24	0	0.00
8/14	2.88	0	0.00	8.24	0	0.00	0	0.00	1	0.12
8/15	2.78	0	0.00	8.14	0	0.00	1	0.12	1	0.12
8/16	2.86	0	0.00	8.44	0	0.00	1	0.12	0	0.00
8/17	2.73	0	0.00	8.64	0	0.00	1	0.12	1	0.12
8/18	2.79	0	0.00	8.25	0	0.00	4	0.49	0	0.00
8/19	3.10	0	0.00	7.88	0	0.00	2	0.25	0	0.00
8/20	2.85	0	0.00	8.51	0	0.00	8	0.94	0	0.00
8/21	2.69	0	0.00	8.03	0	0.00	4	0.50	1	0.12
8/22	2.70	0	0.00	7.44	0	0.00	4	0.54	3	0.40
8/23	2.77	0	0.00	8.25	0	0.00	7	0.85	1	0.12
8/24	2.89	0	0.00	8.33	0	0.00	3	0.36	2	0.24
8/25	2.79	0	0.00	8.50	0	0.00	3	0.35	3	0.35
8/26	2.62	0	0.00	8.40	0	0.00	7	0.83	8	0.95
8/27	2.76	0	0.00	8.40	0	0.00	0	0.00	4	0.48
8/28	2.66	0	0.00	9.44	0	0.00	2	0.21	8	0.85
8/29	2.84	0	0.00	8.36	0	0.00	6	0.72	4	0.48
8/30	2.95	0	0.00	7.74	0	0.00	1	0.13	4	0.52
8/31	2.99	0	0.00	7.96	0	0.00	1	0.13	1	0.13
9/01	2.85	0	0.00	8.78	0	0.00	4	0.46	2	0.23
9/02	2.65	0	0.00	7.84	0	0.00	1	0.13	0	0.00
9/03	2.93	0	0.00	8.48	0	0.00	9	1.06	2	0.24
9/04	2.43	0	0.00	8.86	0	0.00	4	0.45	5	0.56
9/05	2.83	0	0.00	7.84	0	0.00	4	0.51	2	0.25
9/06	2.65	0	0.00	8.11	0	0.00	1	0.12	2	0.25
9/07	2.68	0	0.00	8.21	0	0.00	2	0.24	2	0.24
Total	551.02	36.	4.23	835.87	85	9.89	119	14.26	59	7.01

APPENDIX C: DAILY FISH PASSAGE ESTIMATES BY ZONE WITH STANDARD ERRORS

Appendix C1.–Daily fish passage estimates by zone with standard errors (SE) at the Pilot Station sonar project on the Yukon River, 2021.

			Total		Percent by bank	
Date	Right bank	Left bank	Passage	SE	Right	Left
5/31	2,259	3,069	5,328	3,341	42.4	57.6
6/01	2,023	2,645	4,668	339	43.3	56.7
6/02	1,864	1,894	3,758	197	49.6	50.4
6/03	1,758	2,278	4,036	240	43.6	56.4
6/04	1,446	2,430	3,876	452	37.3	62.7
6/05	1,209	2,118	3,327	262	36.3	63.7
6/06	1,418	2,274	3,692	147	38.4	61.6
6/07	1,515	2,749	4,264	155	35.5	64.5
6/08	1,389	2,676	4,065	187	34.2	65.8
6/09	1,448	4,187	5,635	320	25.7	74.3
6/10	1,454	4,195	5,649	199	25.7	74.3
6/11	1,422	4,413	5,835	247	24.4	75.6
6/12	1,313	4,576	5,889	349	22.3	77.7
6/13	1,362	4,927	6,289	450	21.7	78.3
6/14	1,367	4,369	5,736	354	23.8	76.2
6/15	1,529	3,726	5,255	323	29.1	70.9
6/16	1,961	3,073	5,034	216	39.0	61.0
6/17	2,139	3,920	6,059	404	35.3	64.7
6/18	2,428	6,125	8,553	391	28.4	71.6
6/19	2,389	6,882	9,271	391	25.8	74.2
6/20	2,426	5,128	7,554	401	32.1	67.9
6/21	2,491	5,880	8,371	513	29.8	70.2
6/22	2,271	4,174	6,445	319	35.2	64.8
6/23	2,510	4,379	6,889	543	36.4	63.6
6/24	2,198	6,132	8,330	539	26.4	73.6
6/25	2,674	4,593	7,267	507	36.8	63.2
6/26	2,601	7,138	9,739	822	26.7	73.3
6/27	2,722	7,750	10,472	416	26.0	74.0
6/28	2,584	6,468	9,052	321	28.5	71.5
6/29	2,375	11,463	13,838	766	17.2	82.8
6/30	2,618	14,231	16,849	1,214	15.5	84.5
7/01	2,746	15,550	18,296	1,389	15.0	85.0
7/02	2,777	10,681	13,458	572	20.6	79.4
7/03	2,340	10,671	13,011	360	18.0	82.0
7/04	2,769	10,861	13,630	550	20.3	79.7
7/05	2,926	8,226	11,152	484	26.2	73.8
7/06	3,199	12,319	15,518	1,552	20.6	79.4
7/07	3,699	16,469	20,168	1,237	18.3	81.7
7/08	2,385	13,508	15,893	728	15.0	85.0
7/09	1,877	8,417	10,294	776	18.2	81.8
7/10	1,850	8,626	10,476	630	17.7	82.3
7/11	1,916	12,033	13,949	717	13.7	86.3
7/12	1,931	10,397	12,328	340	15.7	84.3
7/13	2,176	9,282	11,458	327	19.0	81.0
7/14	2,092	9,507	11,599	543	18.0	82.0
7/15	2,507	8,884	11,391	565	22.0	78.0
7/16	3,280	9,290	12,570	397	26.1	73.9
7/17	3,433	13,999	17,432	1,339	19.7	80.3
7/18	4,486	18,733	23,219	915	19.3	80.7
7/19	3,511	18,489	22,000	872	16.0	84.0

-continued-

Appendix C1.–Page 2 of 2.

