Regional Operational Plan SF.2A.2018.16

Operational Plan: Late Run Kasilof River Chinook Salmon Sonar Assessment, 2018–2021

by

James Miller

Suzanne Maxwell

Brandon Key

William Glick

and

Adam Reimer

June 2018

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

REGIONAL OPERATIONAL PLAN SF.2A.2018.16

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by
James Miller
Alaska Department of Fish and Game, Division of Sport Fish, Anchorage
Suzanne Maxwell
Alaska Department of Fish and Game, Division of Commercial Fisheries, Soldotna
Brandon Key
Alaska Department of Fish and Game, Division of Sport Fish, Soldotna
William Glick
Alaska Department of Fish and Game, Division of Commercial Fisheries, Soldotna
and
Adam Reimer
Alaska Department of Fish and Game, Division of Sport Fish, Soldotna

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

June 2018

James Miller,
Alaska Department of Fish and Game, Division of Sport Fish,
333 Raspberry Road, Anchorage, AK 99518-1599

Suzanne Maxwell,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276

Brandon Key,
Alaska Department of Fish and Game, Division of Sport Fish,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276

William Glick,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276

and

Adam Reimer,
Alaska Department of Fish and Game, Division of Sport Fish,
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8276

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SIGNATURE/TITLE PAGE

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Approval

Title	Name	Signature	Date
Project leader (SF)	James Miller		
Project leader (CF)	Suzanne Maxwell		
Biometrician (SF)	Adam Reimer		
Biometrician (CF)	Xinxian Zhang		
Research Coordinator (SF)	Tim McKinley		
Research Coordinator (CF)	Jack Erickson		
Regional Supervisor (SF)	Tom Vania		
Regional Supervisor (CF)	Bert Lewis		

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ABSTRACT

A sport fishery for late-run Kasilof River Chinook salmon is prosecuted downstream of river mile 8 and a commercial fishery occurs in nearby marine waters, but inriver abundance of late-run Chinook salmon is unknown for most years. The goal of this study is to estimate the daily net upstream passage of salmon 75 cm mid eye to tail fork length (METF) or longer past RM 8 of the Kasilof River from 15 June through 31 August 2018–2021 using adaptive resolution imaging sonar (ARIS). ARIS provides high resolution images that allow accurate fish length measurements at far ranges. This technology is currently used by the Alaska Department of Fish and Game on the Kenai River to estimate large (≥75 cm METF) Chinook salmon passage. Use of ARIS on the Kasilof River will take advantage of similar Kenai River methodology and the same trained personnel. In addition, these estimates can be combined with estimates from other projects (e.g., Eastside set net harvest genetics sampling) to estimate the annual total run size of large Kasilof River Chinook salmon.

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

INTRODUCTION

PURPOSE

The purpose of this project is to use adaptive resolution imaging sonar (ARIS) to estimate the inriver abundance of Kasilof River late-run Chinook salmon 75 cm mid eye to tail fork length (METF) or longer.

BACKGROUND

The Kasilof River is a turbid, glacially influenced stream on the western Kenai Peninsula that originates at the outlet of Tustumena Lake and flows 19 miles (31 km) to the eastern shore of Cook Inlet (Figure 1). Two tributaries feed into the Kasilof River: Coal Creek at river mile (RM) 4.1 and Crooked Creek at RM 6.9. The lower 5 miles 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 May–June and a late run that enters 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 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). Escapement of naturally-produced and hatchery-reared Chinook salmon to the Crooked Creek weir (located 3.2 miles upstream from the confluence with Kasilof River) during the same time period averaged 1,737 fish.

A sport fishery also occurs for the late run of Kasilof River Chinook salmon, although effort and harvest is reduced relative to the early-run fishery. The late-run sport fishery is prosecuted downstream of the Sterling Highway bridge crossing located at about RM 8. By regulation, sport fishing for Chinook salmon fishing is prohibited upstream of the bridge. 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 commercial Eastside set net (ESSN) fishery from 2013 to 2016 was 1,190 fish or about 24% of the total ESSN Chinook salmon harvest each year (calculated from Eskelin and Barclay *In prep*). 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 for fish 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 RM 8 operated by the Division of Commercial Fisheries to estimate adult sockeye salmon escapement. This project currently operates 2 standard dual frequency identification sonar (DIDSON) units (one deployed near each river bank) from mid-June to mid-August 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 is used predominantly to apportion pink and coho salmon, whose migration begins 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 currently used on the Kasilof River do not provide the necessary resolution to accurately differentiate large Chinook salmon from other smaller species of salmon beyond approximately 10 meters in range (river width at the site is approximately 60 m). For this reason, the Kasilof River sockeye salmon sonar project has not been capable of providing late-run Chinook salmon escapement estimates using current methodologies and equipment.

The next generation of DIDSON technology, adaptive resolution imaging sonar (ARIS), provides higher resolution images that allow accurate fish length measurements out to 30+ meters, thus providing the ability to estimate fish size at farther ranges. This technology is currently used by ADF&G on the Kenai River to estimate large (≥75 cm METF) Chinook salmon passage (Miller et al. 2016). Replacement of the two DIDSON units currently used on the Kasilof River with 2 ARIS units will allow this project to employ methodology similar to the Kenai River to estimate 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 GSI project (Eskelin and Barclay 2017) to estimate the annual total run size of large Kasilof River Chinook salmon. Second, the same ADF&G personnel will be responsible for processing Kenai and Kasilof River sonar data. Those personnel are trained to visually identify ARIS fish images near and above the 75 cm threshold for measurement, so using the same threshold for both rivers allows streamlined data processing without developing additional protocol and 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. We compiled length information from Kasilof River Chinook, coho, and sockeye

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

salmon migrating during August[2] from a variety of sources (see Figure 2 caption) to examine the utility of a 75 cm threshold on the Kasilof River. 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.

We can expect that approximately 8% of the inriver run of Kasilof River Chinook salmon near the sonar site to be smaller than a 75 cm METF threshold and therefore not counted by sonar; these 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. However, Kasilof River age, sex, and length distributions are similar to Kenai River Chinook salmon (*cf.* Fleischman and Reimer 2017) where the 75 cm length threshold is already in use.

