Late-Run Kasilof River Chinook Salmon Sonar Assessment, 2018

by

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Symbols and Abbreviations

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Weights and measures (metric)					
centimeter	cm				
deciliter	dL				
gram	g				
hectare	ha				
kilogram	kg				
kilometer	km				
liter	L				
meter	m				
milliliter	mL				
millimeter	mm				

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@

compass directions:

east	E
north	N
south	S
west	W

copyright	©

corporate suffixes:

Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations

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

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ABSTRACT

Although a sport fishery for late-run Kasilof River Chinook salmon (*Oncorhynchus tshawytscha*) is prosecuted downstream of river kilometer (RKM) 13 and a commercial fishery occurs in nearby marine waters, the inriver abundance of late-run Kasilof River Chinook salmon has been unknown for most years. The goal of this study was to estimate the daily net upstream passage of salmon 75 cm or longer from mid eye to tail fork (METF) past RKM 13 of the Kasilof River from 15 June through 31 August 2018 using adaptive resolution imaging sonar (ARIS). Net upstream passage of Chinook salmon greater than or equal to 75 cm METF as measured by ARIS was estimated to be 3,458 (SE 166). Chinook salmon passage estimates were lower than those from a prior mark–recapture study, but run timing was similar.

Key words: Chinook salmon, *Oncorhynchus tshawytscha*, abundance, adaptive resolution imaging sonar, ARIS, Kasilof River

INTRODUCTION

The Kasilof River is a turbid, glacially influenced stream on the western Kenai Peninsula that originates at the outlet of Tustumena Lake and flows 31 river kilometers (RKM) to the eastern shore of Cook Inlet (Figure 1). Two tributaries feed into the Kasilof River: Coal Creek at RKM 6.6 and Crooked Creek at RKM 11.1. The lower 8 RKM of the Kasilof River is tidally influenced.

The Kasilof River supports populations of Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka*), pink salmon (*O. gorbuscha*), Dolly Varden (*Salvelinus malma*), and steelhead (*O. mykiss*) (Johnson and Blossom 2017). Chinook salmon return to the Kasilof River in 2 runs: an early run that enters the river in primarily May–June and a late run that enters primarily in July–August. The early run is composed of both naturally produced and hatchery-reared Chinook salmon destined for Crooked Creek. The naturally produced Crooked Creek stock is descended from both wild fish and naturalized hatchery fish. The hatchery-reared fish are the progeny of both wild and naturally produced Crooked Creek fish that were artificially spawned and reared in a hatchery before being released back into Crooked Creek as smolt. The late run is composed of a wild stock that spawns in the mainstem of the Kasilof River.

The early run of Kasilof River Chinook salmon supports an inriver sport fishery that occurs in May and June. The entire river is open to sport fishing for Chinook salmon during the early run, but most effort occurs below the Sterling Highway bridge crossing located at about RKM 13 and primarily below the Crooked Creek confluence. The average annual sport harvest of early-run Chinook salmon (both naturally produced and hatchery-reared) between 2005 and 2016 was 1,464 fish (Begich et al. 2017). A personal use gillnet fishery occurs at the mouth of the Kasilof River in mid-June and harvests an average of 133 Chinook salmon annually (2005–2016 for both naturally produced and hatchery-reared; calculated from Lipka et al. 2020). Early-run Chinook salmon harvest in the commercial Eastside set gillnet (ESSN) fishery is unknown but considered negligible because the run timing of most of the early run precedes this fishery. Escapement of naturally produced and hatchery-reared Chinook salmon to the Crooked Creek weir (located 5.1 RKM upstream from the confluence with Kasilof River) from 2005 to 2016 averaged 1,737 fish (Begich et al. 2017).

A sport fishery also occurs for the late run of Kasilof River Chinook salmon, although effort and harvest are reduced relative to the early-run fishery. The late-run sport fishery (July 1–July 31) is prosecuted downstream of the Sterling Highway bridge. By regulation, sport fishing for Chinook

salmon is prohibited upstream of the bridge during the late run. The average annual sport harvest of late-run Chinook salmon between 2013 and 2016 was 779 fish (calculated from Begich et al. 2017: page 107)[1]. In addition, average annual harvest of late-run Kasilof River Chinook salmon in the ESSN fishery from 2013 to 2016 was 1,190 fish or about 25% of the total ESSN Chinook salmon harvest each year (calculated from Eskelin and Barclay 2018). Inriver abundance of late-run Chinook salmon is unknown for most years. Reimer and Fleischman (2012) conducted a mark–recapture study from 2005 to 2008 to estimate late-run Chinook salmon abundances. The mark–recapture study produced inriver abundance estimates of 12,097 fish for 2005, 8,611 fish for 2006, 8,522 fish for 2007, and 8,276 fish for 2008.

The only salmon escapement monitoring project on the Kasilof River mainstem is a well-established sonar site located near RKM 13 operated by the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries to estimate adult sockeye salmon escapement. Since 2010, this project has operated 2 standard dual-frequency identification sonar (DIDSON) units (1 deployed near each river bank) to estimate salmon passage in conjunction with a fish wheel used to apportion estimates to species and collect age, sex, and length (ASL) data (Glick and Willette 2016b). Larger Chinook salmon are capable of swimming offshore of the fish wheel, so the fish wheel has been used predominantly to apportion pink and coho salmon, whose migrations begin as the sockeye salmon migration declines.

To produce estimates of Chinook salmon escapement using sonar, accurate estimates of fish size at all ranges must be obtained. The standard DIDSON units used on the Kasilof River through 2017 did not provide the necessary resolution to accurately differentiate large Chinook salmon from other smaller species of salmon beyond approximately 10 m in range from the sonar (river width at the site is approximately 60 m). For this reason, the Kasilof River sockeye salmon sonar project was not capable of providing late-run Chinook salmon escapement estimates. In addition, the sockeye salmon sonar project only operated through the first or second week of August, whereas the 2005–2008 mark–recapture study showed that significant numbers of Chinook salmon continue to pass the site through the end of August.

The next generation of DIDSON technology, adaptive resolution imaging sonar (ARIS), provides higher resolution images that allow accurate fish length measurements out to 30+ m, thus providing the ability to estimate fish size at farther ranges. This technology has been used by ADF&G on the Kenai River to estimate large (≥75 cm mid eye to tail fork [METF]) Chinook salmon passage since 2013 (Miller et al. 2016a, 2016b; Key et al. 2017). In 2018, for consistent methodology, the 2 DIDSON units used on the Kasilof River were replaced with 2 ARIS units like those used on the Kenai River to estimate the abundance of Chinook salmon 75 cm METF or longer.

There are advantages to using the same length threshold for both the Kasilof and Kenai rivers. First, threshold estimates can be combined with estimates from other projects, such as those from the ESSN Chinook salmon harvest genetic stock information project (Eskelin and Barclay 2017), to estimate the annual total run size of large Kasilof River late-run Chinook salmon. Second, the same ADF&G personnel are responsible for processing both Kenai and Kasilof river sonar data. These personnel are trained to visually identify ARIS fish images near and above the 75 cm threshold for measurement (Key et al. 2017), so using the same threshold for both rivers allows

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[1] The 2016 harvest estimate was obtained from Jenny Gates, Sport Fish Biologist, ADF&G, Soldotna; personal communication.

streamlined data processing without developing additional methods for the data collected by the ARIS located at the Kasilof River.

A 75 cm METF threshold effectively separates Chinook salmon from other species on the Kasilof River. Length information from Kasilof River Chinook, coho, and sockeye salmon migrating during August[2] was compiled from a variety of sources (Figure 2) to examine the utility of a 75 cm threshold for Kasilof River salmon. Almost all sampled sockeye and coho salmon were less than the 75 cm threshold, although a small percentage of coho salmon (about 1.5%) could exceed the threshold after accounting for the error associated with measuring fish length using imaging sonar. The most recent Kasilof River coho salmon abundance estimate in August 2008 was approximately 6,700 fish (derived from Bromaghin et al. 2010). If 1.5% of those fish were measured as 75 cm or longer, approximately 100 coho salmon would have been included in a sonar count of large Chinook salmon.

Historically, most of the inriver run of Kasilof River Chinook salmon near the sonar site is larger than a 75 cm METF threshold and therefore would be counted by sonar, although missed Chinook salmon would be predominantly ocean-age-2 males. This is based on the 2005–2008 mark–recapture study of Kasilof River Chinook salmon (Reimer and Fleischman 2012) where approximately 91% of ocean-age-2, 6% of ocean-age-3, and 0% of ocean-age-4 or -5 fish were less than 75 cm METF. Additionally, 84% of captured ocean-age-2 fish were male.

OBJECTIVE

The objective of this project is to estimate the daily net upstream passage of salmon 75 cm METF or longer past RKM 13 of the Kasilof River from 15 June through 31 August such that the seasonal estimate is within 10% of the true value 95% of the time.

METHODS

The ADF&G Divisions of Commercial Fisheries (CF) and Sport Fish (SF) worked cooperatively at the same site and used the same equipment to enumerate fish in the Kasilof River. CF was responsible for enumerating sockeye salmon as described in Glick and Willette (2016a), whereas SF was responsible for enumeration of large Chinook salmon as described below.

SITE DESCRIPTION

The CF sonar site is located near RM 8 just upstream of the Sterling Highway Bridge (Figure 1). River width at this location increases throughout the summer as discharge increases, reaching a maximum width of approximately 60 m in August. The substrate slopes gradually from each bank (with a slightly steeper incline in the first 3 m of the north bank) and is composed mostly of large rocks 20–60 mm in diameter with larger rocks and boulders exceeding 1 m^3 along the north bank (Glick and Willette 2016b).

ACOUSTIC SAMPLING

Acoustic sampling occurred from 15 June to 31 August. Although very few late-run Chinook salmon pass the RM 8 sonar site in June, monitoring late-run Chinook salmon began the same date (15 June) that monitoring began for sockeye salmon. Late-run Chinook salmon passage

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[2] Available coho and Chinook salmon length data came from projects that sample multiple spawning stocks. Samples collected in August are probably most representative of those that will pass the sonar site during the sonar project dates.

estimates could be inflated if early-run Chinook salmon destined for Crooked Creek in late June strayed upriver past the RM 8 site prior to returning downriver to enter Crooked Creek. Early-run fish that may have temporarily strayed upriver past the sonar site were accounted for in the late-run Chinook salmon estimate by subtracting downstream passing fish from the upstream count (see below).

Acoustic sampling operations were consistent with those described in Glick and Willette (2016a), except that the 2 standard DIDSON systems used in past years were replaced with 2 ARIS 1800 systems (Sound Metrics Corporation), and the field season was extended. One ARIS unit was deployed from each bank. The ARIS 1800 systems were each configured with a standard lens and operated at a frequency of 1.8 MHz (nearshore) and 1.1 MHz (offshore) and set to ninety-six $0.3° \times 14°$ beams to provide the resolution necessary for obtaining accurate length measurements at all ranges. Profiles of the river bottom were created following the methods of Maxwell and Smith (2007) at the start of the season and again when the river had risen to determine the best beam fit and aim for the transducer using images collected with ARIS and then processed with DIDSON software. The ARIS images were collected using the same resolution and range used for DIDSON. The best beam fit included full coverage of the water column at close range where most sockeye salmon migrate. A narrow vertical beam width in this region would compromise detection of sockeye salmon. Early in the season, when water levels were low, 8° concentrator lenses were used to adjust the vertical beam width to better fit in the water column and thus decrease vertical interference from surface and bottom reverberation. Later, as water levels rose, the concentrator lenses were removed to allow for better coverage of the water column. The concentrator lenses did not affect horizontal beam width. Components of the ARIS 1800 system are listed in Table 1. Key et al. (2017) provides further detail on the ARIS system and a comparison with DIDSON.

Sampling was controlled by computers housed in a "sonar shack" located on the south bank. Communication cables from the south-bank ARIS unit fed directly into the south-bank ARIS Command Module and data collection computer (Figure 3). On the north bank, data from the ARIS system was transmitted via a wireless bridge to a data collection computer on the south bank (Figure 3). A battery bank, charged daily using a combination of solar panels and a generator, provided power to the north-bank sonar electronics and wireless bridge. AC power was used to power all south-bank equipment. The ARIS units were mounted on Sound Metrics Corporation (SMC) AR2 pan-and-tilt units for remote aiming in the horizontal and vertical axes. The sonar and rotator units were deployed in the river using an aluminium H-style mount (Figure 4). As described in Glick and Willette (2016a), deflection weirs were installed on each bank to force fish to pass offshore of the sonar and through the insonified zone. In the horizontal plane, the sonars were aimed perpendicular to the flow of the river current to maximize the probability of insonifying migrating salmon from a lateral aspect. In the vertical plane, the sonars were aimed to insonify the near-bottom region of the river. Internal sensors in the ARIS units provided measurements of compass heading, pitch, and roll as well as water temperature.

In designing ARIS, the manufacturer (SMC) separated the data collection (ARIScope) and data processing (ARISFish) software components. In addition to transmit frequency mentioned above, ARIScope has several data collection parameters that are user selectable including frame rate, window length, sample period, transmit pulse width, focus, transmit power level, and receiver gain. The maximum achievable frame rate was used for each stratum. Frame rate for each stratum was arrived at empirically by first fixing the parameters for start and end ranges and

sample period for each stratum and then finding the maximum achievable frame rate. Window length varied depending on the range (in meters) of the stratum being sampled; in this case, there were 2 strata (nearshore [approximately 1–10 m] and offshore [approximately 10–30 m]) per ARIS system (south bank or north bank). In combination with transmit pulse width, sample period (or, equivalently, the detail parameter) controls the downrange resolution for the image. Most data were collected at a sample period of 10 µs (microseconds; approximately 1,250 samples/beam for the 1–10 m strata and 2,600 samples/beam for the 10–30 m strata). The 10 µs resolution has been recommended by the manufacturer (Bill Hanot, personal communication, Sound Metrics Corporation, Seattle, WA) for the Kenai River, and tethered fish experiments conducted by Miller et al. (2016a) in the Kenai River found that the resolution settings tested for data collection (5 µs, 10 µs, and 27 µs) had minimal effect on the accuracy of ARIS length (AL) measurements and that a sample period of 10 µs provided an adequate balance between the accuracy of AL measurements and the amount of storage space required for processing and archiving data in the office. Higher resolution was used early in the season until it was confirmed based on image clarity that the 10 µs resolution was adequate for the Kasilof River.