Date	Right bank	Left bank	Total		Percent by bank	
			Passage	SE	Right	Left
7/20	2,194	17,754	19,948	772	11.0	89.0
7/21	3,472	19,357	22,829	1,444	15.2	84.8
7/22	4,163	19,428	23,591	1,408	17.6	82.4
7/23	3,844	22,974	26,818	3,250	14.3	85.7
7/24	3,936	22,878	26,814	1,060	14.7	85.3
7/25	3,127	17,760	20,887	1,389	15.0	85.0
7/26	1,755	12,648	14,403	1,064	12.2	87.8
7/27	1,879	8,402	10,281	1,612	18.3	81.7
7/28	1,972	7,387	9,359	1,299	21.1	78.9
7/29	2,164	8,482	10,646	812	20.3	79.7
7/30	2,412	9,923	12,335	501	19.6	80.4
7/31	2,338	12,325	14,663	580	15.9	84.1
8/01	3,215	9,815	13,030	712	24.7	75.3
8/02	2,835	9,581	12,416	775	22.8	77.2
8/03	2,579	7,754	10,333	401	25.0	75.0
8/04	3,220	7,379	10,599	692	30.4	69.6
8/05	2,085	5,945	8,030	636	26.0	74.0
8/06	2,151	8,300	10,451	1,229	20.6	79.4
8/07	3,009	17,095	20,104	1,672	15.0	85.0
8/08	2,776	19,498	22,274	842	12.5	87.5
8/09	3,711	17,785	21,496	857	17.3	82.7
8/10	2,935	14,008	16,943	1,177	17.3	82.7
8/11	2,610	9,694	12,304	723	21.2	78.8
8/12	2,702	9,251	11,953	458	22.6	77.4
8/13	1,488	7,191	8,679	200	17.1	82.9
8/14	1,204	6,195	7,399	370	16.3	83.7
8/15	1,334	6,556	7,890	508	16.9	83.1
8/16	1,010	4,775	5,785	564	17.5	82.5
8/17	1,463	3,810	5,273	433	27.7	72.3
8/18	1,267	5,103	6,370	504	19.9	80.1
8/19	1,456	5,728	7,184	421	20.3	79.7
8/20	1,674	6,338	8,012	565	20.9	79.1
8/21	1,882	6,725	8,607	539	21.9	78.1
8/22	1,739	4,633	6,372	377	27.3	72.7
8/23	1,662	6,716	8,378	824	19.8	80.2
8/24	1,789	8,548	10,337	655	17.3	82.7
8/25	1,815	6,510	8,325	498	21.8	78.2
8/26	1,755	5,552	7,307	729	24.0	76.0
8/27	1,686	6,005	7,691	638	21.9	78.1
8/28	1,600	5,608	7,208	336	22.2	77.8
8/29	1,456	4,547	6,003	361	24.3	75.7
8/30	902	4,448	5,350	225	16.9	83.1
8/31	1,107	4,094	5,201	345	21.3	78.7
9/01	1,043	3,474	4,517	334	23.1	76.9
9/02	1,338	3,322	4,660	437	28.7	71.3
9/03	1,476	2,869	4,345	389	34.0	66.0
9/04	1,597	2,358	3,955	157	40.4	59.6
9/05	1,704	2,546	4,250	380	40.1	59.9
9/06	1,431	3,251	4,682	156	30.6	69.4
9/07	1,794	3,712	5,506	506	32.6	67.4
Season	218,819	821,841	1,040,660	66,433	21.0	79.0

APPENDIX D: DAILY FISH PASSAGE ESTIMATES BY SPECIES

Appendix D1.–Daily fish passage estimates by species at the Pilot Station sonar project on the Yukon River, 2021.

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Cisco	Broad	Humpback	Sheefish	Other[c]	Total
5/31	337	0	337	0	0	0	0	554	1,350	582	1,478	1,027	5,328
6/01	328	0	328	0	0	0	0	471	1,213	515	1,232	909	4,668
6/02	285	0	285	0	0	0	0	1,423	419	603	382	646	3,758
6/03	315	0	315	0	0	0	0	1,581	442	556	477	665	4,036
6/04	448	116	564	0	0	0	0	1,036	678	411	667	520	3,876
6/05	406	98	504	0	0	0	0	873	584	362	566	438	3,327
6/06	1,449	0	1,449	87	0	0	0	206	360	221	756	613	3,692
6/07	645	0	645	531	0	0	0	221	387	1,548	277	655	4,264
6/08	2,479	0	2,479	0	0	0	0	0	337	79	472	698	4,065
6/09	2,961	555	3,516	434	0	0	0	68	107	823	391	296	5,635
6/10	2,587	450	3,037	1,291	0	0	0	118	0	352	138	713	5,649
6/11	2,257	191	2,448	0	0	0	0	129	0	1,285	1,014	959	5,835
6/12	763	145	908	1,554	0	0	0	1,390	693	204	676	464	5,889
6/13	3,012	455	3,467	622	0	0	0	1,044	395	211	70	480	6,289
6/14	1,516	106	1,622	1,035	0	0	0	582	0	995	890	612	5,736
6/15	1,109	0	1,109	1,173	0	0	0	305	0	515	1,468	685	5,255
6/16	1,092	0	1,092	1,167	0	0	0	107	0	331	1,272	1,065	5,034
6/17	2,419	162	2,581	0	0	0	0	774	0	361	1,419	924	6,059
6/18	3,139	181	3,320	2,855	0	0	0	431	0	239	451	1,257	8,553
6/19	3,247	546	3,793	2,582	0	0	0	841	58	415	715	867	9,271
6/20	4,099	668	4,767	914	0	0	0	0	46	462	1,132	233	7,554
6/21	2,881	954	3,835	2,344	0	0	0	0	64	55	1,348	725	8,371
6/22	1,744	606	2,350	1,360	0	0	0	478	27	23	735	1,472	6,445
6/23	1,215	657	1,872	1,603	0	0	0	926	180	470	1,092	746	6,889
6/24	2,583	161	2,744	2,913	0	0	0	908	0	672	550	543	8,330
6/25	1,498	503	2,001	1,094	0	0	0	809	579	316	981	1,487	7,267
6/26	3,800	232	4,032	1,515	0	0	0	873	370	828	1,500	621	9,739
6/27	2,421	177	2,598	3,806	0	0	0	1,384	446	1,341	688	209	10,472
6/28	2,746	619	3,365	1,550	0	0	0	1,738	663	1,153	583	0	9,052