OBJECTIVE

Estimate the daily net upstream passage of salmon 75 cm METF or longer past RM 8 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 Divisions of Commercial Fisheries and Sport Fish will work cooperatively at the same site and use the same equipment. The Division of Commercial Fisheries (CF) will be responsible for enumerating sockeye salmon as described in Glick and Willette (2016a) whereas the Division of Sport Fish (SF) will be responsible for enumeration of large Chinook salmon.

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 right bank, looking downstream) and is composed mostly of large rocks 20–60 mm in diameter with larger rocks and boulders exceeding 1 m^3 along the right bank (Glick and Willette 2016b).

ACOUSTIC SAMPLING

Acoustic sampling operations will be consistent with those described in Glick and Willette (2016a), except that the two standard DIDSON systems used in past years will be replaced with 2 ARIS 1800 systems (Sound Metrics Corporation[3]) and the field season will be extended. The two ARIS units will be deployed (one from each bank) from 15 June through 31 August. The

[2] The length data available for coho and Chinook salmon from the Kasilof River is not ideal because it was collected at upstream and later (coho) or downstream and earlier (Chinook) than would be relevant for this project. Sample lengths of both species collected in August are probably most representative of those that will pass the sonar site during the sonar project dates.

[3] Product names used in this publication are included for completeness but do not constitute product endorsement.

ARIS 1800 systems will each be configured with a standard lens and operate at a frequency of 1.8 MHz (nearshore) and 1.1 MHz (offshore) and set to 96, 0.3° × 14° beams to provide the resolution necessary for obtaining accurate length measurements at all ranges. An 8° concentrator lens may be used early in the season when water level is low. Profiles of the river bottom will be created following the methods of Maxwell and Smith (2007) at the start of the season and again when the river has risen to determine the best beam fit and aim for the transducer. The best beam fit and aim will be modified using images collected with ARIS and then processed with DIDSON software. The ARIS images will be collected using the same resolution and range used for DIDSON. The best beam fit will include 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. If needed, vertical interference from surface and bottom reverberation will be decreased by use of a concentrator lens to adjust the vertical beam width to better fit in the water column. The concentrator lens will not affect horizontal beam width. Components of the ARIS 1800 system are listed in Table 1. Miller et al. (2016) provides further detail on the ARIS system and a comparison with DIDSON.

Sampling will be controlled by computers housed in a “sonar shack” located on the left bank. Communication cables from the left bank ARIS unit will feed directly into the left-bank ARIS Command Module and data collection computer (Figure 3). On the right bank, data from the ARIS system will be transmitted via a wireless bridge to a data collection computer on the left bank (Figure 3). A battery bank, charged daily using a combination of solar panels and a generator, will provide sufficient power to the right-bank sonar electronics and wireless bridge. AC power from the nearby Kasilof River State Recreational Site will be available to power all left-bank equipment. The ARIS units will be 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 will be deployed in the river using an aluminium H-style mount (Figure 4). As described in Glick and Willette (2016a), deflection weirs will be installed on each bank to force fish to pass offshore of the sonar and through the insonified zone. In the horizontal plane, the sonars will be 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 will be aimed to insonify the near-bottom region of the river. Internal sensors in the ARIS units will provide measurements of compass heading, pitch, and roll as well as water temperature.

In designing ARIS, the manufacturers (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 (Table 2). The maximum achievable frame rate will be used for each stratum. Frame rate for each stratum will be 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 will vary depending on the range (in meters) of the stratum being sampled; in this case, there are two strata (nearshore [1–10 m] and offshore [10–30 m]) per ARIS system (left bank or right bank). In combination with transmit pulse width, sample period (or equivalently, detail) controls the downrange resolution for the image. All data will be 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), or a higher resolution if necessary. 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. (2016) 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. Transmit pulse width will vary 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 will be set to “Auto” or will be manually set to ensure the transmit pulse width is 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 will be 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) will be set to maximum for each stratum but receiver gain will vary 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 right and left bank), the setting will be reduced from maximum based on image quality. In the offshore strata (both right and left bank), where the signal is more diminished and lower gains can cause detection issues, gain settings will be set to 24 dB. Finally, the autofocus feature will be enabled for all data collection so that the sonar automatically sets the lens focus to the midrange of the selected range window.

A systematic sample design (Cochran 1977) will be used to sequentially sample discrete range strata (“range windows”) for a total of 10 minutes per hour for each stratum. Ten minute sample periods are currently used in conjunction with sonar to estimate Chinook salmon passage on the Kenai River (Miller et al. 2016). The ARIS can be programmed to automatically sample each range stratum using ARIScope. Dividing the total range to be insonified into shorter range strata allows the aim of the sonar beam to be optimized for sampling a 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 makes it easier to count fish throughout the range at high passage rates. Multiple range strata also allow data at different ranges to be collected at different frequencies in order to optimize image resolution. The ARIS on each bank will be programmed to sample 2 range strata (1–10 m and 10–30 m) and will operate 24 hours per day, 7 days per week.

ARIS video files will be stored onto 2 sets of 2 TB external hard drives (Figure 3). One set will be kept at the sonar site where CF staff will manually count all fish images from a computer screen to estimate the numbers of sockeye salmon passing the sonar using methods described in Glick and Willette (2016a). The other set of hard drives will be transported daily by SF staff to the Soldotna ADF&G office where SF staff will conduct 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) will be included on data drives transported to the office.

MANUAL ARIS FISH LENGTH MEASUREMENTS

Measurements of fish length will be obtained using ARISFish V2.6 software supplied by SMC. Detailed instructions for taking manual measurements and the software settings and parameters that will be used for this project are given in Appendix A1. Electronic echograms provide 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 create a positive bias in the passage estimates (Appendix A2), measured fish will be subjected to a "centerline rule" (Appendix A3). Only those fish that cross the longitudinal central axis of the ARIS video image will be candidates for measuring. Fish that do not cross the centerline will be ignored..

For the purpose of this study, fish size will be 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 will be 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 will be referred to as "large fish." Based on tethered fish experiments and other data, Miller et al. (2016) concluded that a fish measured 75 cm by ARIS is also approximately 75 cm METF.