Transmit pulse width varied by stratum. As the insonified range increases, longer transmit pulse widths are generally required for sufficient power to achieve the greater range. At ranges beyond 10 m, the transmit pulse width was set to "Auto" or was manually set to ensure the transmit pulse width was long enough to get 2 samples within the transmit pulse as recommended by the manufacturer (Bill Hanot, personal communication, Sound Metrics Corporation, Seattle, WA). At ranges less than 10 m, transmit pulse width was set long enough to get 1 sample within the transmit pulse (sample period plus 2 microseconds, also recommended by the manufacturer). Transmit level (transmit power) was set to maximum for each stratum but receiver gain varied by stratum up to the maximum setting of 24 dB. In low scatter environments at close range, high receiver gain settings can amplify problems caused by ringing. In the nearshore strata (both south bank and north bank), the setting was reduced from maximum based on image quality. In the offshore strata (both south bank and north bank), where the signal is more diminished and lower gains can cause detection issues, gain settings were set to 24 dB. Finally, the autofocus feature was enabled for all data collection so that the sonar automatically set the lens focus to the midrange of the selected range window.

A systematic sample design (Cochran 1977) was used to sequentially sample discrete range strata ("range windows") for a total of 10 minutes per hour for each stratum. The ARIS was programmed to automatically sample each range stratum using ARIScope. Dividing the total range to be insonified into shorter range strata allowed the aim of the sonar beam to be optimized for sampling the given river section (i.e., generally the aim must be raised in the vertical dimension as sections farther from shore are sampled), and the reduced window size made it easier to count fish throughout the range at high passage rates. Using multiple range strata also allowed for data at different ranges to be collected at different frequencies in order to optimize image resolution. The ARIS on each bank was programmed to sample 2 range strata (approximately 1–10 m and 10–30 m) and was operated 24 hours per day, 7 days per week. Table 2 summarizes range coverage by strata along with the changes in range parameters throughout the season as water level rose and aims were refined. The end range of the inshore stratum on each bank was extended from 9.5 m to 12.0 m on 11 July because high fish passage near the 9.0–10.0 m range resulted in substantial numbers of fish moving between strata, potentially introducing a positive bias in passage estimates. Table 3 provides an example (from 15 July) of the sampling schedule and ARIS parameter values used for data collection.

ARIS video files were stored onto 2 sets of 2 TB external hard drives (Figure 3). One set was kept at the sonar site where CF staff manually counted all fish images from a computer screen in either video playback mode or echogram mode to estimate the numbers of sockeye salmon passing the sonar using methods described in Glick and Willette (2016a). The other set of hard drives was transported daily by SF staff to the Soldotna ADF&G office where SF staff conducted manual measurements of fish images as described in the following section using copies of the same 10-minute data files that were used to produce sockeye salmon escapement estimates. A copy of an Excel spreadsheet containing preliminary hourly fish counts by stratum for the day (produced daily by CF field staff) was included on data drives transported to the office.

MANUAL ARIS FISH LENGTH MEASUREMENTS

Measurements of fish length were obtained using ARISFish V2.6 software supplied by SMC. Detailed instructions for taking manual measurements and the software settings and parameters that were used for this project are given in Appendix A1. Electronic echograms provided a system to manually count, track, and size individual fish (Figure 5).

To avoid the problem of counting fish in multiple spatial strata, which would have created a positive bias in the passage estimates (Appendix A2), measured fish were subjected to a "centerline rule" (Appendix A3). Only those fish that cross the longitudinal central axis of the ARIS video image were considered candidates for measuring. Fish that did not cross the centerline were ignored.

For this study, fish size was divided into 2 categories based on ARIS length (AL) measurements. Fish with AL measurements greater than or equal to 30 cm and less than 75 cm are referred to as small fish. The minimum length criterion of 30 cm was chosen to encompass almost all sockeye salmon passing the sonar site based on length measurements collected from the fish wheel (Figure 2). Fish with AL measurements greater than or equal to 75 cm are referred to as large fish. Based on tethered fish experiments conducted in the Kenai River and length relationships of free-swimming fish in the Kenai River, Miller et al. (2016a) concluded that a fish measuring 75 cm AL is also approximately 75 cm METF.

Estimates of large-fish abundance were produced by this project. Throughout the season, all large fish were counted and measured, and travel direction (upstream or downstream) was automatically recorded. In the offshore strata, where fish passage rates were relatively low, length and direction of travel were recorded for all salmon-shaped fish regardless of size. In the nearshore strata, where fish passage was relatively high due to large numbers of sockeye salmon, 2 sampling protocols were used depending on hourly nearshore stratum counts (10-minute samples) provided by CF:

1) If the hourly 10-minute count in the nearshore stratum was less than 100 fish, length and direction of travel were recorded for all salmon-shaped fish greater than or equal to 30 cm AL that met the centerline rule (Appendix A3) for that stratum.

2) If the hourly 10-minute count in the nearshore stratum exceeded 100 fish, the lengths of the first 5 fish in each sample period were measured and recorded regardless of size. The 5-fish protocol mimics that used on the Kenai River to allow consistency for technicians that were measuring samples from both rivers. For the remainder of the sample (after the

first 5 fish), only fish in video images that visually appeared[3] to be near 75 cm AL were measured, and only those fish that measured greater than or equal to 75 cm AL were recorded. Fish less than 75 cm AL were not recorded in any way, including fish chosen for measurement that turned out to be less than 75 cm. For the remainder of this report we will refer to this measurement protocol as the "large fish only" (LFO) protocol.

Abundance could be underestimated if large fish were inadvertently missed or not selected for measurement during LFO processing. To assess this potential bias, all files that were selected for LFO processing inseason were reprocessed postseason, measuring all fish in the file.

DATA ANALYSIS

Fish Passage

Each ARIS system was scheduled to operate 10 minutes per hour for each spatial stratum, 24 hours per day. There were 2 spatial strata (approximately 1–10 m and 10–30 m) sampled per ARIS system (south or north bank). The number of fish y that satisfied a set of criteria X (e.g., fish with ARIS length equal to or greater than 75 cm and that migrated in an upstream direction) during day i were estimated as follows:

$$\hat{y}_i = \sum_k \sum_s \hat{y}_{iks} \tag{1}$$

where $\hat{y}_{iks}$ was fish passage in stratum s of transducer k during day i, which was estimated as

$$= \frac{24}{h_{iks}} \sum_{j=1}^{h_{iks}} \hat{y}_{ijks} \tag{2}$$

where h_{iks} was the number of hours during which fish passage was estimated, and $\hat{y}_{ijks}$ was hourly fish passage during hour j, which was estimated as

$$\hat{y}_{ijks} = \frac{60}{m_{ijks}} c_{ijks} \tag{3}$$

where

m_{ijks} = number of minutes (usually 10) sampled, and

c_{ijks} = number of fish satisfying criteria X (e.g., upstream direction of travel; ARIS length greater than or equal to 75 cm).

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[3] Technicians rely on professional judgement to determine if fish are close to 75 cm AL. Accurate judgement is honed early in the season when low passage rates result in every fish being measured.

The variance of the daily estimates of y, due to systematic sampling in time, was approximated (successive difference model[4]; Wolter 1985) with adjustments for missing data as follows:

$$\hat{V}\left[\hat{y}_i\right] \cong 24^2(1-f)\frac{\sum\limits_{j=2}^{24}\phi_{ij}\phi_{i(j-1)}\left(\hat{y}_{ij}-\hat{y}_{i(j-1)}\right)^2}{2\sum\limits_{j=1}^{24}\phi_{ij}\sum\limits_{j=2}^{24}\phi_{ij}\phi_{i(j-1)}} \tag{4}$$

where f was the sampling fraction (temporal sampling fraction, usually 0.17), ϕ_{ij} was 1 if $\hat{y}_{ij}$ existed for hour j of day i, or 0 if not, and

$$\hat{y}_{ij} = \sum_k \sum_s \hat{y}_{ijks} \tag{5}$$

Downstream estimates of passage were obtained by changing criteria X for fish counts c_{ijks} in Equation 3 to downstream fish greater than or equal to 75 cm AL. Estimates of daily net upstream passage were obtained by calculating separate estimates of upstream and downstream passage (Equations 1–3) and subtracting the downstream estimate from the upstream estimate. The estimated variance of net upstream daily passage is the sum of the upstream and downstream variances.

LFO Protocol Analysis

The number of fish counted during large fish only (LFO) processing, x, was binomially distributed with parameters N, the number of fish counted when all fish were measured, and θ, the proportion of the fish counted during LFO processing:

$$x \sim \text{Binom}(\theta, N) \tag{6}$$

The proportion of the run missed due to LFO processing will depend on the number of LFO files, which in turn depends on the threshold chosen when implementing LFO processing. We queried 2010–2018 Kasilof River sonar data and tallied the number of files in each year that exceeded 20, 30, 40, and 50 targets. The number of files n_t with greater than t targets followed a negative binomial distribution with parameters μ_t, the mean number of files with more than t targets, and $\emptyset_t$, a measure of overdispersion for μ_t:

$$n_t \sim \text{NegBinom}(\mu_t, \emptyset_t) \tag{7}$$

The proportion of the passage included in the escapement estimate while implementing each LFO threshold v_t was then calculated as follows:

$$v_t = \frac{n_t^*(\theta-1)+3720}{3720} \tag{8}$$

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[4]   This is an assessment of the uncertainty due to subsampling (counting fish for 10 minutes per hour and expanding). The formulation in Equation 4 is conservative in the sense that it has been shown to overestimate the true uncertainty when applied to salmon passage data (Reynolds et al. 2007; Xie and Martens 2014).

Where n_t^* is a prediction from NegBinom($\mu_t, \emptyset_t$) and 3720 is the total number of files collected. These quantities were estimated using a statistical model written in the Stan programming language (Stan Development Team[5]). All parameters used noninformative prior distributions truncated to the appropriate support.

RESULTS

Data collection occurred from 15 June through 31 August. A total of 66,714 fish images 30 cm (ARIS length; AL) or larger were measured, of which 821 were 75 cm AL or larger.

SIZE DISTRIBUTION

Mean length of "small fish" (30 cm ≤ AL < 75 cm) was 51.4 cm. Mean length of "large fish" (≥75 cm AL) was 94.3 cm (Figure 6). Small fish dominated passage during the entire run.

SPATIAL AND TEMPORAL DISTRIBUTION

The majority of upstream migration past the sonar (summed over offshore and inshore) occurred on the north bank of the river (60% of small fish and 70% of large fish; Figure 7). Greater than 50% of the upstream passage of large fish occurred in the north bank inshore stratum alone. Downstream passing fish were more evenly distributed among strata (Figure 8). Daily percentages of large fish that were bound upstream and downstream are tabulated in Appendix B1.

Small fish migrated closer to the riverbank than large fish, although small fish were still detected midriver (Figures 9 and 10). Median passage of small fish was 3.5 m from the face of the transducer on both banks (Figure 9). Median passage of large fish was 6.9 m on the north bank and 8.7 m on the south bank (Figure 10). Large fish were distributed across the river, but most large-fish passage occurred within 23 m of the sonar on each bank.

Length distribution of large fish varied by time period (Figure 11). The 15 June–14 July time period displayed a higher percentage of fish in the 75–85 cm AL range relative to other time periods, and the 15 July–31 July time period displayed a higher percentage of fish 90–95 cm AL.

Chinook salmon passage occurred mostly during daylight hours. When upstream-bound large fish were classified as day (sunrise to sunset) versus night (sunset to sunrise) migrators, the proportion migrating at night was disproportionately small compared to the relative length of night throughout most of the run (Figure 12).

CHINOOK SALMON PASSAGE ESTIMATE

Assuming all "large fish" are Chinook salmon, an estimated 3,458 (SE 166) late-run Chinook salmon ≥75 cm AL passed the Kasilof River sonar site between 15 June and 31 August 2018. Median passage of Chinook salmon ≥75 cm AL occurred on 5 August (Table 4, Figure 13).

LFO PROTOCOL ANALYSIS

The large fish only (LFO) protocol was used sparingly in 2018; only 104 of 3,720 hourly samples exceeded the 100-fish threshold. A total of 21 fish greater than or equal to 75 cm were counted in those samples using the inseason LFO protocol, and 23 fish greater than or equal to

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[5]   Stan Development Team. 2018. Stan Modeling Language Users Guide and Reference Manual, Version 2.18.0.   http://mc-stan.org

75 cm were counted during the postseason all-fish measurement. An estimated proportion of 0.88 (95% CI 0.74–0.97) migrating Chinook salmon were counted during hourly samples when the LFO protocol was in use.

Sampling crews found the 100-fish LFO threshold too high during the 2018 (inaugural) field season and had difficulty providing daily estimates of Chinook salmon abundance due to the time required to measure the large number of small fish in files that fell below the 100-fish LFO threshold. Table 5 presents estimates of the number of files that would be subject to LFO processing and the proportion of the Chinook salmon escapement greater than or equal to 75 cm AL that would be counted using LFO thresholds of 20, 30, 40, and 50 fish during future seasons. An estimated 97% (95% CI 93–100%.) of the large Chinook salmon passage would be included in the escapement estimates with a 20-fish threshold; this estimate would increase to 99% (95% CI 97–100%) of passage with a 50-fish threshold (Table 5). These proportions are large because all fish are measured in most files so that errors that occur during LFO processing results in small numbers of missed fish even with low LFO thresholds.

DISCUSSION

The abundance of late-run Kasilof River Chinook salmon has been previously estimated using mark–recapture techniques during the 2005–2008 seasons (Reimer and Fleischman 2012). We used these estimates, reduced[6] to account for escapement of fish less than 75 cm METF, to compare run timing. Run timing in 2018 was similar to 2005–2008 run timing derived from Chinook salmon catch per unit effort (CPUE) data collected during the Reimer and Fleischman (2012) study. During those years, significant Chinook salmon catch rates started in mid-July and continued through most of August. Based on these catch rates and the timing of sonar operations in 2018 (mid-June through the end of August), it can be assumed that nearly the entire late run was enumerated in 2018.