-continued-

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Cisco	Broad	Humpback	Sheefish	Other[c]	Total
6/29	4,460	1,098	5,558	5,301	0	0	0	715	610	1,148	506	0	13,838
6/30	5,189	697	5,886	7,935	0	0	0	806	207	799	639	577	16,849
7/01	4,895	1,633	6,528	9,755	0	0	0	338	218	254	472	731	18,296
7/02	3,819	1,016	4,835	5,791	0	0	0	707	100	225	403	1,397	13,458
7/03	4,622	1,516	6,138	3,733	0	0	0	997	0	1,809	334	0	13,011
7/04	3,941	1,803	5,744	4,408	0	0	0	691	351	925	490	1021	13,630
7/05	3,600	762	4,362	3,041	0	0	0	1,279	324	1,979	130	37	11,152
7/06	2,722	788	3,510	8,686	0	0	0	2,330	0	420	500	72	15,518
7/07	2,355	336	2,691	13,189	0	0	144	1,966	0	1,081	158	939	20,168
7/08	2,348	777	3,125	8,709	0	0	81	2,080	173	845	471	409	15,893
7/09	1,470	469	1,939	5,748	0	0	64	1,289	136	538	291	289	10,294
7/10	1,494	419	1,913	6,406	0	0	256	759	239	494	183	226	10,476
7/11	1,741	234	1,975	7,287	0	0	0	3,038	247	1,017	167	218	13,949
7/12	1,376	298	1,674	5,849	0	0	432	2,590	0	123	468	1192	12,328
7/13	864	303	1,167	4,662	0	0	0	3,861	0	1,017	272	479	11,458
7/14	515	521	1,036	3,411	0	0	146	2,225	0	3,868	172	741	11,599
7/15	819	198	1,017	1,406	0	0	176	4,014	0	4,309	173	296	11,391
7/16	373	17	390	2,657	0	0	0	3,565	0	5,042	674	242	12,570
7/17	161	40	201	4,055	0	0	289	9,088	159	3,199	441	0	17,432
7/18	1,223	71	1,294	11,259	0	0	650	3,472	187	5,957	228	172	23,219
7/19	375	0	375	0	6,817	0	641	5,462	576	7,910	219	0	22,000
7/20	79	0	79	0	6,652	0	804	3,852	0	8,266	232	63	19,948
7/21	281	0	281	0	3,153	0	1,914	8,514	553	8,067	57	290	22,829
7/22	247	0	247	0	3,005	0	1,568	6,751	277	11,404	102	237	23,591
7/23	137	0	137	0	3,370	0	1,509	6,728	0	14,889	60	125	26,818
7/24	138	0	138	0	1,971	0	4,454	3,250	601	16,232	127	41	26,814
7/25	220	0	220	0	1,878	0	1,480	5,787	78	11,150	0	294	20,887
7/26	0	0	0	0	2,446	0	771	1,442	392	9,148	0	204	14,403
7/27	0	0	0	0	2,501	0	260	1,241	197	5,463	0	619	10,281
7/28	0	0	0	0	1,133	0	263	3,753	443	3,226	202	339	9,359
7/29	0	0	0	0	1,404	0	332	4,119	487	3,710	221	373	10,646

-continued-

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Cisco	Broad	Humpback	Sheefish	Other[c]	Total
7/30	0	0	0	0	6,057	0	268	2,291	275	2,614	229	601	12,335
7/31	0	0	0	0	7,313	0	702	1,425	384	4,607	0	232	14,663
8/01	332	0	332	0	7,897	0	287	2,400	0	1,962	0	152	13,030
8/02	0	0	0	0	3,844	109	502	2,814	363	3,547	599	638	12,416
8/03	353	0	353	0	2,492	0	252	2,471	88	4,345	229	103	10,333
8/04	0	0	0	0	1,889	99	95	1,252	106	5,947	336	875	10,599
8/05	0	0	0	0	1,207	0	186	1,965	345	4,114	0	213	8,030
8/06	337	0	337	0	916	312	392	3,536	0	4,632	326	0	10,451
8/07	0	0	0	0	756	267	249	5,850	0	12,613	198	171	20,104
8/08	0	0	0	0	1,823	49	859	2,932	551	15,825	0	235	22,274
8/09	0	0	0	0	4,765	562	895	2,092	389	12,716	0	77	21,496
8/10	0	0	0	0	4,032	350	763	2,601	967	7,990	66	174	16,943
8/11	0	0	0	0	1,596	619	155	3,827	205	5,709	132	61	12,304
8/12	0	0	0	0	2,223	1,437	0	2,660	0	5,633	0	0	11,953
8/13	0	0	0	0	1,443	906	0	3,938	246	2,062	0	84	8,679
8/14	0	0	0	0	595	485	193	1,609	0	4,421	0	96	7,399
8/15	0	0	0	0	2,561	505	0	3,377	61	1,354	0	32	7,890
8/16	0	0	0	0	1,007	655	91	2,968	217	779	68	0	5,785
8/17	0	0	0	0	653	521	58	1,600	202	2,113	31	95	5,273
8/18	0	0	0	0	1,815	566	0	2,193	74	1,611	0	111	6,370
8/19	0	0	0	0	3,891	558	0	2,273	182	95	0	185	7,184
8/20	0	0	0	0	3,431	684	0	3,339	340	218	0	0	8,012
8/21	0	0	0	0	4,180	798	0	2,924	306	259	0	140	8,607
8/22	0	0	0	0	1,969	1,288	0	2,166	226	485	0	238	6,372
8/23	0	0	0	0	3,793	1,345	0	2,864	44	217	85	30	8,378
8/24	0	0	0	0	6,387	1,714	0	1,489	150	311	167	119	10,337
8/25	0	0	0	0	4,014	1,750	0	1,681	255	545	40	40	8,325
8/26	0	0	0	0	2,881	2,340	0	1,027	149	830	0	80	7,307
8/27	0	0	0	0	3,279	1,815	0	1,435	245	888	0	29	7,691

-continued-

Appendix D1.–Page 4 of 4.

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Pink	Coho	Cisco	Broad	Humpback	Sheefish	Other[c]	Total
8/28	0	0	0	0	2,215	2,844	0	148	271	1730	0	0	7,208
8/29	0	0	0	0	2,008	1,767	0	1,610	165	420	33	0	6,003
8/30	0	0	0	0	2,623	1,554	0	656	0	403	85	29	5,350
8/31	0	0	0	0	2,735	1,875	0	173	0	192	33	193	5,201
9/01	0	0	0	0	2,128	1,365	0	242	335	419	0	28	4,517
9/02	0	0	0	0	1,364	1,349	0	831	191	773	152	0	4,660
9/03	0	0	0	0	1,662	1,540	0	899	79	0	0	165	4,345
9/04	0	0	0	0	1,457	1,109	0	271	334	392	0	392	3,955
9/05	0	0	0	0	2,477	1,205	0	320	68	124	56	0	4,250
9/06	0	0	0	0	1,787	1,240	0	1,088	93	398	76	0	4,682
9/07	0	0	0	0	2,702	1,673	0	350	0	425	67	289	5,506
Total	104,267	20,578	124,845	153,718	146,197	37,255	22,181	195,566	23,859	264,160	34,820	38,059	1,040,660

[a] Chinook salmon >655 mm mid eye to tail fork (METF).

[b] Chinook salmon ≤655 mm METF.

[c] Includes sockeye salmon, cisco, whitefish, sheefish, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX E: DAILY CUMULATIVE FISH PASSAGE PROPORTIONS AND TIMING BY SPECIES

Appendix E1.–Daily cumulative fish passage proportions and timing by species, at the Pilot Station sonar project on the Yukon River, 2021.