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

1) If the hourly nearshore stratum count is less than 100 fish, length and direction of travel will be recorded for all salmon-shaped fish greater than or equal to 30 cm AL that meet the centerline rule (Appendix A3) for that stratum.
2) If the hourly nearshore stratum count exceeds 100 fish, the length of the first 5 fish in each sample period will be measured and recorded regardless of size. The 5-fish protocol mimics that used on the Kenai River to allow consistency for technicians that will be measuring samples from both rivers. For the remainder of the sample (after the first 5 fish), only fish judged[4] to be near 75 cm AL will be measured and only those fish that measure greater than or equal to 75 cm AL will be recorded. Fish less than 75 cm AL will not be recorded in any way, including fish chosen for measurement that turn out to be less than 75 cm.

Protocol 2 is designed to allow timely daily abundance estimates of large fish during periods of high small fish passage while providing a representative AL distribution of all fish. It is likely Protocol 2 will be used sparingly on the Kasilof River. Between 2010 and 2017, the number of hourly nearshore stratum counts that exceeded this criterion ranged from 10 to 133.

Technicians will be trained to measure any fish near the 75 cm AL cutoff and only record those that exceed the cutoff when implementing Protocol 2. However, bias in our abundance estimates could result if large fish are not selected for measurement. The magnitude of this bias will be assessed postseason by remeasuring all fish in 75 of the samples processed under Protocol 2. The difference in counts under each sampling protocol will be used to evaluate the size of any bias. Assuming the differences follow a Poisson distribution, 75 samples would give about 87% power

[4] 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.

to detect an error rate of 2/24 (2 missed fish every 24 samples) if the true error rate is 1/48 (1 missed fish every 48 samples).

DATA ANALYSIS

Fish Passage

Each ARIS system will be scheduled to operate 10 minutes per hour for each spatial stratum, 24 hours per day. There will be 2 spatial strata (1–10 m and 10–30 m) sampled per ARIS system (left or right bank). The number of fish y that satisfy 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 will be estimated as follows:

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

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

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

where h_{iks} is the number of hours during which fish passage is estimated for stratum s of transducer k during day i, and $\hat{y}_{ijks}$ is hourly fish passage for stratum s of transducer k during hour j of day i, which will be estimated as

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

where

m_{ijks} = number of minutes (usually 10) sampled for stratum s of transducer k during hour j of day i, and

c_{ijks} = number of fish satisfying criteria **X** (e.g., upstream direction of travel; ARIS length greater than or equal to 75 cm) in stratum s of transducer k during hour j of day i.

The variance of the daily estimates of y, due to systematic sampling in time, will be approximated (successive difference model[5]; Wolter 1985) with adjustments for missing data as follows:

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

[5] 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 f is the sampling fraction (temporal sampling fraction, usually 0.17), ϕ_{ij} is 1 if $\hat{y}_{ij}$ exists for hour j of day i, or 0 if not, and

$$\hat{y}_{ij} = \sum_{k} \sum_{s} \hat{y}_{ijks} \; . \qquad (5)$$

Other estimates of passage will be obtained by changing the criteria **X** for fish counts c_{ijks} in Equation 3. For example, for estimates of downstream large fish, **X** would be "downstream direction of travel, ARIS length greater than or equal to 75 cm." Estimates of daily net upstream passage will be 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 will be the sum of the upstream and downstream variances.

SCHEDULE AND DELIVERABLES

Dates	Activity
15 June–31 August	Data collection
1 September–31 October	Complete manual fish measurements
	Analyze data
	Produce final large-Chinook salmon abundance estimate
1 November–31 March	Write Fisheries Data Series Report
1 March–31 March	Review operational plan

RESPONSIBILITIES

James Miller, Fishery Biologist III, Co-Project Manager

Duties: General supervision of all aspects of the study. Co-authors operational plan and postseason report, prepares and tracks budget, tracks implementation of operational plan, provides assistance and direction when needed. Shares responsibility for postseason reporting and data analysis.

Suzanne Maxwell, Fishery Biologist III, Co-Project Manager

Duties: General supervision of all aspects of the study. Co-authors operational plan and postseason report, prepares and tracks budget, tracks implementation of operational plan, provides assistance and direction when needed. Shares responsibility for postseason reporting and data analysis.

Adam Reimer, Biometrician II

Duties: Provides guidance on sampling design and estimation procedures. Assists with inseason and postseason data analysis. Reviews project operational plan. Shares responsibility for postseason reporting and data analysis.

Brandon Key, Fishery Biologist II

Duties: Supervises manual fish length measurement process. Uploads ARIS files to permanent storage in the Soldotna ADF&G office. Works with project managers and biometrician to process data and generate abundance estimates using SAS software. Assists with authoring or reviewing operational plan and annual report.

William Glick, Fishery Biologist II

Duties: Supervises field operations including on-site field crew and data collection. Assists with authoring or reviewing operational plan and annual report.

April Faulkner, Fishery Biologist I, Crew Leader

Duties: Assists with inseason deployment and operation of ARIS sonar. Supervises and trains Fish and Wildlife Technician II field personnel when necessary.

Fish and Wildlife Technician II (3)

Duties: Assists with inseason deployment and operation of ARIS sonar (2) or assists with measuring fish images in the Soldotna sonar office (1).

BUDGET SUMMARY

The total proposed budget for the Kasilof River Chinook salmon sonar project (fiscal year 2018) is $244,800. Budget and personnel requirements are summarized below.

Line item	Category	Budget ($K)
100	Personal Services	3.0
200	Travel	0.0
300	Contractual	0.3
400	Commodities	2.3
500	Equipment	239.2
Total		244.8

Funded personnel for FY18.

PCN	Name	Level	Funded man months
11-S2S08	Vacant – Non-perm	Fish & Wildlife Technician II	0.5
Total			0.5

The total proposed budget for the Kasilof River Chinook salmon sonar project for fiscal years FY19–FY22 is $110,000. Annual budget and personnel requirements are summarized below.

Annual budget summary for FY19–FY22.

Line item	Category	Budget ($K)
100	Personal Services	21.0
200	Travel	0.0
300	Contractual	4.5
400	Commodities	2.0
500	Equipment	0.0
Total		27.5

Annual funded personnel for FY19-FY22.