The relationship between AL measurements and fork length measurements (FL; measured snout to fork of tail) has been studied extensively on the nearby Kenai River (Miller et al. 2016b) using tethered fish of known length. Across a wide variety of experimental conditions, linear relationships between AL and FL are characterized by a positive intercept and an FL coefficient of less than one[7]. These results suggest AL underestimates FL for salmon-sized fish, with the bias increasing with length. Salmon lengths are generally measured as mid eye to tail fork (METF) and linear regressions between METF length and FL are characterized by negligible intercepts and FL coefficients of greater than 1. Combining conversions from AL to FL and METF to FL result in a relationship where AL generally overestimates METF length for smaller fish and underestimates METF length for large fish. ARIS and METF lengths are approximately equal at 75 cm. A crude way to spot-check this relationship for the Kasilof River project is to compare the average METF of sockeye salmon caught in a fish wheel near the sonar site (47.8 cm; Figure 14) with the average AL of small fish measured by the Kasilof River sonar crew (51.4 cm). The difference between these measurements (AL approximately 3.6 cm greater than METF) is in the same direction but larger than expected based on the tethered fish regressions

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[6] We performed a crude adjustment for comparison only. The proportion of fish 75 cm METF or longer (among fish sampled after 10 July of each year) was multiplied by the posterior median of estimated abundance for the same year. Only fish sampled after 10 July are included because prior to 10 July significant numbers of Crooked Creek Chinook salmon were present (see Reimer and Fleischman 2012: Table 4).

[7] Kenai River tethered fish experiments also suggest AL increases (conditional on FL) with increasing range, although the result was insignificant for the typical target ranges on the Kasilof River.

(AL approximately 1 cm greater than METF) from Kenai River tethered fish (Miller et al. 2016a). This discrepancy is probably due to some combination of the following reasons: coho salmon were measured for AL, sampling bias by the fish wheel, or a difference in the AL to FL relationship specific to the Kasilof River drainage. In a fish wheel selectivity study conducted on the Yentna River from 2009 to 2012, Willette et al. (2016) found significant differences in fish wheel recapture probabilities across years, within years, and between length classes for each species studied (pink, sockeye, coho, and chum [*O. keta*] salmon). In an unpublished study conducted on the Yentna River in 2012, one of the authors (S. Maxwell, ADF&G, Division of Commercial Fisheries, Soldotna) found AL and FL to be nearly equivalent for a grouped sample of free-swimming sockeye, pink, coho, and chum salmon released into the sonar beam 4 m from the face of the transducer. Although these reasons are plausible, we cannot be sure of the exact reason for this discrepancy.

We replaced DIDSON with ARIS at the Kasilof River sonar site in 2018 in order to assess daily passage of late-run Chinook salmon greater than or equal to 75 cm AL while continuing to assess daily sockeye salmon passage. Efforts during the 2018 season demonstrate that estimates of sockeye salmon and large ($\geq$75 cm AL) Chinook salmon passage can be simultaneously generated at the RM 8 site using ARIS technology. The ARIS 1800 provided the ability to enumerate all fish passing the site as has been done in the past using DIDSON. In addition, the ARIS 1800 provided adequate image resolution at both near and far range to accurately estimate fish size and differentiate large Chinook salmon ($\geq$75 cm AL) from other smaller fish (30 cm $\leq$ AL < 75 cm).

The time required to measure large quantities of small fish hampered our ability to produce daily estimates of large Chinook salmon passage throughout the season. We found the 100-fish LFO threshold to be too high, making same-day production of daily large Chinook salmon passage estimates impossible during periods of very high small-fish passage. We recommend using a lower 50-fish LFO threshold during the 2019 season. Postseason analysis suggests that an LFO threshold of 50 fish would result in an average of 275 files that qualify for the LFO protocol and an estimated 0.99 proportion of the large Chinook salmon passage that is included in the escapement estimate (Table 5). If a 50-fish LFO threshold had been used in 2018, a total of 364 files would have qualified for the LFO protocol, or 260 less full-measure files than when using a 100-fish LFO threshold. An LFO threshold smaller than 50 fish is not recommended at this time because most of the file size data came from years (2010–2017) when the sonar project was focused on sockeye salmon passage and only operated through the first or second week of August. If we assume that most high passage rates (all fish combined) occur during the sockeye salmon season, then the number of large files (i.e., those above the LFO cutoff) that would have occurred after sockeye salmon counting ceased is minimal. At lower thresholds, this assumption is more likely to be violated.

ACKNOWLEDGEMENTS

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TABLES

Table 1.–ARIS system components used for data collection.

System component	Quantity	Description
Sonar	2	ARIS 1800 (north bank and south bank)
Lens assembly	2	standard lens for ARIS 1800 model with ~14° × 28° beam pattern
Concentrator lens	2	8° concentrator lens (1 for each sonar) used 15–29 June on north bank and 15 June–12 July on south bank
Remote pan and tilt	2	Sound Metrics AR2 rotators—controlled via ARIScope software
Data collection computer	2	Dell Precision 7520 laptop computers (1 for each sonar)

Table 2.–Summary of sonar stratum range changes by date at the Kasilof River sonar site, 2018.

Sonar location	Range stratum	Time (min) [a]	Coverage range (m) by date		
			15 June	28 June [b]	11 July [c]
North bank	1	:10	0.7–9.5	0.7–9.5	0.7–12.0
	2	:00	9.5–25.0	9.5–29.0	12.0–29.7
South bank	1	:10	0.7–9.5	0.7–9.5	0.7–12.0
	2	:00	9.5–25.0	9.5–29.0	12.0–29.7

[a] Sample start time in number of minutes past the top of the hour.

[b] Sonar on both banks moved closer to shore due to rising water level. Stratum 2 range extended to 29 m on both banks.

[c] Stratum 1 range extended to 12.0 m on both banks, Stratum 2 start range changed to 12.0 m, and end range extended to 29.7 m on both banks.

Table 3.–Sampling schedule and ARIScope parameter values on 15 July 2018 for each range stratum, Kasilof River sonar.

Sonar location	ARIS serial no.	Range stratum	Time (min)[a]	Frame rate (fps)[b]	Start range (m)	End range (m)	Frequency (MHz)	Transmit level	Gain (dB)	Pulse width (μs)	Start delay (μs)	Sample period (μs)	Samples per beam	Pitch (°)	Heading (°)
North bank	1692	1	:10	9	0.7	12.0	High (1.8)	Max	24	12	962	10	1,554	−4.4	149
		2	:00	4	12.0	29.7	Low (1.1)	Max	24	20	16,499	10	2,434	−4.4	149
South bank	1712	1	:10	9	0.7	12.0	High (1.8)	Max	24	12	960	10	1,550	−5.6	312
		2	:00	4	12.0	29.7	Low (1.1)	Max	24	20	16,483	10	2,431	−5.6	312

[a] Sample start time in number of minutes past the top of the hour.

[b] Frame rate in frames per second.

Table 4.–Net upstream daily passage of late-run Chinook salmon ≥75 cm AL using ARIS, Kasilof River, 2018.

Date	Fish ≥75 cm AL Passage	SE	Date	Fish ≥75 cm AL Passage	SE
15 Jun	0	0	24 Jul	102	25
16 Jun	0	0	25 Jul	46	20
17 Jun	0	0	26 Jul	96	23
18 Jun	0	0	27 Jul	42	16
19 Jun	−6	6	28 Jul	18	8
20 Jun	0	0	29 Jul	30	16
21 Jun	6	6	30 Jul	139	30
22 Jun	12	8	31 Jul	157	29
23 Jun	0	0	1 Aug	115	21
24 Jun	6	4	2 Aug	54	19
25 Jun	6	6	3 Aug	139	22
26 Jun	0	0	4 Aug	193	31
27 Jun	0	0	5 Aug	151	22
28 Jun	12	8	6 Aug	0	9
29 Jun	6	6	7 Aug	30	15
30 Jun	6	6	8 Aug	151	37
1 Jul	0	0	9 Aug	169	27
2 Jul	31	15	10 Aug	151	39
3 Jul	18	9	11 Aug	133	31
4 Jul	−18	10	12 Aug	133	33
5 Jul	6	6	13 Aug	73	24
6 Jul	12	7	14 Aug	24	19
7 Jul	12	14	15 Aug	30	17
8 Jul	6	9	16 Aug	42	31
9 Jul	12	8	17 Aug	42	28
10 Jul	18	10	18 Aug	72	18
11 Jul	18	10	19 Aug	60	17
12 Jul	12	7	20 Aug	114	28
13 Jul	37	15	21 Aug	90	27
14 Jul	12	8	22 Aug	60	19
15 Jul	42	18	23 Aug	60	18
16 Jul	30	14	24 Aug	57	24
17 Jul	24	10	25 Aug	−7	17
18 Jul	18	15	26 Aug	42	21
19 Jul	12	12	27 Aug	66	29
20 Jul	30	12	28 Aug	54	29
21 Jul	30	15	29 Aug	−12	21
22 Jul	48	28	30 Aug	24	23
23 Jul	72	29	31 Aug	−12	27
			Total	3,458	166

Table 5.–Predicted numbers (and 95% CI) of files (n_t^*) and proportions (and 95% CI) of Chinook salmon (≥75 cm AL) passage included in the escapement estimate (v_t) using LFO thresholds of 20, 30, 40, and 50 fish at the Kasilof River Chinook salmon sonar using 2010–2018 Kasilof River sonar data.

| LFO [a] | n_t^* | | v_t | |
threshold	Number	Confidence interval	Proportion	Confidence interval
20	809	323–1,521	0.97	0.93–1.00
30	531	185–1,040	0.98	0.95–1.00
40	373	120–763	0.99	0.97–1.00
50	275	80–592	0.99	0.97–1.00

[a] LFO means large fish only (≥75 cm AL).

FIGURES
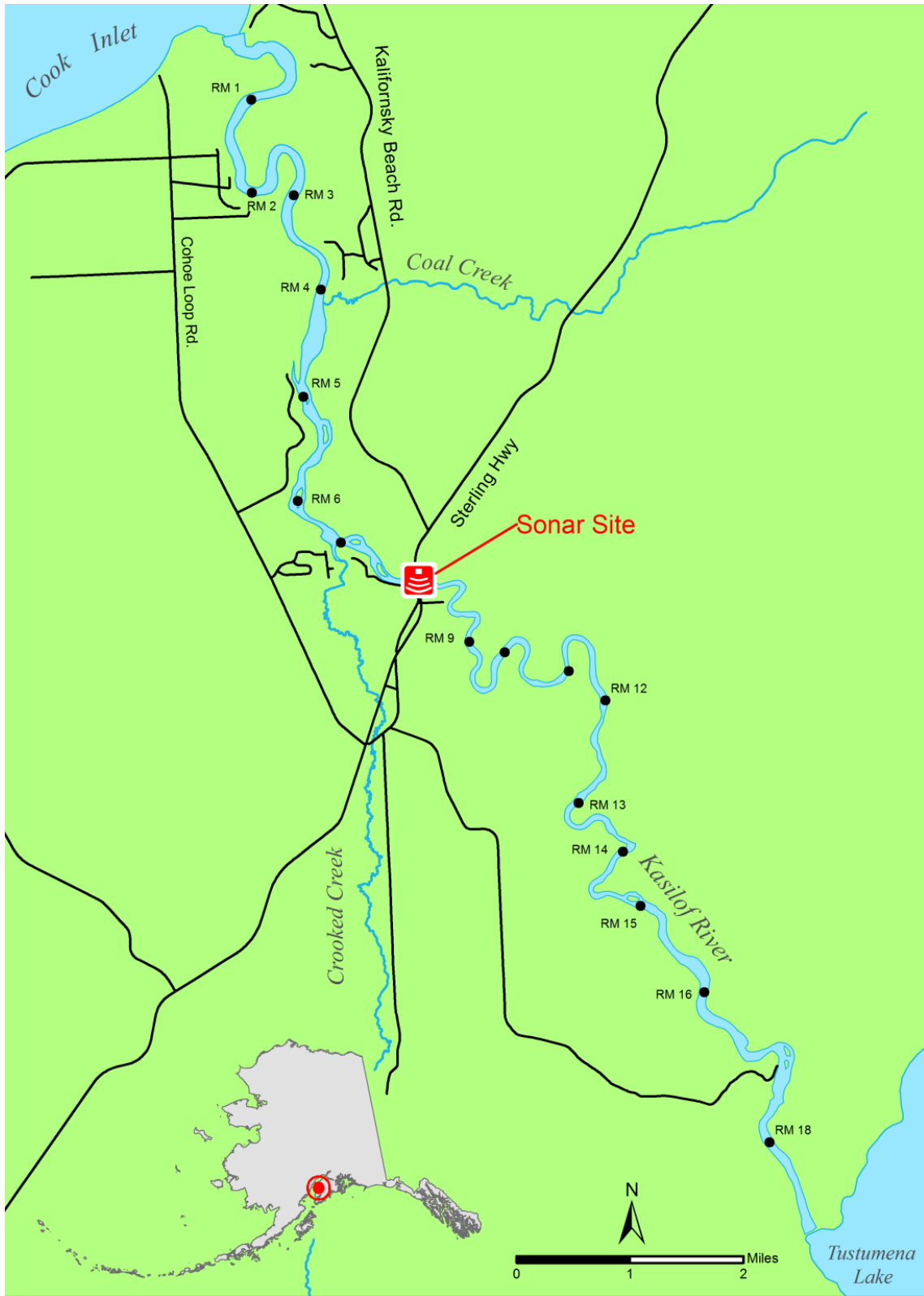
Figure 1.–Map of the Kasilof River showing sonar site location, Kenai Peninsula, Southcentral Alaska.
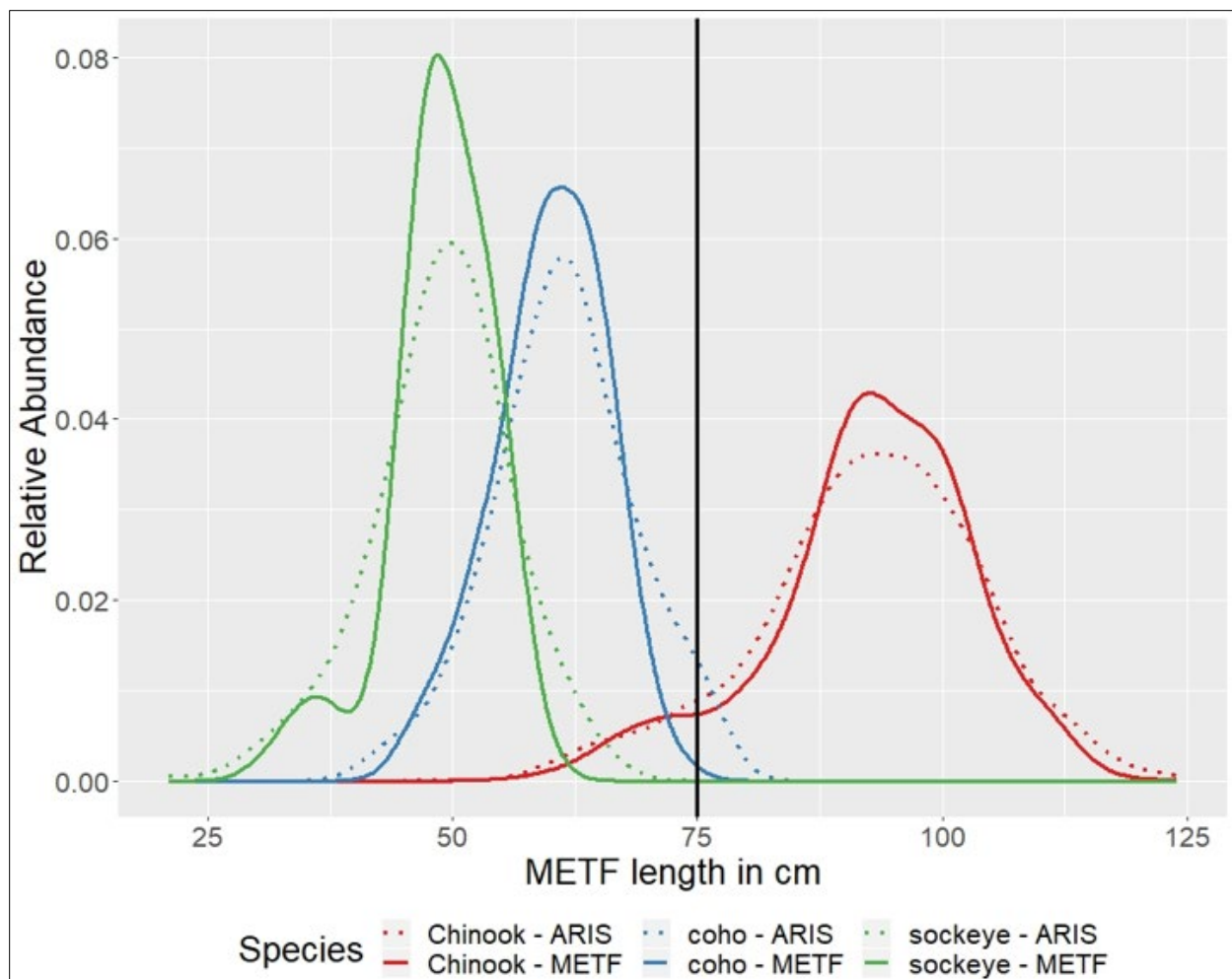
Figure 2.–Length distributions of coho, sockeye, and Chinook salmon in the Kasilof River.