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Coho	Pink	Cisco	Humpback	Broad	Sheefish	Other[c]	Total
5/31	0.003	0.000	0.003	0.000	0.000	0.000	0.000	0.003	0.002	0.057	0.042	0.027	0.005
6/01	0.006	0.000	0.005	0.000	0.000	0.000	0.000	0.005	0.004	0.107	0.078	0.051	0.010
6/02	0.009	0.000	0.008	0.000	0.000	0.000	0.000	0.013	0.006	0.125	0.089	0.068	0.013
6/03	0.012	0.000	0.010	0.000	0.000	0.000	0.000	0.021	0.009	0.144	0.102	0.085	0.017
6/04	0.016	0.006	0.015	0.000	0.000	0.000	0.000	0.026	0.010	0.172	0.122	0.099	0.021
6/05	0.020	0.010	0.019	0.000	0.000	0.000	0.000	0.030	0.011	0.196	0.138	0.110	0.024
6/06	0.034	0.010	0.030	0.001	0.000	0.000	0.000	0.031	0.012	0.211	0.160	0.127	0.028
6/07	0.040	0.010	0.035	0.004	0.000	0.000	0.000	0.033	0.018	0.228	0.168	0.144	0.032
6/08	0.064	0.010	0.055	0.004	0.000	0.000	0.000	0.033	0.018	0.242	0.181	0.162	0.036
6/09	0.093	0.037	0.083	0.007	0.000	0.000	0.000	0.033	0.022	0.246	0.192	0.170	0.041
6/10	0.117	0.059	0.108	0.015	0.000	0.000	0.000	0.033	0.023	0.246	0.196	0.189	0.046
6/11	0.139	0.069	0.127	0.015	0.000	0.000	0.000	0.034	0.028	0.246	0.225	0.214	0.052
6/12	0.146	0.076	0.135	0.025	0.000	0.000	0.000	0.041	0.029	**0.275**	0.245	0.226	0.058
6/13	0.175	0.098	0.162	0.029	0.000	0.000	0.000	0.047	0.029	0.292	0.247	0.239	0.064
6/14	0.190	0.103	0.175	0.036	0.000	0.000	0.000	0.050	0.033	0.292	**0.272**	**0.255**	0.069
6/15	0.200	0.103	0.184	0.044	0.000	0.000	0.000	0.051	0.035	0.292	0.315	0.273	0.074
6/16	0.211	0.103	0.193	0.051	0.000	0.000	0.000	0.052	0.036	0.292	0.351	0.301	0.079
6/17	0.234	0.111	0.214	0.051	0.000	0.000	0.000	0.056	0.038	0.292	0.392	0.325	0.085
6/18	**0.264**	0.119	0.240	0.070	0.000	0.000	0.000	0.058	0.039	0.292	0.405	0.358	0.093
6/19	0.295	0.146	**0.271**	0.087	0.000	0.000	0.000	0.062	0.040	0.294	0.425	0.381	0.102
6/20	0.335	0.178	0.309	0.093	0.000	0.000	0.000	0.062	0.042	0.296	0.458	0.387	0.109
6/21	0.362	0.225	0.340	0.108	0.000	0.000	0.000	0.062	0.042	0.299	0.497	0.406	0.117
6/22	0.379	**0.254**	0.358	0.117	0.000	0.000	0.000	0.065	0.042	0.300	**0.518**	0.445	0.124
6/23	0.391	0.286	0.373	0.127	0.000	0.000	0.000	0.069	0.044	0.308	0.549	0.464	0.130
6/24	0.415	0.294	0.395	0.146	0.000	0.000	0.000	0.074	0.047	0.308	0.565	0.479	0.138
6/25	0.430	0.318	0.411	0.153	0.000	0.000	0.000	0.078	0.048	0.332	0.593	**0.518**	0.145
6/26	0.466	0.330	0.444	0.163	0.000	0.000	0.000	0.083	0.051	0.347	0.636	0.534	0.155
6/27	0.489	0.338	0.465	0.188	0.000	0.000	0.000	0.090	0.056	0.366	0.656	0.539	0.165
6/28	**0.516**	0.368	0.492	0.198	0.000	0.000	0.000	0.099	0.060	0.394	0.673	0.539	0.173
6/29	0.559	0.422	**0.536**	0.232	0.000	0.000	0.000	0.102	0.065	0.419	0.687	0.539	0.187
6/30	0.608	0.456	0.583	**0.284**	0.000	0.000	0.000	0.106	0.068	0.428	0.705	0.555	0.203
7/01	0.655	**0.535**	0.635	0.348	0.000	0.000	0.000	0.108	0.069	0.437	0.719	0.574	0.220
7/02	0.692	0.584	0.674	0.385	0.000	0.000	0.000	0.112	0.069	0.441	0.731	0.610	0.233
7/03	0.736	0.658	0.723	0.409	0.000	0.000	0.000	0.117	0.076	0.441	0.740	0.610	0.246
7/04	**0.774**	0.746	**0.769**	0.438	0.000	0.000	0.000	0.120	0.080	0.456	**0.754**	0.637	**0.259**
7/05	0.809	**0.783**	0.804	0.458	0.000	0.000	0.000	0.127	0.087	0.470	0.758	0.638	0.270
7/06	0.835	0.821	0.832	**0.514**	0.000	0.000	0.000	0.139	0.089	0.470	0.772	0.640	0.285