PCN	Name	Level	Funded man months
11-1381	April Falkner	Fishery Biologist I	0.5
11-1495	Vacant	Fish & Wildlife Technician II	0.75
11-1374	Vacant	Fish & Wildlife Technician II	0.75
11-S2S08	Vacant – Non-perm	Fish & Wildlife Technician II	2.5
Total			4.5

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TABLES

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

System component	Quantity	Description
Sounders	2	ARIS 1800 Left bank Right 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) if necessary
Remote pan and tilt	2	Sound Metrics AR2 rotators—controlled via ARIScope software
Data collection computer	2	Dell Latitude E6430 laptop computers (1 for each sonar)

Table 2.–Proposed ARIScope data collection parameter settings.

Parameter	Setting
Frequency (kHz)	1.8 for the 1–10 m strata 1.1 for the 10–30 m strata
Window length (m)	Approximately 10 m or 20 m
Frame rate (frames/sec)	Maximum allowable
Sample period (µs)	10 (or higher resolution if necessary)
Pulse width (µs)	Set to ~12 for 1 m to 10 m strata Set to "Auto" for 10 m to 30 m strata
Transmit level (power)	Maximum
Gain (dB)	Variable
Focus	Auto

FIGURES

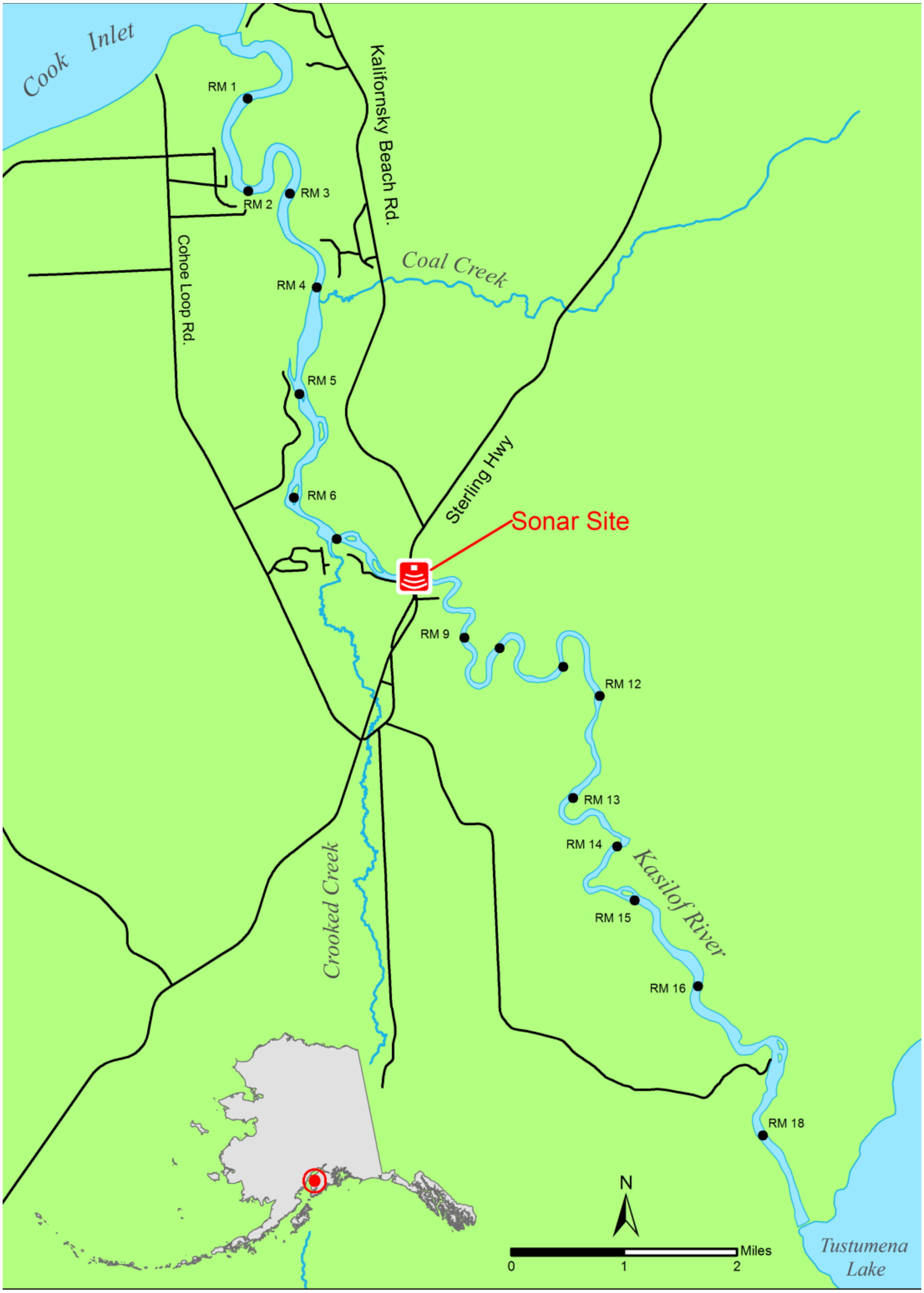


Figure 1.–Map of the Kasilof River showing sonar site location, Kenai Peninsula, Southcentral Alaska.