Source: Reimer and Fleischman (2012) used 5.0-inch and 7.5-inch mesh gillnets in 2005–2008 to capture Chinook salmon during August in an area downstream of the sonar site. Gates et al. (2009, 2010) used 4.5-inch mesh gillnets in 2007 and 2008 to capture and tag adult coho salmon in the latter half of August in an area upstream of the sonar site. Sockeye salmon length data are from the Kasilof River fish wheel in August 2017 (Wendy Gist, personal communication, ADF&G Fisheries Biologist, Soldotna, Alaska).

Note: Dashed lines illustrate the derived length distribution of each species after accounting for ARIS length measurement error (Normal[0, 4.9 cm] estimated from tethered fish studies conducted on the Kenai River (see Miller et al. 2016). "ARIS" means ARIS length; "METF" means length from mid eye to tail fork.
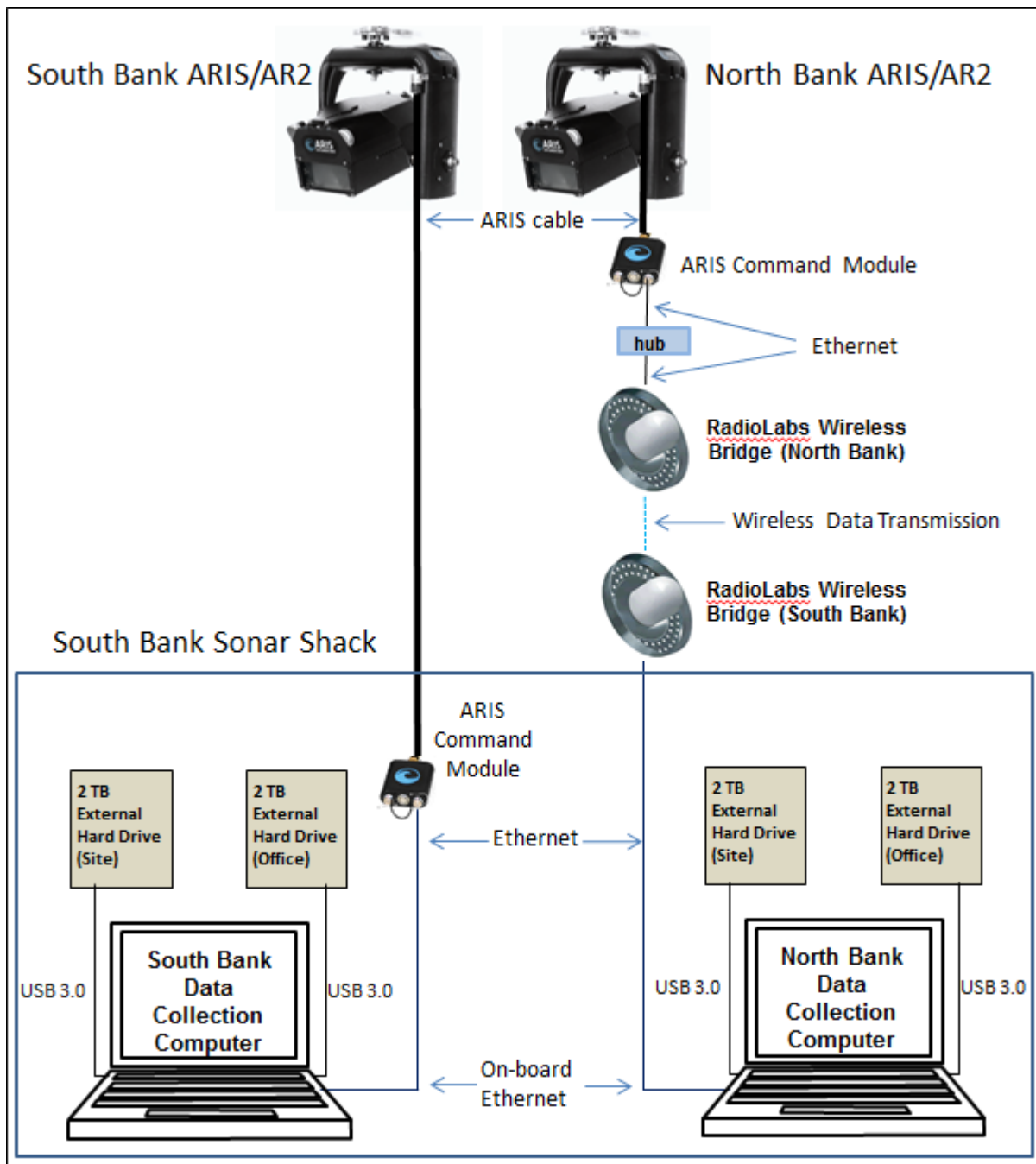
23

Figure 3.–ARIS data collection schematic for the Kasilof River.

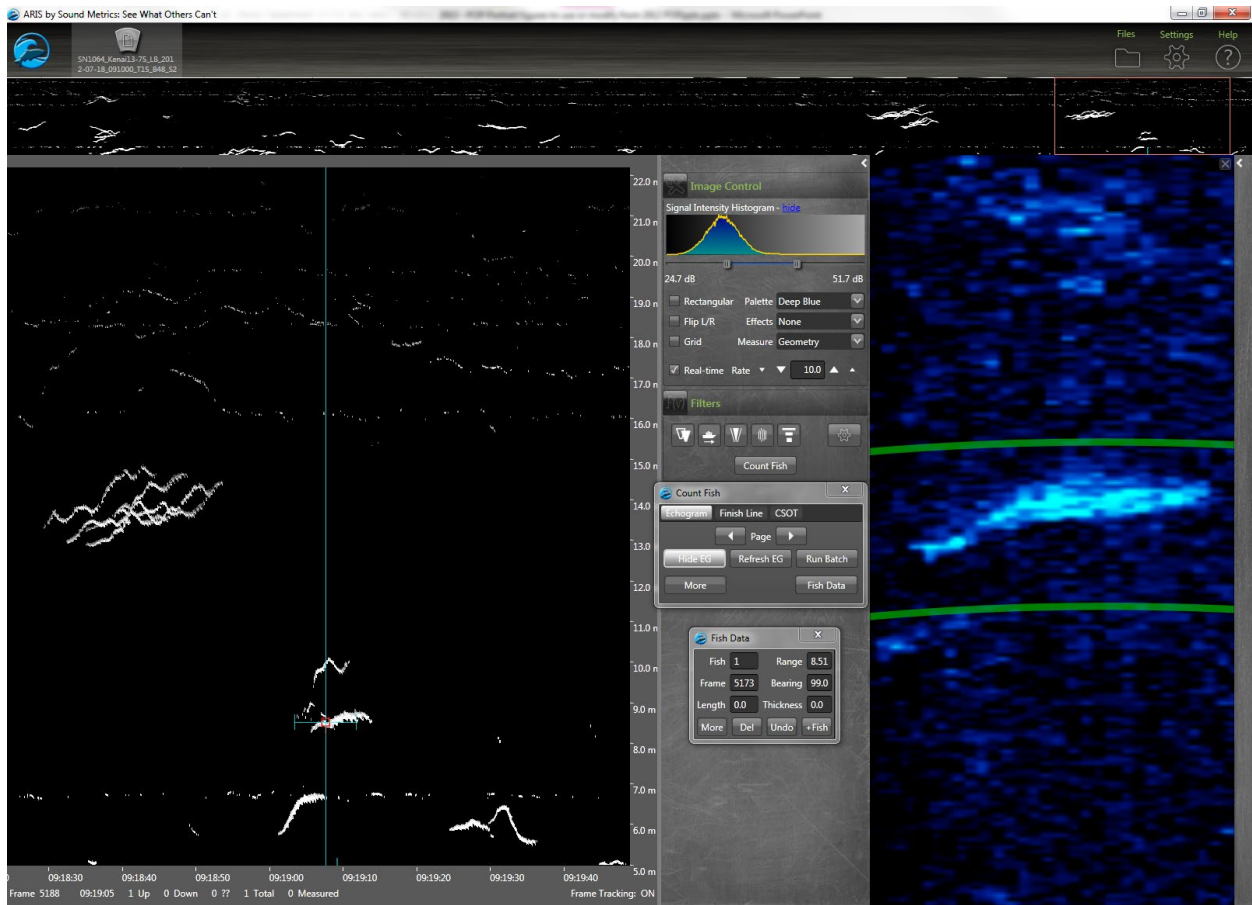Figure 4.–ARIS mounted on an aluminum H-mount for nearshore deployment.

Figure 5.–ARISFish display window showing an echogram (left) with traces of migrating fish that can be simultaneously displayed in video mode (right) where fish images can be enlarged and measured.

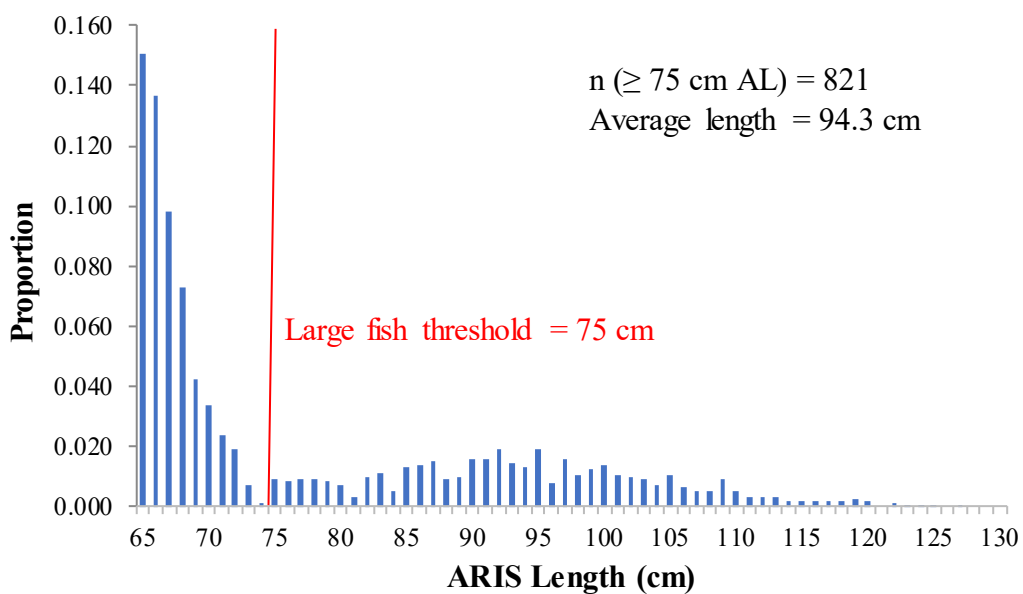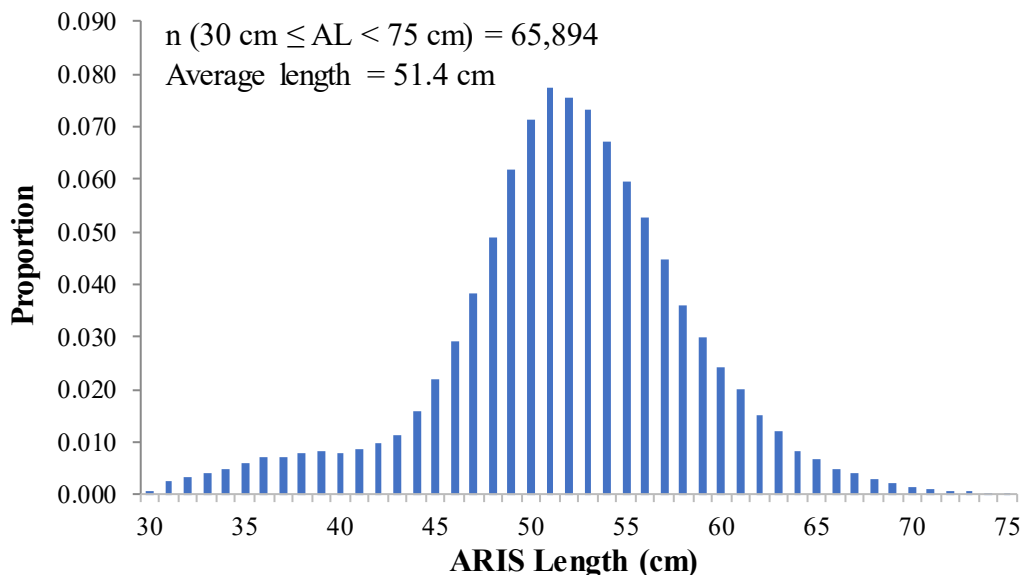# Sonar Length Frequency Distribution of Kasilof River Fish

n (30 cm ≤ AL < 75 cm) = 65,894
Average length = 51.4 cm

n (≥ 75 cm AL) = 821
Average length = 94.3 cm

Large fish threshold = 75 cm

Figure 6.–Length frequency distribution of small fish (30 cm ≤ AL < 75 cm; top) and large fish (≥75 cm AL; bottom), Kasilof River sonar project, 2018.