-continued-

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Coho	Pink	Cisco	Humpback	Broad	Sheefish	Other[c]	Total
7/07	0.857	0.837	0.854	0.600	0.000	0.006	0.000	0.149	0.093	0.470	0.777	0.665	0.304
7/08	0.880	0.875	0.879	0.657	0.000	0.010	0.000	0.159	0.096	0.477	0.790	0.676	0.319
7/09	0.894	0.898	0.895	0.694	0.000	0.013	0.000	0.166	0.098	0.483	0.799	0.683	0.329
7/10	0.908	0.918	0.910	0.736	0.000	0.025	0.000	0.170	0.100	0.493	0.804	0.689	0.339
7/11	0.925	0.930	0.926	**0.783**	0.000	0.025	0.000	0.185	0.104	**0.503**	0.809	0.695	0.353
7/12	0.938	0.944	0.939	0.821	0.000	0.044	0.000	0.199	0.104	0.503	0.822	0.726	0.364
7/13	0.946	0.959	0.948	0.852	0.000	0.044	0.000	0.218	0.108	0.503	0.830	0.739	0.375
7/14	0.951	0.984	0.957	0.874	0.000	0.051	0.000	0.230	0.123	0.503	0.835	**0.758**	0.387
7/15	0.959	0.994	0.965	0.883	0.000	0.059	0.000	**0.250**	0.139	0.503	0.840	0.766	0.397
7/16	0.963	0.995	0.968	0.900	0.000	0.059	0.000	0.269	0.158	0.503	0.859	0.772	0.410
7/17	0.964	0.997	0.970	0.927	0.000	0.072	0.000	0.315	0.170	0.510	0.872	0.772	0.426
7/18	0.976	1.000	0.980	1.000	0.000	0.101	0.000	0.333	0.193	0.518	0.879	0.777	0.449
7/19	0.980	1.000	0.983	1.000	0.047	0.130	0.000	0.361	0.223	0.542	0.885	0.777	0.470
7/20	0.980	1.000	0.984	1.000	0.092	0.166	0.000	0.380	**0.254**	0.542	0.892	0.779	0.489
7/21	0.983	1.000	0.986	1.000	0.114	**0.252**	0.000	0.424	0.285	0.565	0.893	0.786	**0.511**
7/22	0.985	1.000	0.988	1.000	0.134	0.323	0.000	0.458	0.328	0.577	0.896	0.792	0.534
7/23	0.987	1.000	0.989	1.000	0.157	0.391	0.000	0.493	0.384	0.577	0.898	0.796	0.559
7/24	0.988	1.000	0.990	1.000	0.171	**0.592**	0.000	**0.509**	0.446	0.602	0.901	0.797	0.585
7/25	0.990	1.000	0.992	1.000	0.184	0.659	0.000	0.539	0.488	0.605	0.901	0.804	0.605
7/26	0.990	1.000	0.992	1.000	0.200	0.693	0.000	0.546	**0.523**	0.621	0.901	0.810	0.619
7/27	0.990	1.000	0.992	1.000	0.217	0.705	0.000	0.553	0.543	0.630	0.901	0.826	0.629
7/28	0.990	1.000	0.992	1.000	0.225	0.717	0.000	0.572	0.555	0.648	0.907	0.835	0.638
7/29	0.990	1.000	0.992	1.000	0.235	0.732	0.000	0.593	0.570	0.669	0.914	0.845	0.648
7/30	0.990	1.000	0.992	1.000	**0.276**	0.744	0.000	0.605	0.579	0.680	0.920	0.861	0.660
7/31	0.990	1.000	0.992	1.000	0.326	**0.776**	0.000	0.612	0.597	0.696	0.920	0.867	0.674
8/01	0.993	1.000	0.994	1.000	0.380	0.789	0.000	0.624	0.604	0.696	0.920	0.871	0.687
8/02	0.993	1.000	0.994	1.000	0.407	0.811	0.003	0.639	0.618	0.711	0.937	0.887	0.698
8/03	0.997	1.000	0.997	1.000	0.424	0.823	0.003	0.651	0.634	0.715	0.944	0.890	0.708
8/04	0.997	1.000	0.997	1.000	0.437	0.827	0.006	0.658	0.657	0.720	0.954	0.913	0.719
8/05	0.997	1.000	0.997	1.000	0.445	0.835	0.006	0.668	0.672	0.734	0.954	0.919	0.726
8/06	1.000	1.000	1.000	1.000	0.451	0.853	0.014	0.686	0.690	0.734	0.963	0.919	0.736
8/07	1.000	1.000	1.000	1.000	0.456	0.864	0.021	0.716	0.738	0.734	0.969	0.923	**0.756**
8/08	1.000	1.000	1.000	1.000	0.469	0.903	0.022	0.731	**0.797**	**0.757**	0.969	0.929	0.777
8/09	1.000	1.000	1.000	1.000	**0.501**	0.943	0.038	0.741	0.846	0.773	0.969	0.931	0.798
8/10	1.000	1.000	1.000	1.000	0.529	0.978	0.047	**0.755**	0.876	0.814	0.971	0.936	0.814
8/11	1.000	1.000	1.000	1.000	0.540	0.985	0.064	0.774	0.897	0.823	0.974	0.938	0.826

-continued-

Appendix E1.–Page 3 of 3.

Date	Chinook			Chum		Coho	Pink	Cisco	Whitefish		Sheefish	Other[c]	Total
	Large[a]	Small[b]	Total	Summer	Fall				Humpback	Broad			
8/12	1.000	1.000	1.000	1.000	0.555	0.985	0.102	0.788	0.919	0.823	0.974	0.938	0.837
8/13	1.000	1.000	1.000	1.000	0.565	0.985	0.126	0.808	0.927	0.833	0.974	0.940	0.846
8/14	1.000	1.000	1.000	1.000	0.569	0.993	0.139	0.816	0.943	0.833	0.974	0.942	0.853
8/15	1.000	1.000	1.000	1.000	0.586	0.993	0.153	0.834	0.948	0.835	0.974	0.943	0.860
8/16	1.000	1.000	1.000	1.000	0.593	0.997	0.171	0.849	0.951	0.845	0.976	0.943	0.866
8/17	1.000	1.000	1.000	1.000	0.598	1.000	0.185	0.857	0.959	0.853	0.977	0.946	0.871
8/18	1.000	1.000	1.000	1.000	0.610	1.000	0.200	0.868	0.965	0.856	0.977	0.949	0.877
8/19	1.000	1.000	1.000	1.000	0.637	1.000	0.215	0.880	0.966	0.864	0.977	0.953	0.884
8/20	1.000	1.000	1.000	1.000	0.660	1.000	0.233	0.897	0.967	0.878	0.977	0.953	0.892
8/21	1.000	1.000	1.000	1.000	0.689	1.000	**0.255**	0.912	0.968	0.891	0.977	0.957	0.900
8/22	1.000	1.000	1.000	1.000	0.702	1.000	0.289	0.923	0.969	0.900	0.977	0.963	0.906
8/23	1.000	1.000	1.000	1.000	0.728	1.000	0.325	0.938	0.970	0.902	0.980	0.964	0.914
8/24	1.000	1.000	1.000	1.000	**0.772**	1.000	0.371	0.945	0.971	0.908	0.984	0.967	0.924
8/25	1.000	1.000	1.000	1.000	0.799	1.000	0.418	0.954	0.974	0.919	0.986	0.968	0.932
8/26	1.000	1.000	1.000	1.000	0.819	1.000	0.481	0.959	0.977	0.925	0.986	0.970	0.939
8/27	1.000	1.000	1.000	1.000	0.842	1.000	**0.530**	0.966	0.980	0.936	0.986	0.971	0.946
8/28	1.000	1.000	1.000	1.000	0.857	1.000	0.606	0.967	0.987	0.947	0.986	0.971	0.953
8/29	1.000	1.000	1.000	1.000	0.870	1.000	0.653	0.975	0.988	0.954	0.987	0.971	0.959
8/30	1.000	1.000	1.000	1.000	0.888	1.000	0.695	0.979	0.990	0.954	0.989	0.972	0.964
8/31	1.000	1.000	1.000	1.000	0.907	1.000	0.746	0.980	0.990	0.954	0.990	0.977	0.969
9/01	1.000	1.000	1.000	1.000	0.922	1.000	**0.782**	0.981	0.992	0.968	0.990	0.978	0.974
9/02	1.000	1.000	1.000	1.000	0.931	1.000	0.818	0.985	0.995	0.976	0.994	0.978	0.978
9/03	1.000	1.000	1.000	1.000	0.942	1.000	0.860	0.990	0.995	0.979	0.994	0.982	0.982
9/04	1.000	1.000	1.000	1.000	0.952	1.000	0.889	0.991	0.996	0.993	0.994	0.992	0.986
9/05	1.000	1.000	1.000	1.000	0.969	1.000	0.922	0.993	0.997	0.996	0.996	0.992	0.990
9/06	1.000	1.000	1.000	1.000	0.982	1.000	0.955	0.998	0.998	1.000	0.998	0.992	0.995
9/07	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: The mean cumulative run timing for both fall chum and coho salmon was based on run timing from July 19 through August 31 in order to compare timing across years, despite years when the project was in operation until September 7. The 25th, 50th, and 75th percentiles are bold.

[a] Chinook salmon >655 mm mid eye to tail fork (METF).

[b] Chinook salmon ≤655 mm METF.