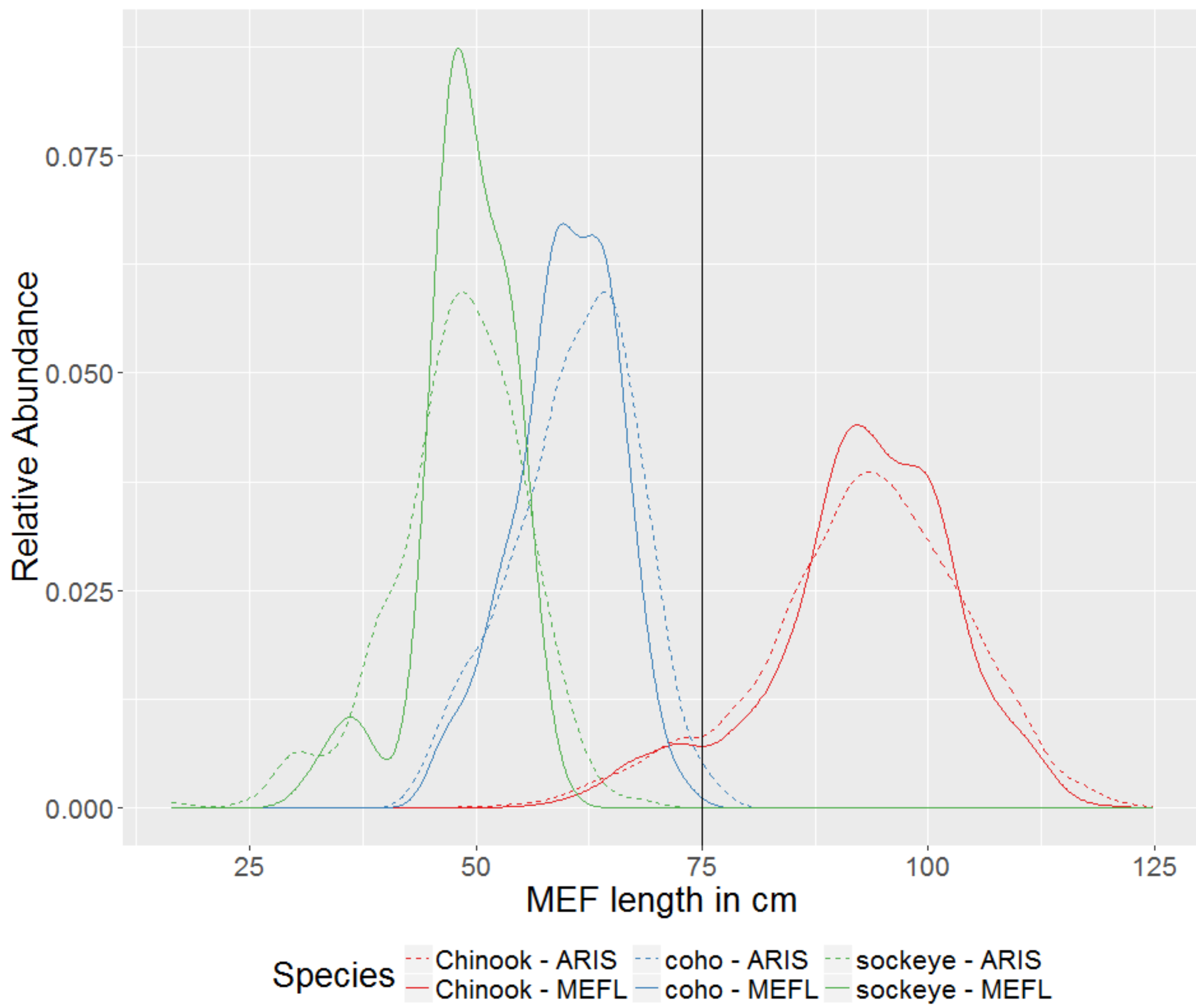


Figure 2.–Length distributions of coho, sockeye, and Chinook salmon in the Kasilof River.

MEFL 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 (*cf*. Miller et al. [2016]). "ARIS" means ARIS length, "MEFL" or "MEF" means mid eye to tail fork length.