Note: Although the large fish threshold is 75 cm AL, the bottom graph plots the length frequency distribution of all fish greater than or equal to 65 cm AL in order to display the distribution on both sides of the 75 cm AL threshold.

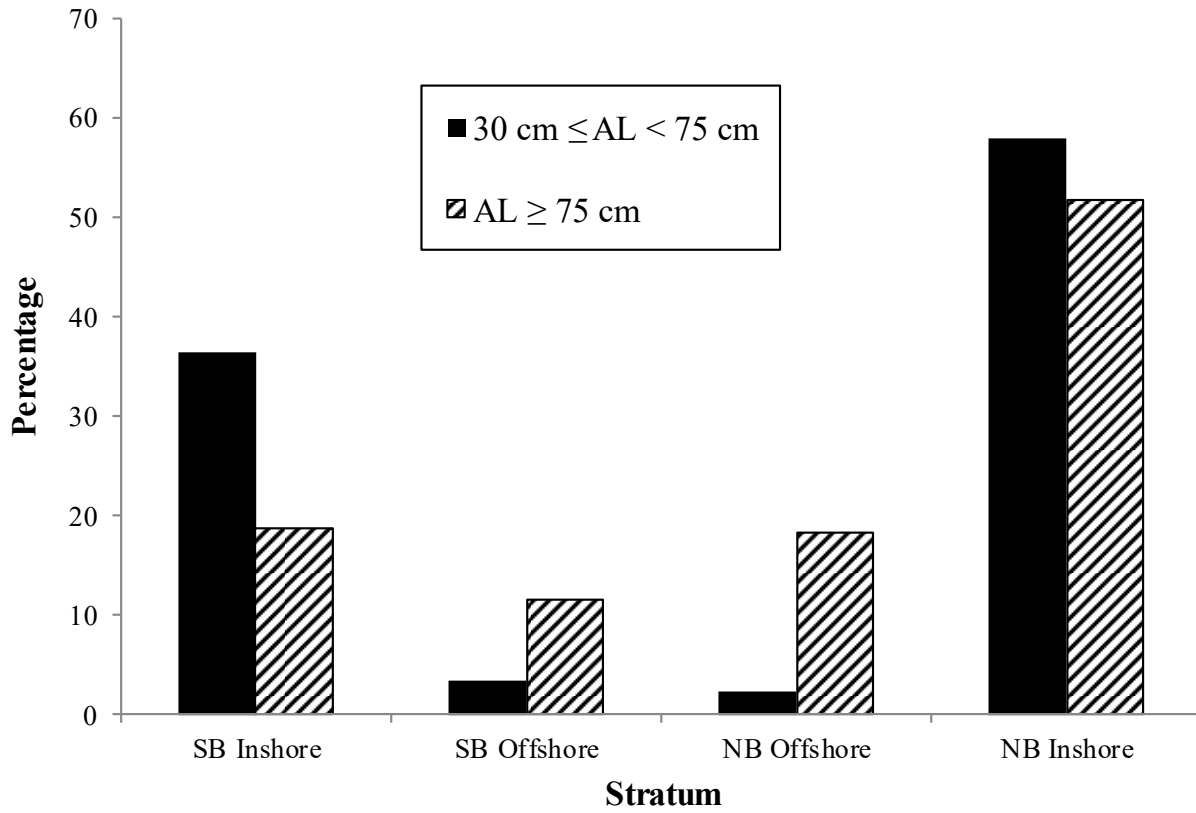# Percent Upstream Passage by Stratum

Figure 7.–Percent upstream passage of small fish (30 cm ≤ AL < 75 cm; solid) and large fish (≥75 cm AL; hatched) by spatial stratum, Kasilof River sonar, 2018.

Note: SB means south bank and NB means north bank.

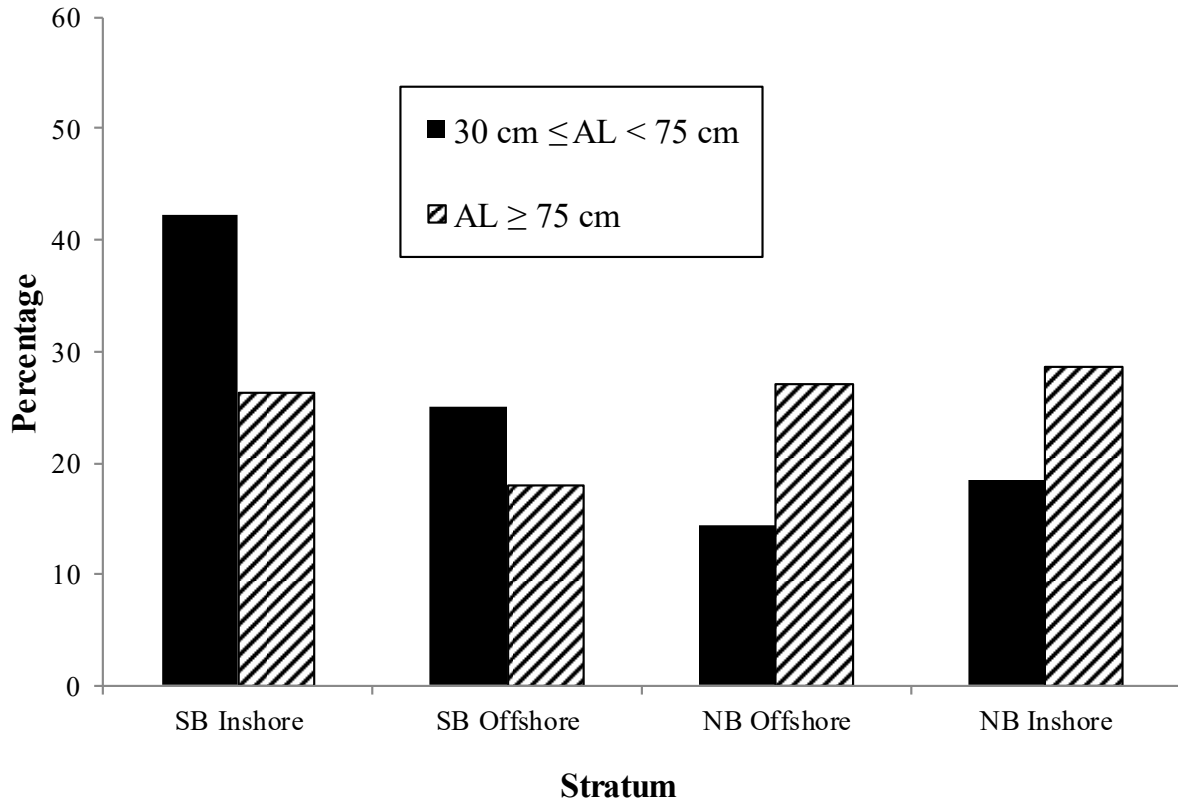**Percent Downstream Passage by Stratum**

Figure 8.–Percent downstream passage of small fish (30 cm ≤ AL < 75 cm; solid) and large fish (≥75 cm AL; hatched) by spatial stratum, Kasilof River sonar, 2018.

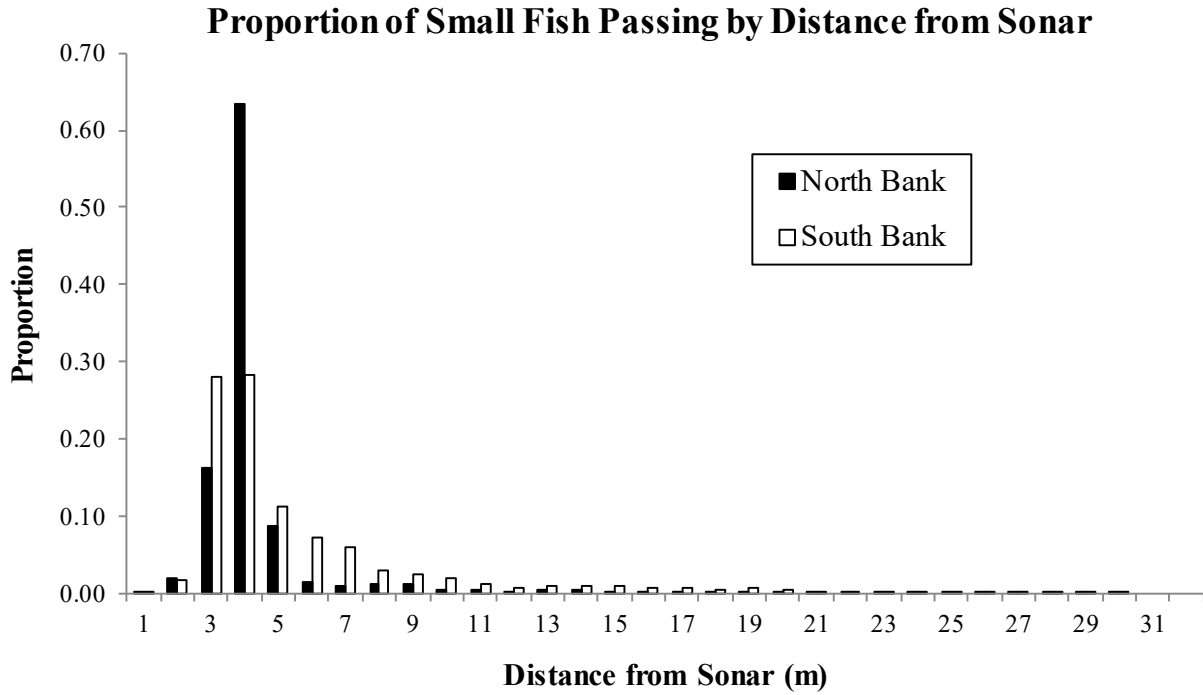*Note*: SB means south bank and NB means north bank.

Figure 9.–Proportion of passage of small fish (30 cm ≤ AL < 75 cm) relative to distance from sonar for each bank (north and south), Kasilof River sonar, 2018.
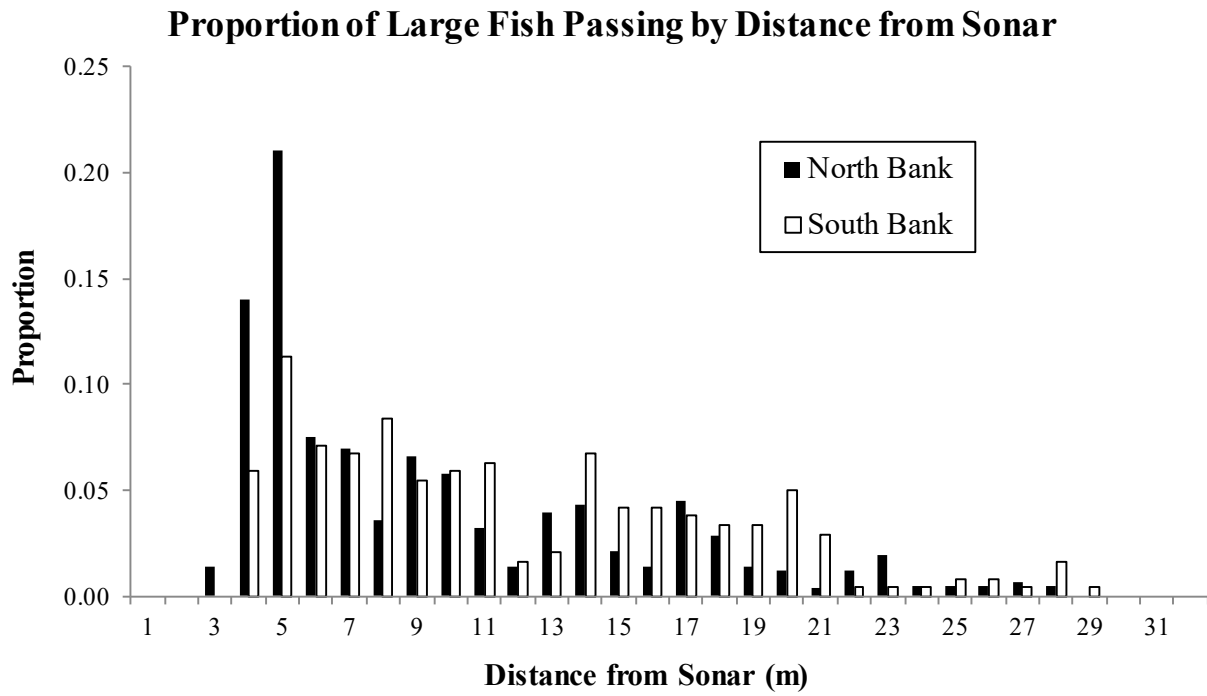
Proportion of Large Fish Passing by Distance from Sonar