[c] Includes sockeye salmon, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX F: DAILY CUMULATIVE FISH PASSAGE ESTIMATES BY SPECIES, AT THE PILOT STATION SONAR PROJECT ON THE YUKON RIVER

Appendix F1.–Daily cumulative fish passage proportions and timing by species at the Pilot Station sonar project on the Yukon River, 2021.

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Coho	Pink	Cisco	Humpback	Broad	Sheefish	Other[c]	Total
5/31	337	0	337	0	0	0	0	554	582	1,350	1,478	1,027	5,328
6/01	665	0	665	0	0	0	0	1,025	1,097	2,563	2,710	1,936	9,996
6/02	950	0	950	0	0	0	0	2,448	1,700	2,982	3,092	2,582	13,754
6/03	1,265	0	1,265	0	0	0	0	4,029	2,256	3,424	3,569	3,247	17,790
6/04	1,713	116	1,829	0	0	0	0	5,065	2,667	4,102	4,236	3,767	21,666
6/05	2,119	214	2,333	0	0	0	0	5,938	3,029	4,686	4,802	4,205	24,993
6/06	3,568	214	3,782	87	0	0	0	6,144	3,250	5,046	5,558	4,818	28,685
6/07	4,213	214	4,427	618	0	0	0	6,365	4,798	5,433	5,835	5,473	32,949
6/08	6,692	214	6,906	618	0	0	0	6,365	4,877	5,770	6,307	6,171	37,014
6/09	9,653	769	10,422	1,052	0	0	0	6,433	5,700	5,877	6,698	6,467	42,649
6/10	12,240	1,219	13,459	2,343	0	0	0	6,551	6,052	5,877	6,836	7,180	48,298
6/11	14,497	1,410	15,907	2,343	0	0	0	6,680	7,337	5,877	7,850	8,139	54,133
6/12	15,260	1,555	16,815	3,897	0	0	0	8,070	7,541	6,570	8,526	8,603	60,022
6/13	18,272	2,010	20,282	4,519	0	0	0	9,114	7,752	6,965	8,596	9,083	66,311
6/14	19,788	2,116	21,904	5,554	0	0	0	9,696	8,747	6,965	9,486	9,695	72,047
6/15	20,897	2,116	23,013	6,727	0	0	0	10,001	9,262	6,965	10,954	10,380	77,302
6/16	21,989	2,116	24,105	7,894	0	0	0	10,108	9,593	6,965	12,226	11,445	82,336
6/17	24,408	2,278	26,686	7,894	0	0	0	10,882	9,954	6,965	13,645	12,369	88,395
6/18	27,547	2,459	30,006	10,749	0	0	0	11,313	10,193	6,965	14,096	13,626	96,948
6/19	30,794	3,005	33,799	13,331	0	0	0	12,154	10,608	7,023	14,811	14,493	106,219
6/20	34,893	3,673	38,566	14,245	0	0	0	12,154	11,070	7,069	15,943	14,726	113,773
6/21	37,774	4,627	42,401	16,589	0	0	0	12,154	11,125	7,133	17,291	15,451	122,144
6/22	39,518	5,233	44,751	17,949	0	0	0	12,632	11,148	7,160	18,026	16,923	128,589
6/23	40,733	5,890	46,623	19,552	0	0	0	13,558	11,618	7,340	19,118	17,669	135,478
6/24	43,316	6,051	49,367	22,465	0	0	0	14,466	12,290	7,340	19,668	18,212	143,808
6/25	44,814	6,554	51,368	23,559	0	0	0	15,275	12,606	7,919	20,649	19,699	151,075
6/26	48,614	6,786	55,400	25,074	0	0	0	16,148	13,434	8,289	22,149	20,320	160,814
6/27	51,035	6,963	57,998	28,880	0	0	0	17,532	14,775	8,735	22,837	20,529	171,286
6/28	53,781	7,582	61,363	30,430	0	0	0	19,270	15,928	9,398	23,420	20,529	180,338
6/29	58,241	8,680	66,921	35,731	0	0	0	19,985	17,076	10,008	23,926	20,529	194,176
6/30	63,430	9,377	72,807	43,666	0	0	0	20,791	17,875	10,215	24,565	21,106	211,025
7/01	68,325	11,010	79,335	53,421	0	0	0	21,129	18,129	10,433	25,037	21,837	229,321
7/02	72,144	12,026	84,170	59,212	0	0	0	21,836	18,354	10,533	25,440	23,234	242,779
7/03	76,766	13,542	90,308	62,945	0	0	0	22,833	20,163	10,533	25,774	23,234	255,790
7/04	80,707	15,345	96,052	67,353	0	0	0	23,524	21,088	10,884	26,264	24,255	269,420

-continued-

Appendix F1.–Page 2 of 3.