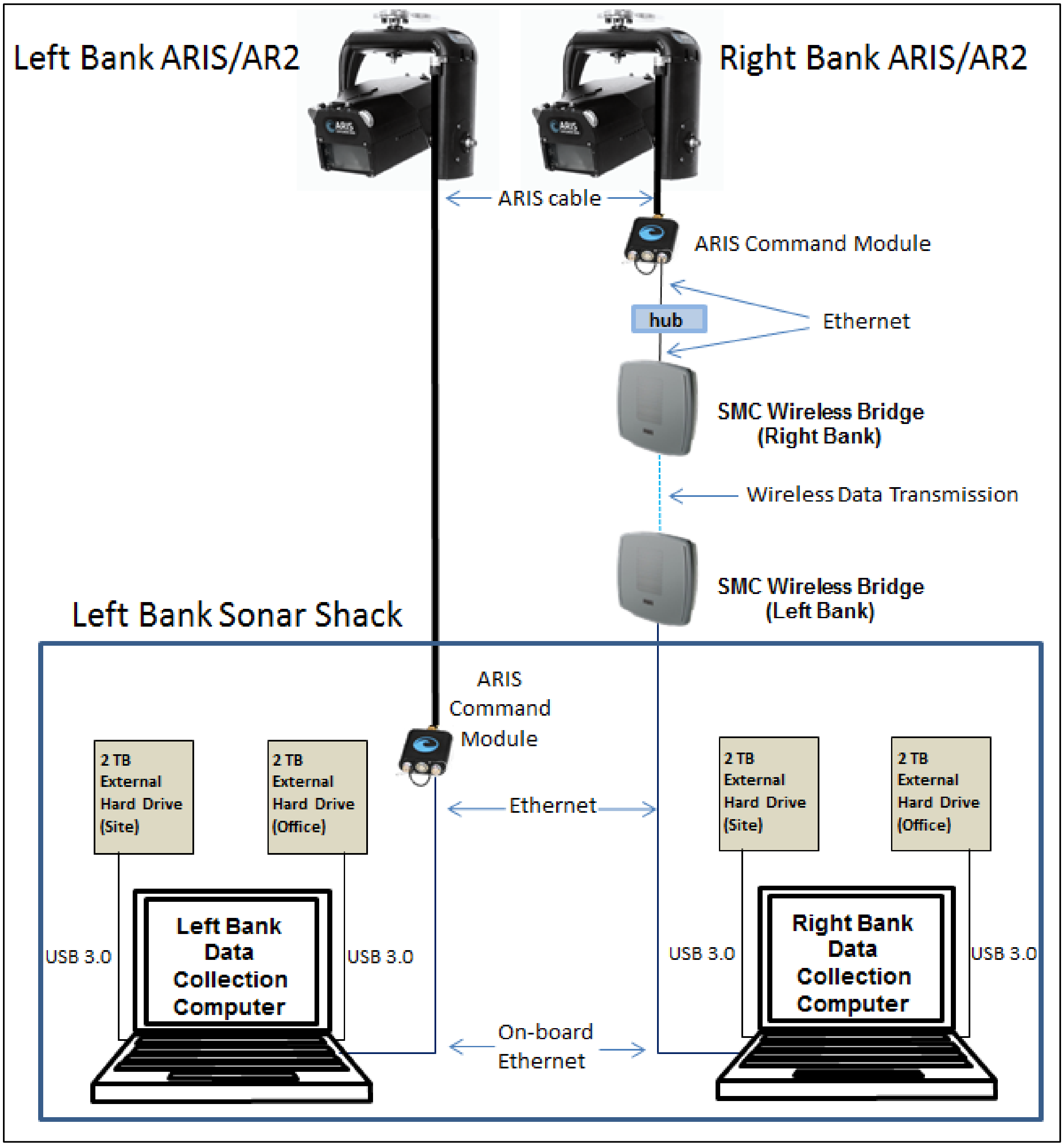


Figure 3.–ARIS data collection schematic for the Kasilof River.

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

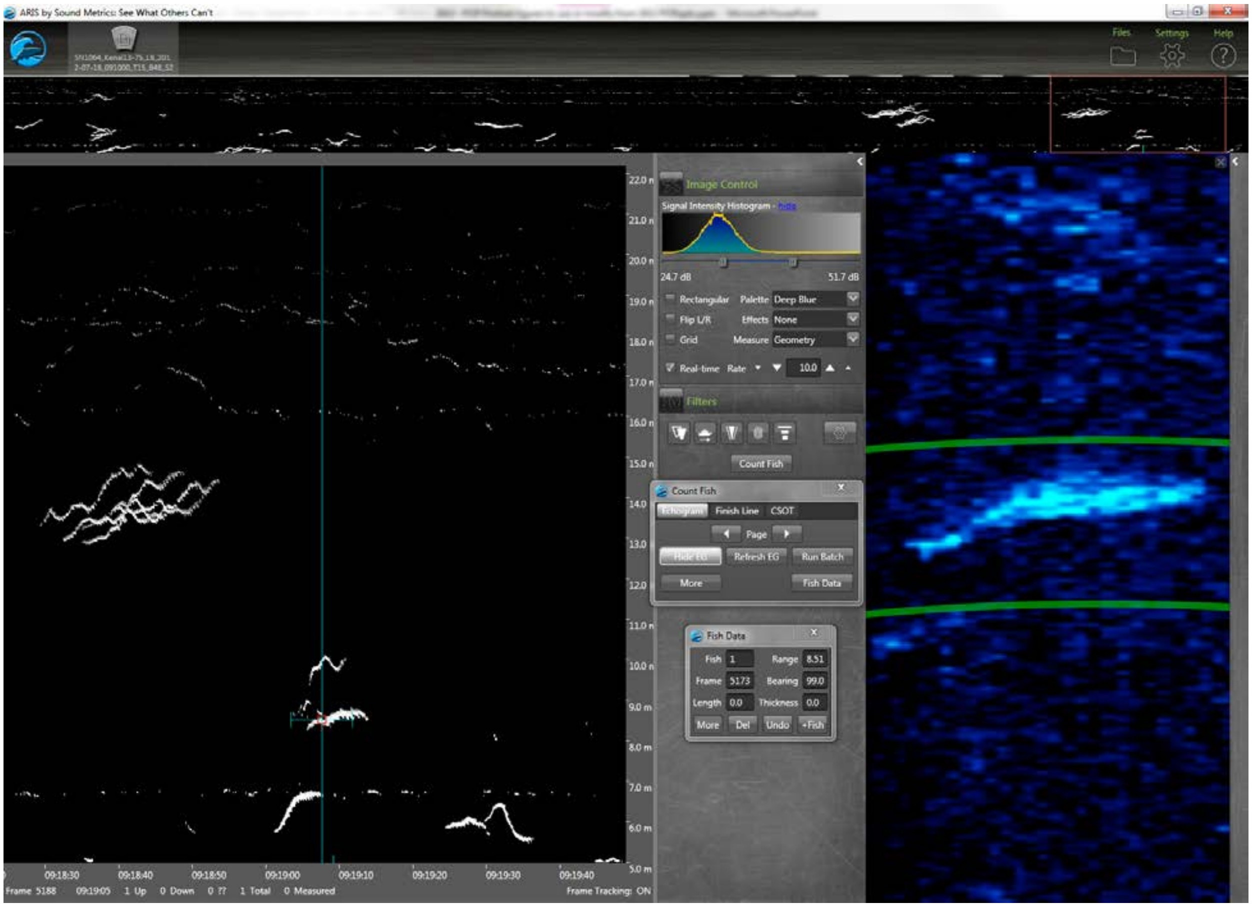


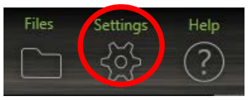
Figure 5.–ARISFish display window showing an echogram (at left) with traces of migrating fish that can be simultaneously displayed in video mode (at right) where fish images can be enlarged and measured.

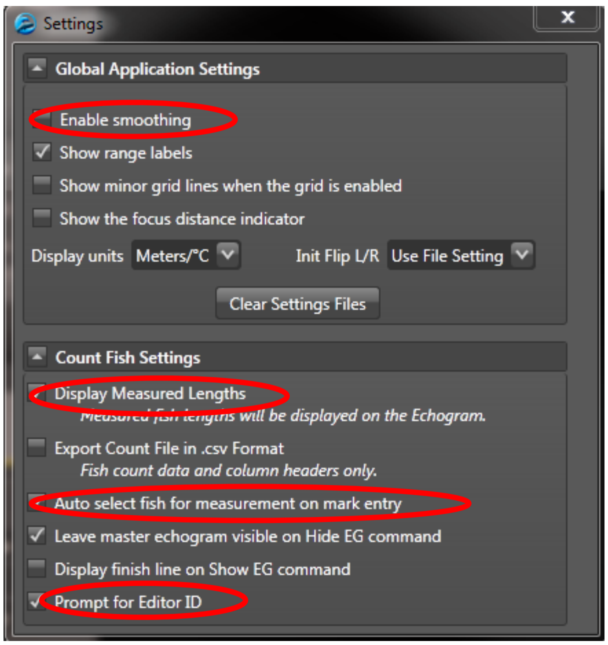
APPENDIX A: INSTRUCTIONS AND SETTINGS USED FOR MANUAL FISH LENGTH MEASUREMENTS FROM ARIS IMAGES USING ARISFISH SOFTWARE VERSION 2.6