Figure 10.–Proportion of passage of large fish (≥75 cm) relative to distance from sonar for each bank (north and south), Kasilof River sonar, 2018
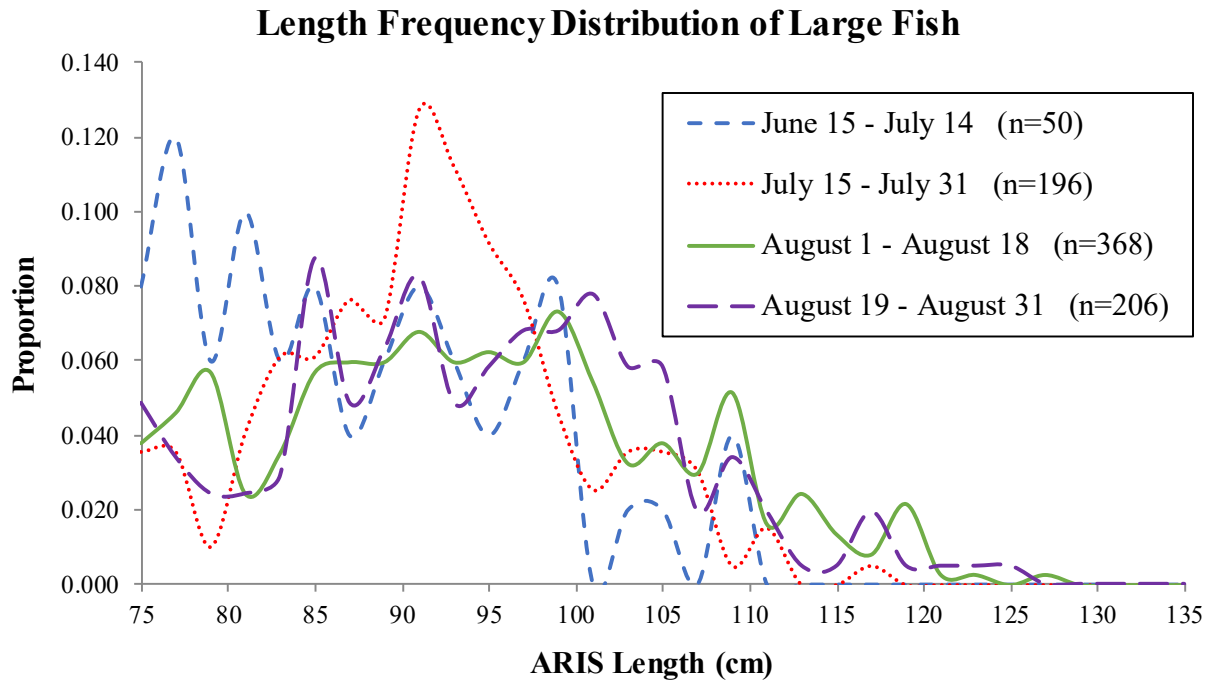
Length Frequency Distribution of Large Fish

Figure 11.–Length frequency distribution of large fish (≥75 cm AL) by time period, Kasilof River sonar, 2018.
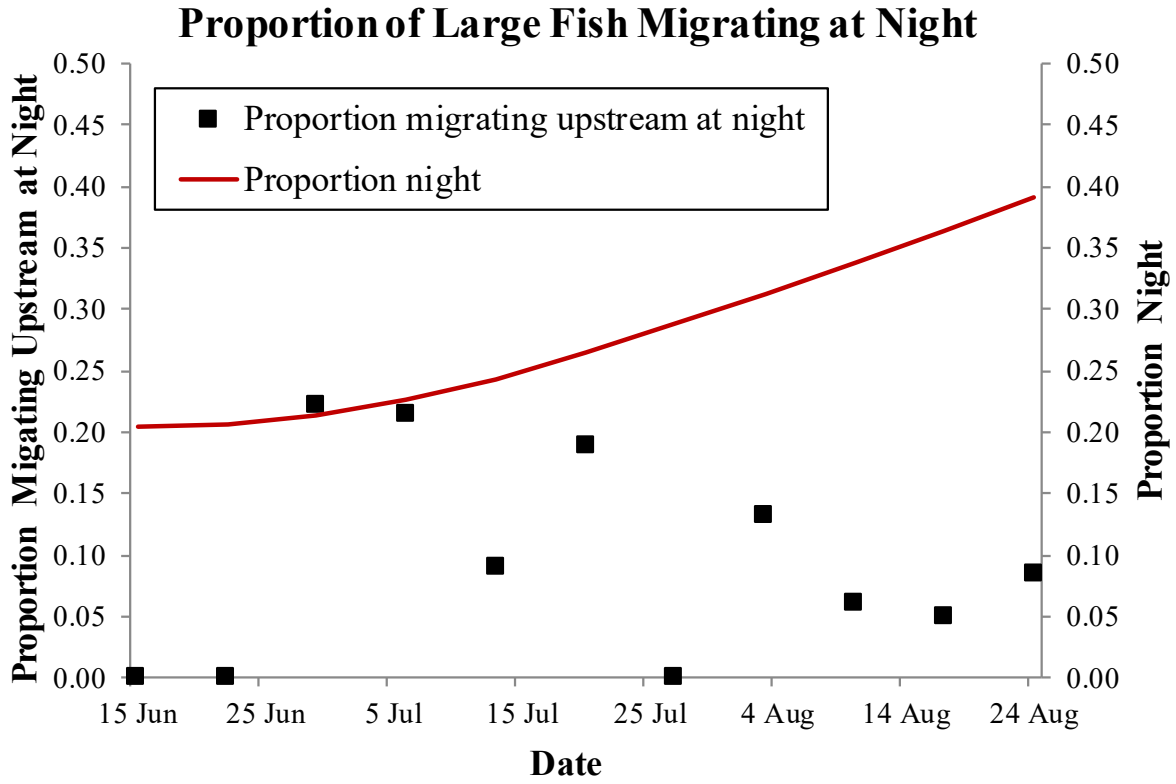
Figure 12.–Weekly proportions of Kasilof River fish greater than or equal to 75 cm AL migrating upstream at night (between sunset and sunrise; black squares), compared to proportion night (proportion of 24-hour period that is between sunset and sunrise; red line) in Kenai, Alaska, 2018.

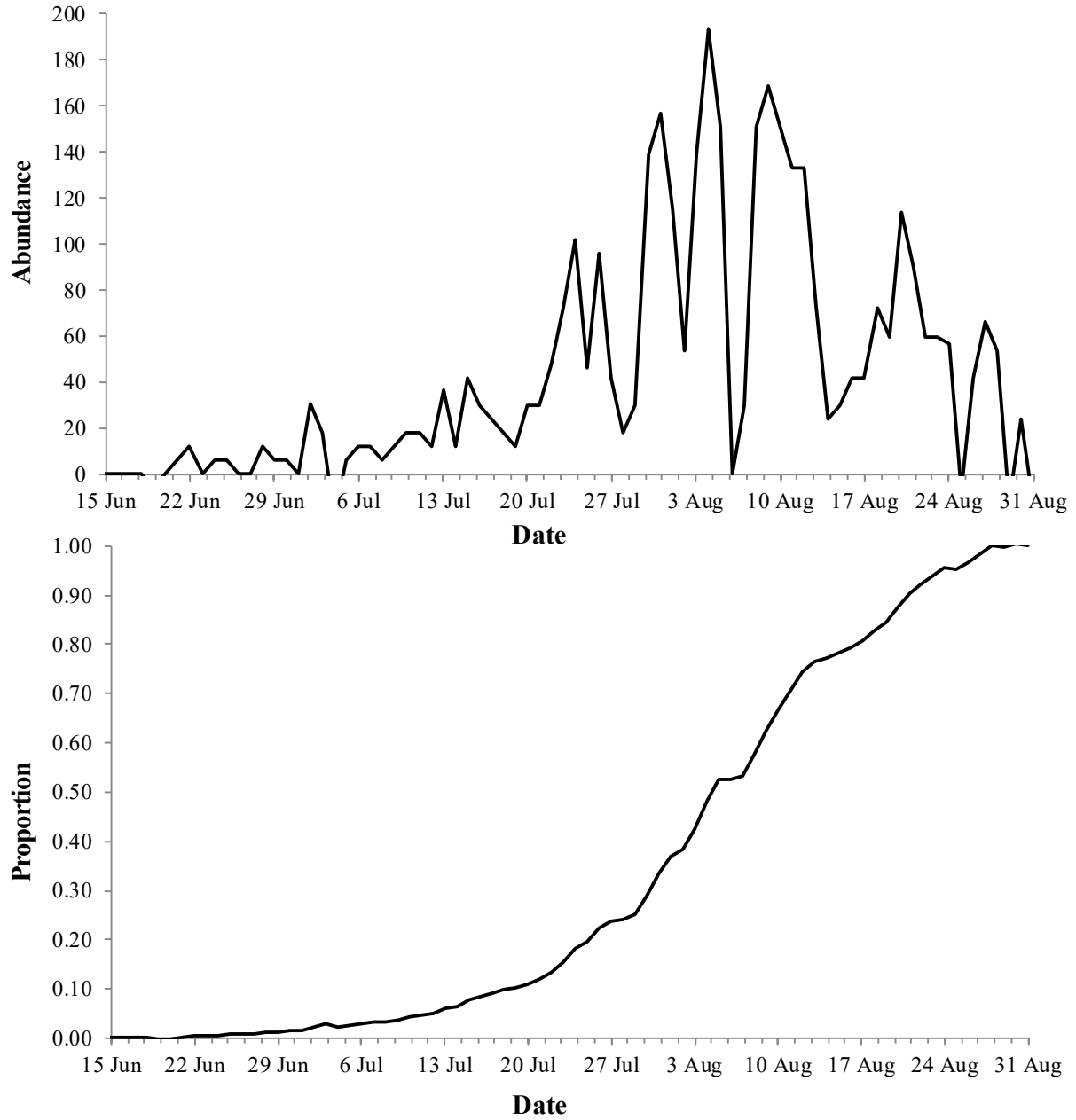# Kasilof River Chinook Salmon Run Timing

Figure 13.–Daily abundance (top) and cumulative daily proportion of end-of-season abundance (bottom) for Kasilof River late-run Chinook salmon greater than or equal to 75 cm AL, 2018.

Fish Length Distribution
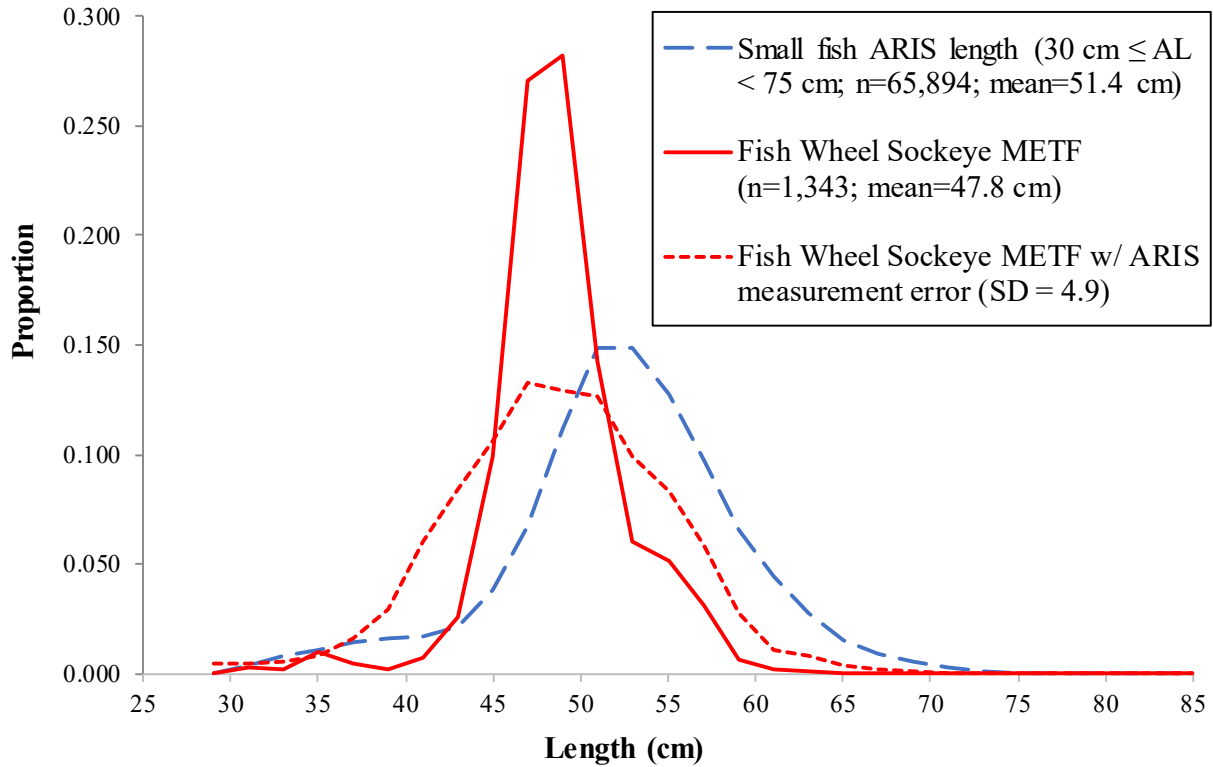
Figure 14.–Length frequency distribution of small fish (30 cm ≤ AL < 75 cm) measured using ARIS and all sockeye salmon captured in the fish wheels (METF; Julia Polasik, personal communication, ADF&G Fisheries Biologist, Soldotna, Alaska) at the Kasilof River sonar site, 2018.

Note: Dashed line illustrates the derived length distribution after accounting for ARIS length measurement error (Normal[0, 4.9 cm] estimated from tethered fish studies conducted on the Kenai River (see Miller et al. 2016). "METF" means length from mid eye to tail fork.

APPENDIX A: INSTRUCTIONS AND SETTINGS USED FOR MANUAL FISH LENGTH MEASUREMENTS FROM ARIS IMAGES USING ARISFISH SOFTWARE VERSION 2.6
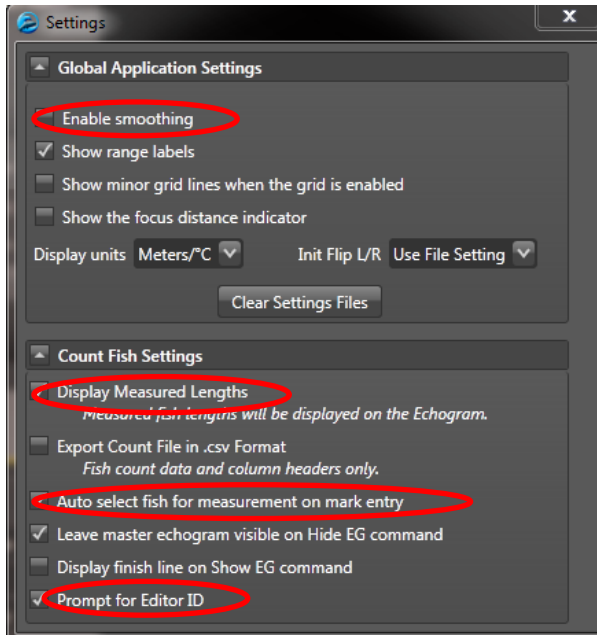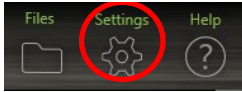
Appendix A1.–Instructions and settings for manual length measurements from ARIS images using ARISFish version 2.6.

1) Set Global Settings after a NEW installation of ARISFish

A. Open ARISFish global settings and ensure you have the following settings to measure fish:

B. Enable smoothing is *off*.
C. Display Measured Lengths is *on*.
D. Auto select fish for measurement on mark entry is *on*.
E. Prompt for Editor ID is *on*.