	Chinook			Chum					Whitefish				
Date	Large[a]	Small[b]	Total	Summer	Fall	Coho	Pink	Cisco	Humpback	Broad	Sheefish	Other[c]	Total
7/05	84,307	16,107	100,414	70,394	0	0	0	24,803	23,067	11,208	26,394	24,292	280,572
7/06	87,029	16,895	103,924	79,080	0	0	0	27,133	23,487	11,208	26,894	24,364	296,090
7/07	89,384	17,231	106,615	92,269	0	0	144	29,099	24,568	11,208	27,052	25,303	316,258
7/08	91,732	18,008	109,740	100,978	0	0	225	31,179	25,413	11,381	27,523	25,712	332,151
7/09	93,202	18,477	111,679	106,726	0	0	289	32,468	25,951	11,517	27,814	26,001	342,445
7/10	94,696	18,896	113,592	113,132	0	0	545	33,227	26,445	11,756	27,997	26,227	352,921
7/11	96,437	19,130	115,567	120,419	0	0	545	36,265	27,462	12,003	28,164	26,445	366,870
7/12	97,813	19,428	117,241	126,268	0	0	977	38,855	27,585	12,003	28,632	27,637	379,198
7/13	98,677	19,731	118,408	130,930	0	0	977	42,716	28,602	12,003	28,904	28,116	390,656
7/14	99,192	20,252	119,444	134,341	0	0	1,123	44,941	32,470	12,003	29,076	28,857	402,255
7/15	100,011	20,450	120,461	135,747	0	0	1,299	48,955	36,779	12,003	29,249	29,153	413,646
7/16	100,384	20,467	120,851	138,404	0	0	1,299	52,520	41,821	12,003	29,923	29,395	426,216
7/17	100,545	20,507	121,052	142,459	0	0	1,588	61,608	45,020	12,162	30,364	29,395	443,648
7/18	101,768	20,578	122,346	153,718	0	0	2,238	65,080	50,977	12,349	30,592	29,567	466,867
7/19	102,143	20,578	122,721	153,718	6,817	0	2,879	70,542	58,887	12,925	30,811	29,567	488,867
7/20	102,222	20,578	122,800	153,718	13,469	0	3,683	74,394	67,153	12,925	31,043	29,630	508,815
7/21	102,503	20,578	123,081	153,718	16,622	0	5,597	82,908	75,220	13,478	31,100	29,920	531,644
7/22	102,750	20,578	123,328	153,718	19,627	0	7,165	89,659	86,624	13,755	31,202	30,157	555,235
7/23	102,887	20,578	123,465	153,718	22,997	0	8,674	96,387	101,513	13,755	31,262	30,282	582,053
7/24	103,025	20,578	123,603	153,718	24,968	0	13,128	99,637	117,745	14,356	31,389	30,323	608,867
7/25	103,245	20,578	123,823	153,718	26,846	0	14,608	105,424	128,895	14,434	31,389	30,617	629,754
7/26	103,245	20,578	123,823	153,718	29,292	0	15,379	106,866	138,043	14,826	31,389	30,821	644,157
7/27	103,245	20,578	123,823	153,718	31,793	0	15,639	108,107	143,506	15,023	31,389	31,440	654,438
7/28	103,245	20,578	123,823	153,718	32,926	0	15,902	111,860	146,732	15,466	31,591	31,779	663,797
7/29	103,245	20,578	123,823	153,718	34,330	0	16,234	115,979	150,442	15,953	31,812	32,152	674,443
7/30	103,245	20,578	123,823	153,718	40,387	0	16,502	118,270	153,056	16,228	32,041	32,753	686,778
7/31	103,245	20,578	123,823	153,718	47,700	0	17,204	119,695	157,663	16,612	32,041	32,985	701,441
8/01	103,577	20,578	124,155	153,718	55,597	0	17,491	122,095	159,625	16,612	32,041	33,137	714,471
8/02	103,577	20,578	124,155	153,718	59,441	109	17,993	124,909	163,172	16,975	32,640	33,775	726,887
8/03	103,930	20,578	124,508	153,718	61,933	109	18,245	127,380	167,517	17,063	32,869	33,878	737,220
8/04	103,930	20,578	124,508	153,718	63,822	208	18,340	128,632	173,464	17,169	33,205	34,753	747,819
8/05	103,930	20,578	124,508	153,718	65,029	208	18,526	130,597	177,578	17,514	33,205	34,966	755,849
8/06	104,267	20,578	124,845	153,718	65,945	520	18,918	134,133	182,210	17,514	33,531	34,966	766,300
8/07	104,267	20,578	124,845	153,718	66,701	787	19,167	139,983	194,823	17,514	33,729	35,137	786,404

-continued-

Appendix F1.–Page 3 of 3.

Date	Chinook			Chum		Coho	Pink	Cisco	Whitefish		Sheefish	Other[c]	Total
	Large[a]	Small[b]	Total	Summer	Fall				Humpback	Broad			
8/08	104,267	20,578	124,845	153,718	68,524	836	20,026	142,915	210,648	18,065	33,729	35,372	808,678
8/09	104,267	20,578	124,845	153,718	73,289	1,398	20,921	145,007	223,364	18,454	33,729	35,449	830,174
8/10	104,267	20,578	124,845	153,718	77,321	1,748	21,684	147,608	231,354	19,421	33,795	35,623	847,117
8/11	104,267	20,578	124,845	153,718	78,917	2,367	21,839	151,435	237,063	19,626	33,927	35,684	859,421
8/12	104,267	20,578	124,845	153,718	81,140	3,804	21,839	154,095	242,696	19,626	33,927	35,684	871,374
8/13	104,267	20,578	124,845	153,718	82,583	4,710	21,839	158,033	244,758	19,872	33,927	35,768	880,053
8/14	104,267	20,578	124,845	153,718	83,178	5,195	22,032	159,642	249,179	19,872	33,927	35,864	887,452
8/15	104,267	20,578	124,845	153,718	85,739	5,700	22,032	163,019	250,533	19,933	33,927	35,896	895,342
8/16	104,267	20,578	124,845	153,718	86,746	6,355	22,123	165,987	251,312	20,150	33,995	35,896	901,127
8/17	104,267	20,578	124,845	153,718	87,399	6,876	22,181	167,587	253,425	20,352	34,026	35,991	906,400
8/18	104,267	20,578	124,845	153,718	89,214	7,442	22,181	169,780	255,036	20,426	34,026	36,102	912,770
8/19	104,267	20,578	124,845	153,718	93,105	8,000	22,181	172,053	255,131	20,608	34,026	36,287	919,954
8/20	104,267	20,578	124,845	153,718	96,536	8,684	22,181	175,392	255,349	20,948	34,026	36,287	927,966
8/21	104,267	20,578	124,845	153,718	100,716	9,482	22,181	178,316	255,608	21,254	34,026	36,427	936,573
8/22	104,267	20,578	124,845	153,718	102,685	10,770	22,181	180,482	256,093	21,480	34,026	36,665	942,945
8/23	104,267	20,578	124,845	153,718	106,478	12,115	22,181	183,346	256,310	21,524	34,111	36,695	951,323
8/24	104,267	20,578	124,845	153,718	112,865	13,829	22,181	184,835	256,621	21,674	34,278	36,814	961,660
8/25	104,267	20,578	124,845	153,718	116,879	15,579	22,181	186,516	257,166	21,929	34,318	36,854	969,985
8/26	104,267	20,578	124,845	153,718	119,760	17,919	22,181	187,543	257,996	22,078	34,318	36,934	977,292
8/27	104,267	20,578	124,845	153,718	123,039	19,734	22,181	188,978	258,884	22,323	34,318	36,963	984,983
8/28	104,267	20,578	124,845	153,718	125,254	22,578	22,181	189,126	260,614	22,594	34,318	36,963	992,191
8/29	104,267	20,578	124,845	153,718	127,262	24,345	22,181	190,736	261,034	22,759	34,351	36,963	998,194
8/30	104,267	20,578	124,845	153,718	129,885	25,899	22,181	191,392	261,437	22,759	34,436	36,992	1,003,544
8/31	104,267	20,578	124,845	153,718	132,620	27,774	22,181	191,565	261,629	22,759	34,469	37,185	1,008,745
9/01	104,267	20,578	124,845	153,718	134,748	29,139	22,181	191,807	262,048	23,094	34,469	37,213	1,013,262
9/02	104,267	20,578	124,845	153,718	136,112	30,488	22,181	192,638	262,821	23,285	34,621	37,213	1,017,922
9/03	104,267	20,578	124,845	153,718	137,774	32,028	22,181	193,537	262,821	23,364	34,621	37,378	1,022,267
9/04	104,267	20,578	124,845	153,718	139,231	33,137	22,181	193,808	263,213	23,698	34,621	37,770	1,026,222
9/05	104,267	20,578	124,845	153,718	141,708	34,342	22,181	194,128	263,337	23,766	34,677	37,770	1,030,472
9/06	104,267	20,578	124,845	153,718	143,495	35,582	22,181	195,216	263,735	23,859	34,753	37,770	1,035,154
9/07	104,267	20,578	124,845	153,718	146,197	37,255	22,181	195,566	264,160	23,859	34,820	38,059	1,040,660

Note: The mean cumulative run timing for both fall chum and coho salmon was based on run timing from July 19 through August 31 in order to compare timing across years, despite years when the project was in operation until September 7.