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 if you are measuring 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)

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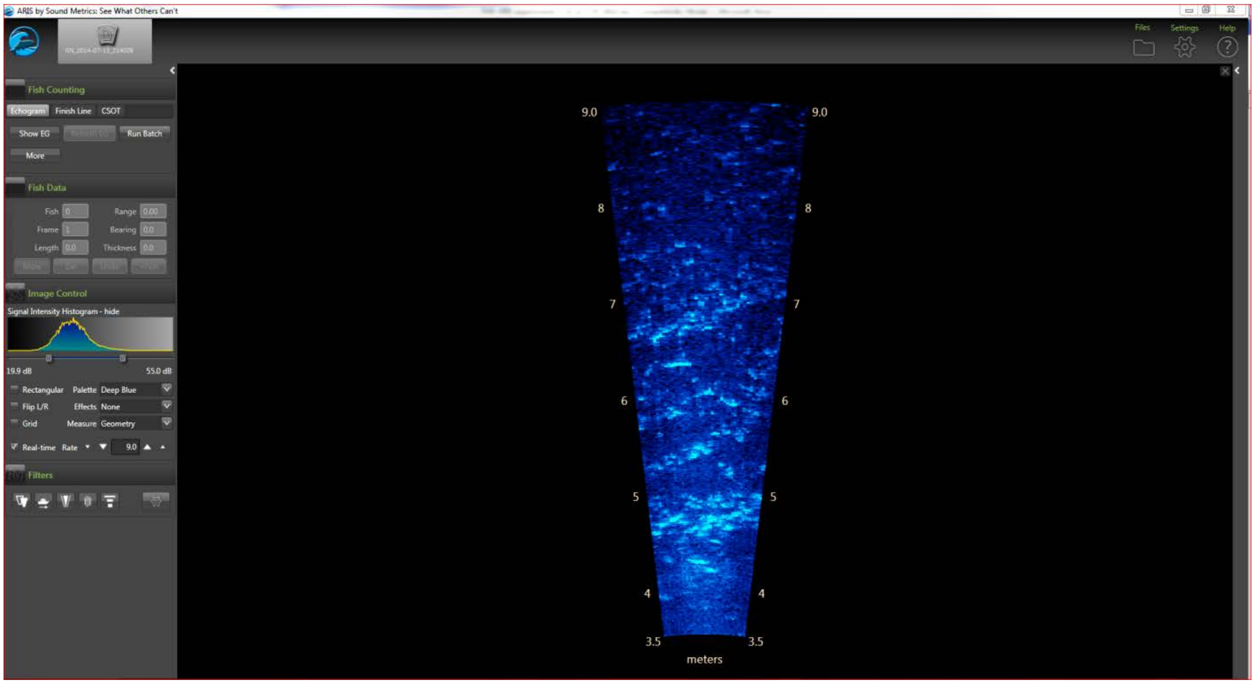
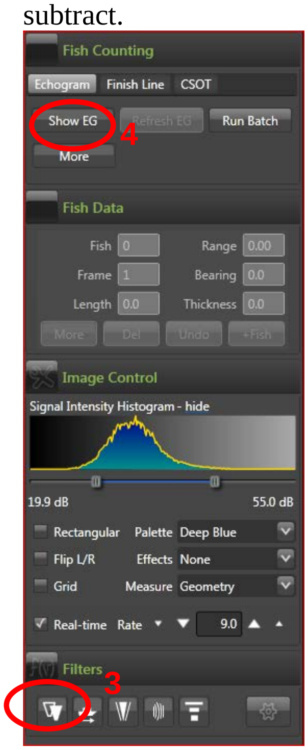
At this point, the ARISFish display should look similar to the image below:



c) Select the **<Background Subtraction>** icon and wait 30 seconds or so for background to subtract.



d) Then select **<Show EG>** to display the Echogram.