2) Set processing parameters for a new set of files for a new day or stratum:

A. Select **<Files> <Open Recently Viewed>**

B. Navigate to the appropriate directory and open a file (or simply double click on the file of interest)

-continued-

At this point, the ARISFish display should look similar to the image below:
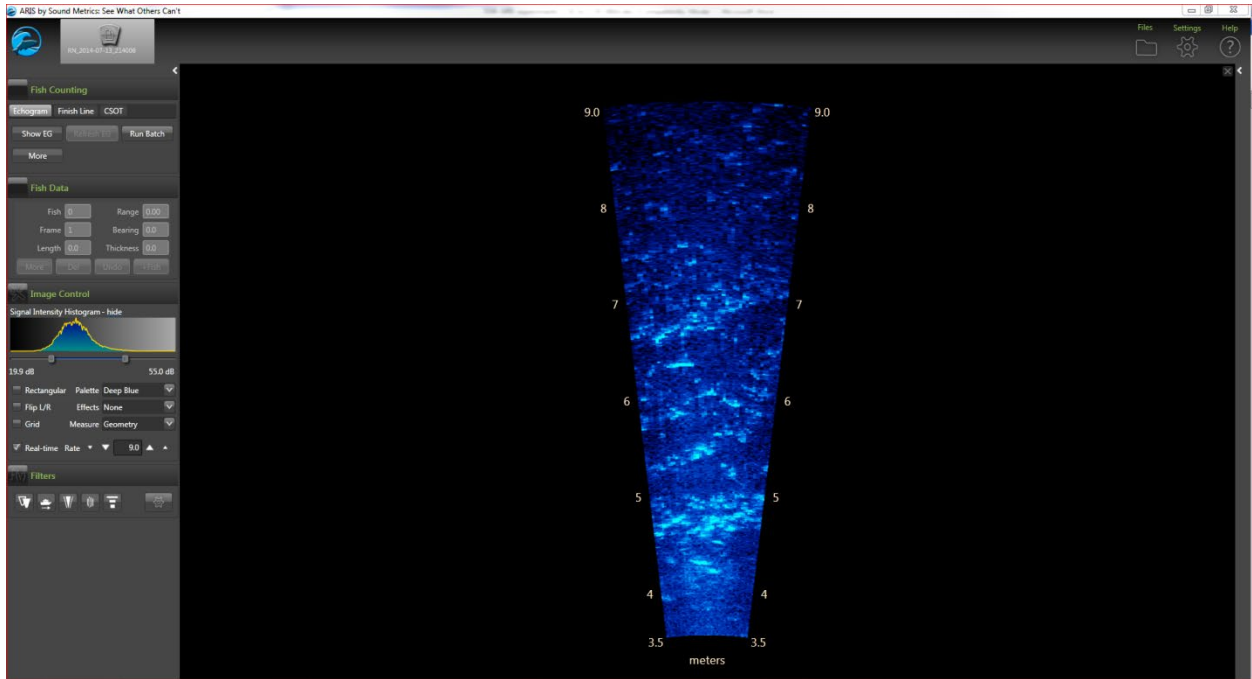
C. Select the **<Background Subtraction>** icon and wait about 30 seconds background to subtract.
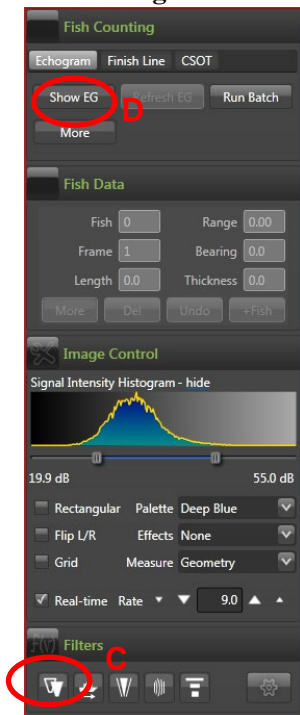
D. Then select **<Show EG>** to display the Echogram.

E. You will be prompted to enter your Editor ID. Press OK.

-continued-

Your display should now look like the one below
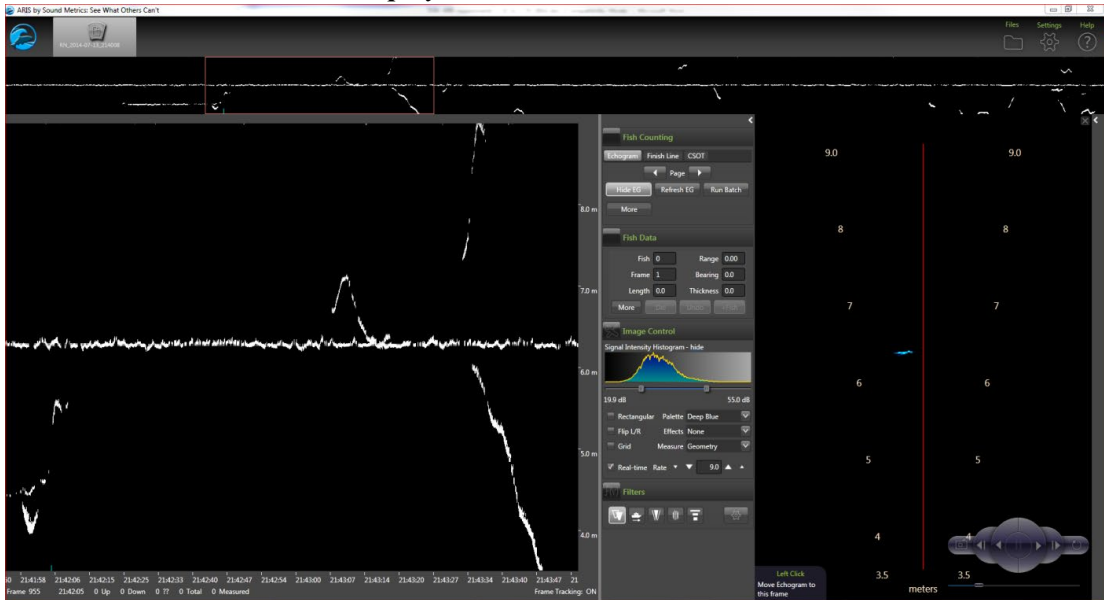
F. Select **<More>** from the Fish Counting window to get the extended window where you can
   o enter your **Editor ID** initials
   o set the **Upstream Fish** direction
   o ensure that **Loop** length is set to at least 8 seconds

   o then select **Less** to unexpand Fish Counting window (you'll be able to access other controls like BS easier if you do this).

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G. Select **<Background Subtraction>** icon on Filters Menu (Toggle)—this will now turn background subtraction off on the video image. **Failing to turn background subtraction off prior to measuring fish image length may result in an underestimate of actual fish length**[8]**.**

H. Set Signal Intensity sliders to optimize video image for measuring fish.

I. Your overall display should look similar to the following:
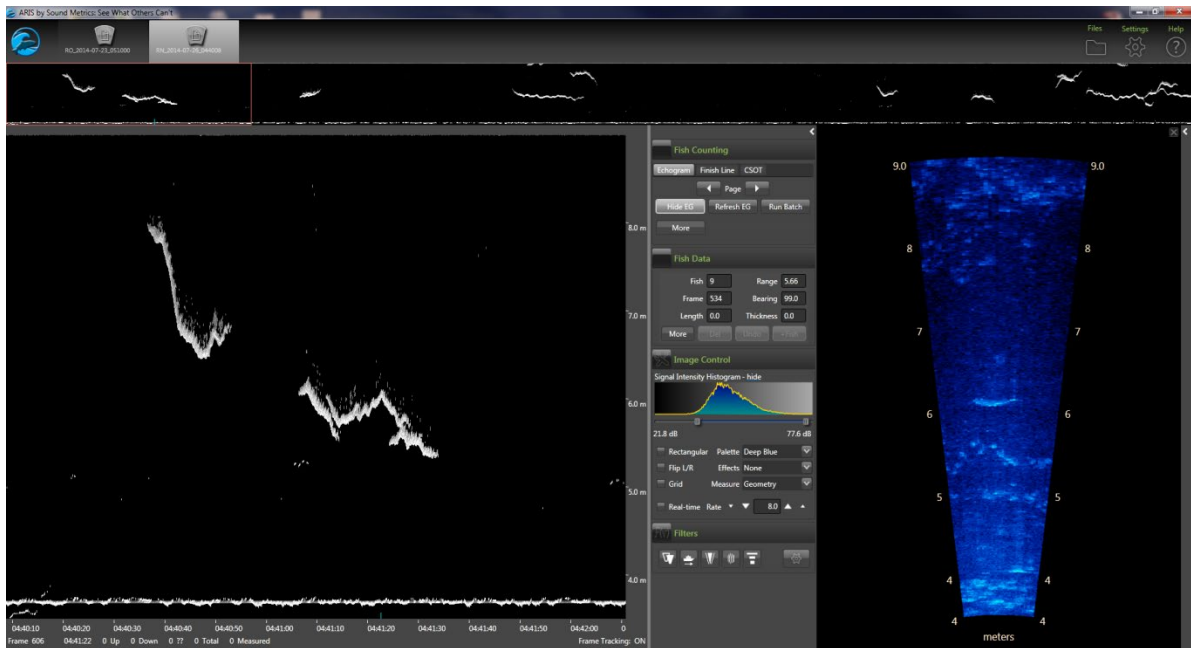
J. Now you are ready to start measuring (or marking) individual fish.
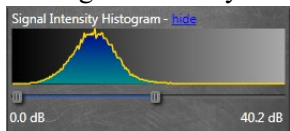K. Once finished measure/marking all fish in the file, turn **<Background Subtraction>** on prior to advancing to the next file.

-continued-

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[8] Now that we use ARIS instead of DIDSON, we mostly no longer use the background selection option while measuring fish image length. The ARIS background selection algorithm is more aggressive than the DIDSON selection and unless one is very careful in selecting a frame, it is easy to underestimate fish length. Toggling between background selection mode and the raw image can sometimes be helpful in determining the end of the tail or snout. If we do use background selection, we generally take background selection off before finalizing the measurement. A well selected frame will give the same length measurement with or without background selection.

L. Select **<Alt><right arrow>** to advance to the next file.
M.   Once the new file opens, turn **<Background Subtraction>** off before beginning to measure fish
    (all other parameter settings and display configuration settings should be preserved from the
    previous file).
N. When you switch banks, you will need to reset the direction of travel parameter in step 5.
O. Now you are ready to start measuring/marking fish in the new file.

**3)   Instructions for manual fish length measurements using SMC ARISFish software
version 2.6**
A.   Ensure **<Background Subtraction>** is toggled *off* as described in step 6 above.
B. **<Left Click>** on the Echogram fish to be measured (Puts red marker on fish and automatically
    activates the movie showing the fish bounded by range arcs.
C. Press **<space bar>** to start or stop the video playback.

D. Use **<right arrow>** and **<left arrow>** to step through movie one frame at a time to find a frame
    that displays the entire fish length well.
    i.   Measurements should be taken from frames where contrast between the fish image and
            background are high and where the fish displays its full length.
    ii.   In general, the best images are obtained when the fish is sinusoidal in shape (rather than
            straight and/or perfectly perpendicular to the sonar beam.
    iii.   Watching the behavior of the head and especially the tail over several frames, and taking
            several measurement, is often helpful in distinguishing the best frame.
E. **<Right Click Drag>** on movie image to zoom in for measurement.
F. **<Left Click Drag>** if necessary to center movie window prior to measuring.

-continued-

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G. Measure fish image:

    i. <u>Fish traveling snout-first upstream or downstream</u> - **<left click>** on the fish <u>snout</u> and continue to **<left click>** along the midline of the fish to create a "segmented

measurement." The segments should follow the midline of the body of the fish, ending with the <u>tail</u>.

    ii. <u>Fish backing downstream through the beam tail-first</u> - **<left click>** on the fish <u>tail</u> and continue to **<left click>** along the midline of the fish to create a "segmented measurement." The segments should follow the midline of the body of the fish, ending with the <u>snout</u>.

    iii. Toggling between BS mode and the raw image can sometimes be helpful in determining the actual end of the tail or snout.

H. Select **<f>** key to add measurement to the .txt file (fish it!)—you will see measurement in red (**<Left Click>** on echogram inside mark, if you want to delete measurement and start over).

I. Select **<v>** key to unzoom movie window (not necessary if you have another fish nearby you want to measure).

J. Next fish…repeat steps 1–8, or

K. Occasionally press <E> to save your work on each sequence when complete (or before you divert to another task).

L. **<Left Click>** on Master Echogram to advance to new echogram section, or

M. **<Alt><Right Arrow>** to advance to next file.

4) To mark (count) fish in SMC ARISFish software version 2.6

    A.   <Left Click> on the fish trace in the echogram if upstream.

    B.   <Ctrl> <Left Click> on the fish trace in the echogram if downstream.

5) Hot keys used in measuring and counting fish in SMC ARISFish software:

    <e> to "save" all echogram measurements to file

    <f> to "fish it" (to accept the measurement and display it on the echogram)

    <u> to "undo" the last segment

    <d> to "delete" all segments

    <space bar> to pause in movie mode

    <right arrow> forward direction when you play movie or advances frame one at a time if the movie is paused