[a] Chinook salmon >655 mm mid eye to tail fork (METF).

[b] Chinook salmon ≤655 mm METF.

[c] Includes sockeye salmon, burbot, longnose sucker, Dolly Varden, and northern pike.

APPENDIX G: PILOT STATION SONAR FISH PASSAGE ESTIMATES BY SPECIES, 1995-2021

Appendix G1.–Salmon passage estimates, by species, at the Pilot Station sonar project on the Yukon River, 1995–2021.

	Chinook			Chum					
Year[a]	Large[b]	Small[c]	Total	Summer	Fall[d]	Total	Coho[d]	Pink	Total
1995	164,867	45,874	210,741	3,632,179	1,156,278	4,788,457	119,893	53,277	5,172,368
1996[e]	ND	ND	ND	ND	ND	ND	ND	ND	ND
1997	114,519	85,244	199,763	1,359,117	579,767	1,938,884	118,065	3,872	2,260,584
1998	88,129	19,909	108,038	824,901	375,222	1,200,123	146,365	103,416	1,557,942
1999	159,805	24,413	184,218	969,459	451,505	1,420,964	76,174	3,947	1,685,303
2000	48,321	6,239	54,560	448,665	273,206	721,871	206,365	61,389	1,044,185
2001[f]	104,060	17,029	121,089	442,546	408,961	851,507	160,272	2,846	1,135,714
2002	111,290	40,423	151,713	1,097,769	367,886	1,465,655	137,077	123,698	1,878,143
2003	287,729	30,359	318,088	1,183,009	923,540	2,106,549	280,552	11,370	2,716,559
2004	138,317	62,444	200,761	1,344,213	633,368	1,977,581	207,844	399,339	2,785,525
2005[g]	165,349	22,527	187,876	2,384,645	1,893,688	4,278,333	194,372	61,091	4,721,672
2006	192,296	36,467	228,763	3,780,760	964,238	4,744,998	163,889	183,006	5,320,656
2007	119,622	50,624	170,246	1,875,491	740,195	2,615,686	192,406	126,282	3,104,620
2008	138,220	36,826	175,046	1,849,553	636,525	2,486,078	145,378	580,127	3,386,629
2009[f]	128,154	49,642	177,796	1,477,186	274,227	1,751,413	240,779	34,529	2,204,517
2010	112,605	25,294	137,899	1,423,372	458,103	1,881,475	177,724	919,036	3,116,134
2011	117,213	31,584	148,797	2,051,501	873,877	2,925,378	149,533	9,754	3,233,462
2012	106,529	21,026	127,555	2,136,476	778,158	2,914,634	130,734	420,344	3,593,267
2013	120,536	16,269	136,805	2,849,683	865,295	3,714,978	110,515	6,126	3,968,424
2014	120,060	43,835	163,895	2,020,309	706,630	2,726,939	283,421	679,126	3,853,381
2015	105,063	41,796	146,859	1,591,505	669,483	2,260,988	121,193	39,690	2,568,730
2016	135,013	41,885	176,898	1,921,748	994,760	2,916,508	168,297	1,364,849	4,626,552
2017	217,821	45,193	263,014	3,093,735	1,829,931	4,923,666	166,320	166,529	5,519,529
2018	122,394	39,437	161,831	1,612,688	928,664	2,541,352	136,347	689,607	3,529,137
2019	172,242	47,382	219,624	1,402,925	842,041	2,244,966	86,401	42,353	2,593,344
2020	124,905	37,347	162,252	692,602	262,439	955,041	107,680	207,942	1,432,915
2021	104,267	20,578	124,845	153,718	146,197	299,915	22,181	37,255	484,196

[a] Estimates for all years were generated with the most current apportionment model and may differ from earlier estimates.

[b] Chinook salmon >655 mm mid eye to tail fork (METF).

[c] Chinook salmon ≤655 mm METF.

[d] This estimate may not include the entire run. However, in 2008–2014, 2018, 2020, and 2021, operations were extended to September 7 instead of the usual end date of August 31.

[e] The Pilot Station sonar project did not operate at full capacity in 1996, and there are no passage estimates for this year (ND means no data).

[f] High water levels were experienced at Pilot Station; therefore, passage estimates are considered conservative.

[g] Estimates include extrapolations for the dates June 10 to June 18 to account for the time before the DIDSON was deployed.

Appendix G2.–Other passage estimates, by species, at the Pilot Station sonar project on the Yukon River, 1995–2021.

		Whitefish				
Year[a]	Cisco	Humpback	Broad	Sheefish	Other[b]	Total
1995	312,907	27,788	297,888	37,322	32,842	708,747
1996[c]	ND	ND	ND	ND	ND	ND
1997	214,397	106,845	16,270	20,464	18,865	376,841
1998	118,820	57,477	6,489	13,513	14,378	210,677
1999	170,377	124,257	13,214	11,383	18,470	337,701
2000	167,897	66,479	7,362	9,725	11,164	262,627
2001[d]	150,350	76,722	6,848	18,894	12,935	265,749
2002	208,230	130,800	16,826	20,359	29,319	405,534
2003	123,129	169,423	31,368	20,902	34,829	379,651
2004	195,371	128,092	18,062	17,990	32,424	391,939
2005[e]	194,677	84,102	8,137	17,109	60,225	364,250
2006	258,877	188,407	18,768	37,875	27,120	531,047
2007	321,498	266,215	26,568	63,639	83,737	761,657
2008	150,308	101,799	10,104	32,399	11,615	306,225
2009[d]	257,549	231,742	24,532	33,424	42,669	589,916
2010	281,456	175,749	19,835	49,250	41,164	567,454
2011	242,950	152,164	14,671	25,139	18,613	453,537
2012	204,330	191,732	16,814	33,246	17,936	464,058
2013	383,326	250,518	16,554	49,568	32,043	732,009
2014	290,524	191,658	19,903	25,098	57,648	584,831
2015	438,860	261,688	23,122	50,261	80,058	853,989
2016	187,421	76,955	10,674	27,759	52,556	355,365
2017	414,668	231,428	37,799	32,865	79,439	796,199
2018	334,832	124,576	14,695	26,485	47,371	547,959
2019	270,434	196,905	25,694	22,673	52,870	568,576
2020	163,546	146,162	21,352	24,849	32,378	388,287
2021	195,566	264,160	23,859	34,820	38,059	556,464

[a] Estimates for all years were generated with the most current apportionment model and may differ from earlier estimates.

[b] Includes sockeye salmon, burbot, longnose sucker, Dolly Varden, and northern pike.

[c] The Pilot Station sonar project did not operate at full capacity in 1996, and there are no passage estimates for this year (ND means no data).

[d] High water levels were experienced at Pilot Station; therefore, passage estimates are considered conservative.

[e] Estimates include extrapolations for the dates June 10 to June 18 to account for the time before the DIDSON was deployed.