    <left arrow> opposite of above

    <Left Click Drag> to show movie over the selected time

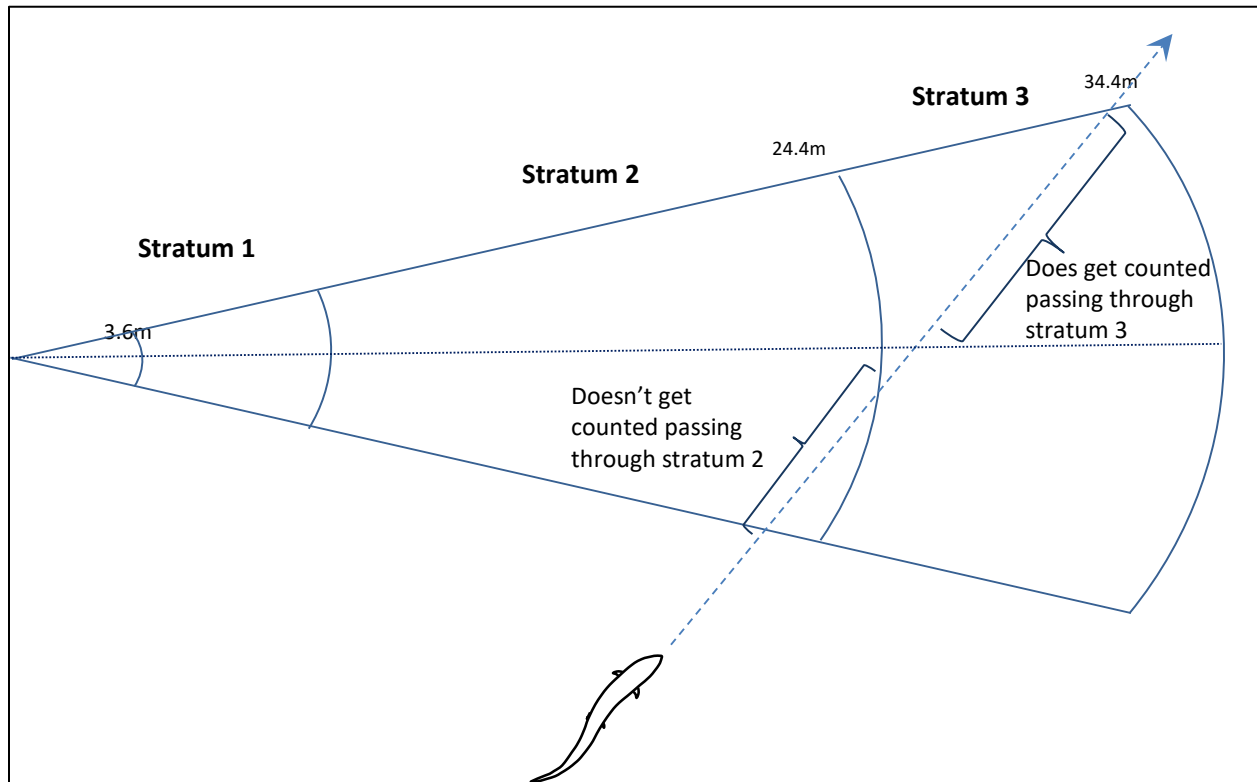   **<Right Click Drag>** zooms the selected area in the image when an echogram fish is selected

6) Instructions for including or excluding fish to be counted or measured

To optimize the aim of sonar beams relative to the bottom of the river, the insonified zone is often divided into individual range strata that are sampled separately. To avoid overcounting fish as they cross stratum boundaries, we apply the "centerline rule" where a fish is not counted unless it crosses the centerline of the sonar beam. Appendix A2 demonstrates the potential for overcounting without applying this criterion. Additional examples are given in Appendix A3. Note that although the centerline examples illustrated in Appendices A2 and A3 make it appear that all strata are sampled simultaneously within an hour, this is not the case. Each stratum for a given bank was sampled at different times within the hour.

Summary of fish measurement rules

A. For a fish to be considered valid for measurement, it must cross the centerline.
  i. If a fish enters or exits the beam on the near- or far-range boundary (beginning or end range), the snout of the fish must cross the centerline before it can be considered a valid fish to measure.
  ii. If the snout of the fish enters the near- or far-range boundary right on the centerline, the fish should be considered valid for measurement.
B. Exclude fish that hold throughout the length of the sample.
C. Exclude fish that are holding at either the beginning or the end of the sample.
  i. Fish that are actively migrating (not holding) as the sample begins or ends should be considered valid targets for measurement as long as they cross the centerline.
D. Exclude fish that enter the beam from upstream, then exit the beam upstream (do not measure even if they cross the centerline).
E. Exclude fish that enter the beam from downstream and then exit the beam downstream (do not measure even if they cross the centerline).
F. Exclude fish that enter the beam from either upstream or downstream and then disappear from the image (unless there is evidence to suggest direction of travel).
G. Use the video image to identify actively migrating fish when several holding fish are present. If you have several fish holding throughout the sample, use the video mode or run your cursor across the echogram while watching the ARIS image to observe fish that are actively transiting the image. Measure fish that are actively transiting the image and that meet all criteria listed above.
H. When subjectively determining fish length under protocol #2 measure all questionably sized fish and omit fish that measure less than 75cm AL after verifying their length.

Consult with others if you come across a questionable fish image or are unclear of the rules listed above.
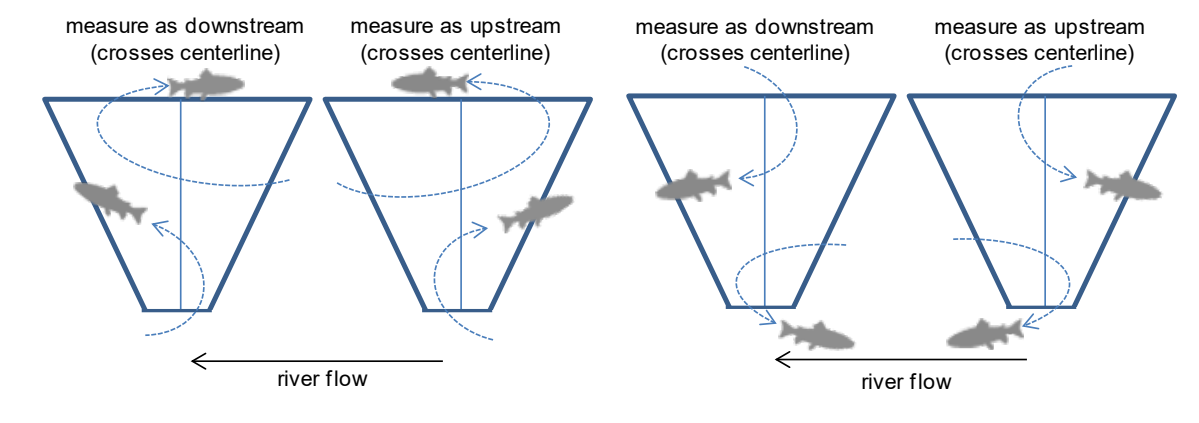
Appendix A2.–Illustration of how the problem of double-counting is avoided.

Stratum 3 34.4m

24.4m

Stratum 2

Stratum 1

3.6m

Does get counted passing through stratum 3

Doesn't get counted passing through stratum 2

Note: To avoid counting this fish in both stratum 2 and stratum 3, the fish will only be counted in stratum 3 where it crosses the centerline of the beam.

Appendix A3.–Examples for applying the "centerline rule" when selecting fish for counting and measurements.

For a fish to be considered valid for measurement (either upstream or downstream), the snout must cross the centerline.

measure
(crosses centerline)

exclude
(does not cross centerline)

measure
(crosses centerline)

exclude
(does not cross centerline)

river flow

river flow

measure
(crosses centerline)

exclude
(does not cross centerline)

measure
(crosses centerline)

exclude
(does not cross centerline)

river flow

river flow

measure as downstream
(crosses centerline)

measure as upstream
(crosses centerline)

measure as downstream
(crosses centerline)

measure as upstream
(crosses centerline)

river flow

river flow

-continued-

If the snout of the fish enters the near- or far-range boundary right on the centerline, the fish should be considered valid for measurement.

Exclude fish that enter the beam from upstream, then exit the beam upstream (do not measure even if they cross the centerline).

river flow
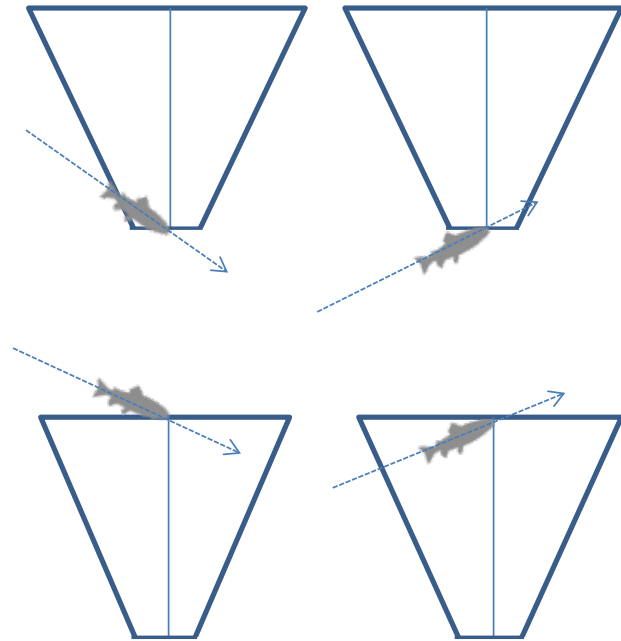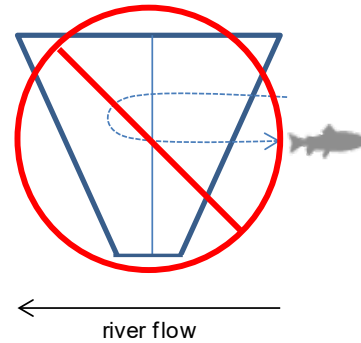
Exclude fish that enter the beam from downstream, then exit the beam downstream (do not measure even if they cross the centerline).

river flow

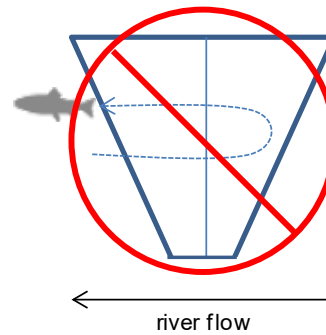-continued-

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Exclude fish that hold throughout the length of the sample.
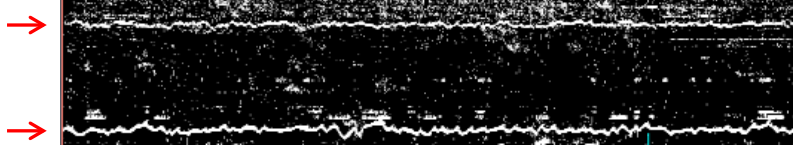
Two fish hold throughout the entire file.
Exclude both fish.

Exclude fish that hold at either the beginning or end of the sample.
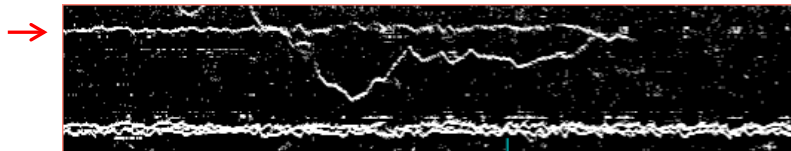
Fish holding as sample begins, then exits the beam about ¾ of the way through the sample. Exclude this fish.
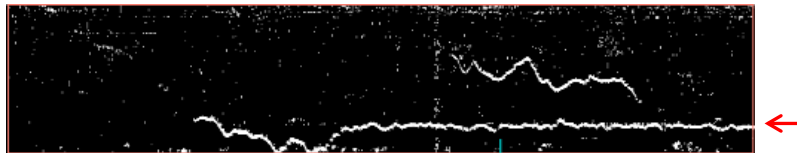
Fish enters the beam mid sample, then holds through the end of the sample. Exclude this fish

Fish that are actively migrating (not holding) as the sample begins or ends should be considered valid targets for measurement as long as they cross the centerline.

Fish is actively migrating through the beam as the sample starts. It crosses the center line and exits upstream so should be measured.

Consult with others if you come across a questionable fish image or are unclear of the rules listed above.

APPENDIX B: DIRECTION OF TRAVEL OF LARGE FISH DETECTED BY ARIS, KASILOF RIVER, 2018

Appendix B1.–Daily count and proportion of large fish (≥75 cm AL) moving upstream and downstream, Kasilof River, 2018.

	Downstream		Upstream		Total number
Date	Number	Percent	Number	Percent	sampled
15 Jun	0	NA	0	NA	0
16 Jun	0	NA	0	NA	0
17 Jun	0	NA	0	NA	0
18 Jun	0	NA	0	NA	0
19 Jun	1	100	0	0	1
20 Jun	0	NA	0	NA	0
21 Jun	0	0	1	100	1
22 Jun	0	0	2	100	2
23 Jun	0	NA	0	NA	0
24 Jun	0	0	1	100	1
25 Jun	0	0	1	100	1
26 Jun	0	NA	0	NA	0
27 Jun	0	NA	0	NA	0
28 Jun	0	0	2	100	2
29 Jun	0	0	1	100	1
30 Jun	0	0	1	100	1
1 Jul	0	NA	0	NA	0
2 Jul	0	0	5	100	5
3 Jul	0	0	3	100	3
4 Jul	3	100	0	0	3
5 Jul	0	0	1	100	1
6 Jul	0	0	2	100	2
7 Jul	1	25	3	75	4
8 Jul	1	33	2	67	3
9 Jul	0	0	2	100	2
10 Jul	0	0	3	100	3
11 Jul	0	0	3	100	3
12 Jul	0	0	2	100	2
13 Jul	1	13	7	88	8
14 Jul	0	0	2	100	2
15 Jul	1	11	8	89	9
16 Jul	1	14	6	86	7
17 Jul	1	17	5	83	6
18 Jul	2	29	5	71	7
19 Jul	1	25	3	75	4
20 Jul	0	0	5	100	5
21 Jul	0	0	5	100	5
22 Jul	7	32	15	68	22
23 Jul	1	7	13	93	14
24 Jul	0	0	17	100	17
25 Jul	2	17	10	83	12
26 Jul	1	6	17	94	18
27 Jul	1	11	8	89	9

-continued-

Appendix B1.–Page 2 of 2.

Date	Downstream		Upstream		Total number sampled
	Number	Percent	Number	Percent	
28 Jul	0	0	3	100	3
29 Jul	1	14	6	86	7
30 Jul	0	0	23	100	23
31 Jul	1	4	27	96	28
1 Aug	1	5	20	95	21
2 Aug	0	0	9	100	9
3 Aug	1	4	24	96	25
4 Aug	1	3	33	97	34
5 Aug	1	4	26	96	27
6 Aug	2	50	2	50	4
7 Aug	1	14	6	86	7
8 Aug	0	0	25	100	25
9 Aug	2	6	30	94	32
10 Aug	5	14	30	86	35
11 Aug	1	4	23	96	24
12 Aug	4	13	26	87	30
13 Aug	6	25	18	75	24
14 Aug	2	25	6	75	8
15 Aug	1	14	6	86	7
16 Aug	4	27	11	73	15
17 Aug	7	33	14	67	21
18 Aug	4	20	16	80	20
19 Aug	2	14	12	86	14
20 Aug	6	19	25	81	31
21 Aug	3	14	18	86	21
22 Aug	1	8	11	92	12
23 Aug	0	0	10	100	10
24 Aug	4	24	13	76	17
25 Aug	6	55	5	45	11
26 Aug	3	23	10	77	13
27 Aug	2	13	13	87	15
28 Aug	8	32	17	68	25
29 Aug	8	57	6	43	14
30 Aug	8	40	12	60	20
31 Aug	2	67	1	33	3
Total	123	15	698	85	821

Note: "NA" means calculation not applicable.