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

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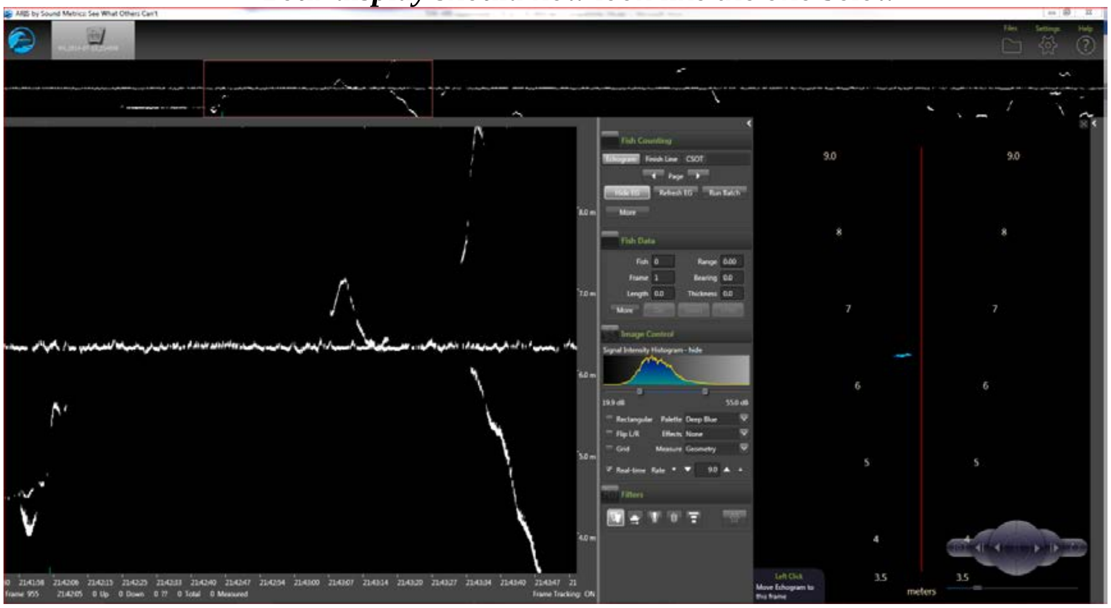
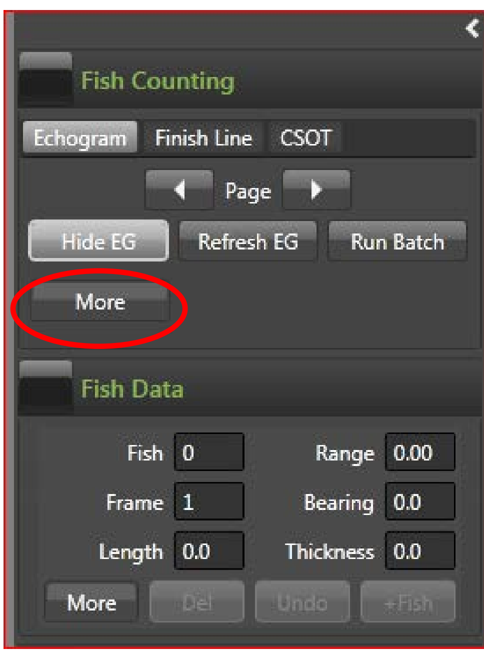
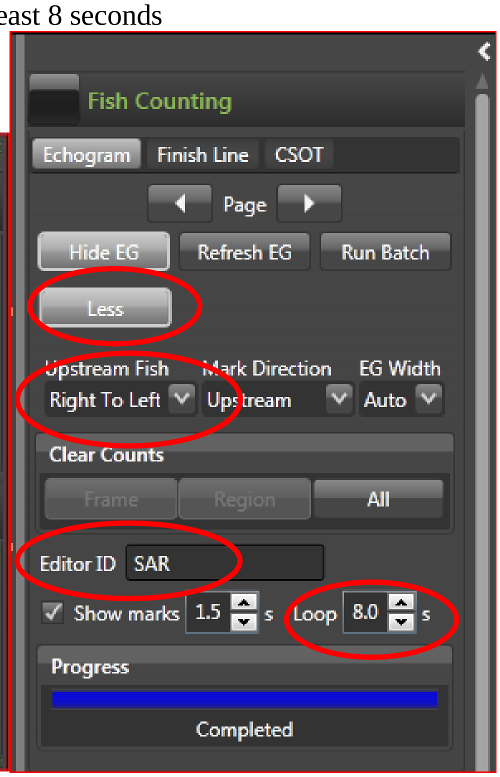
Your display should now look like the one below



f) Select **<More>** from the Fish Counting window to get the extended window where you can
   i. enter your **Editor ID** initials
   ii. set the **Upstream Fish** direction
   iii. ensure that **Loop** length is set to at least 8 seconds





   iv. 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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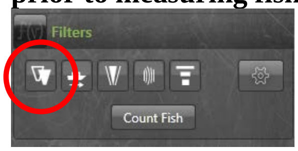
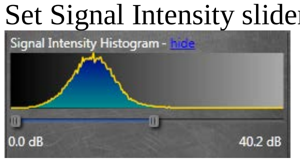
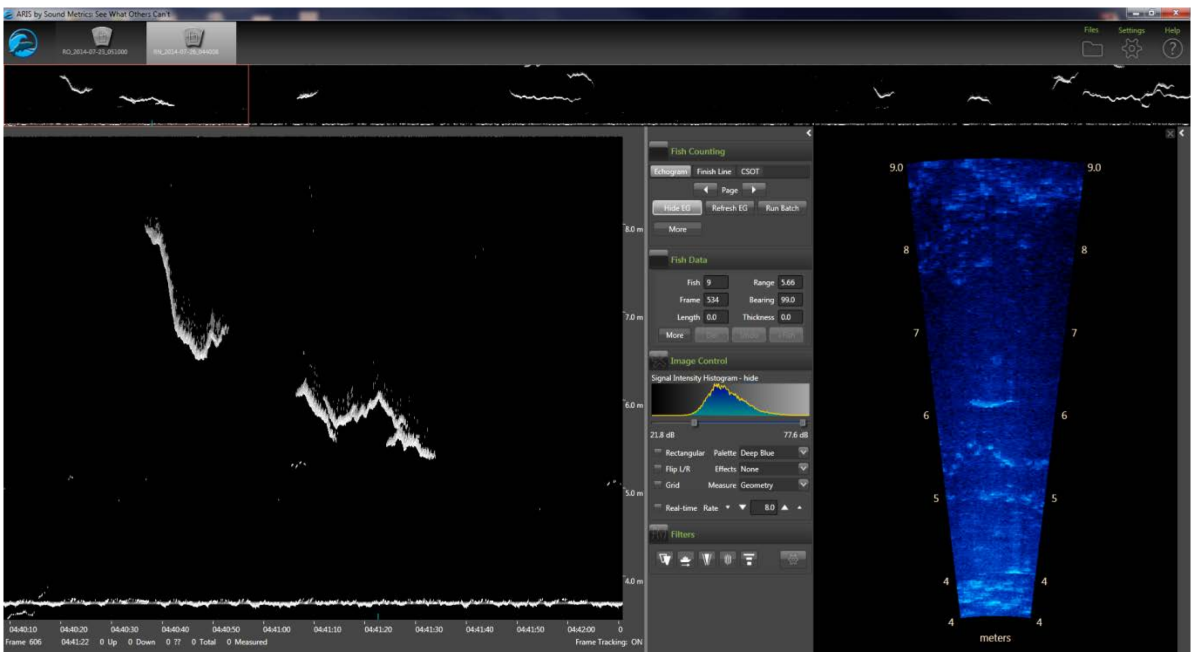
g) Select <**Background Subtraction**> icon on Filters Menu (Toggle)—this will now turn background subtraction off on the video image. **Failing to turn background subtraction off prior to measuring fish image length may result in an underestimate of actual fish length**[6]**.**



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.

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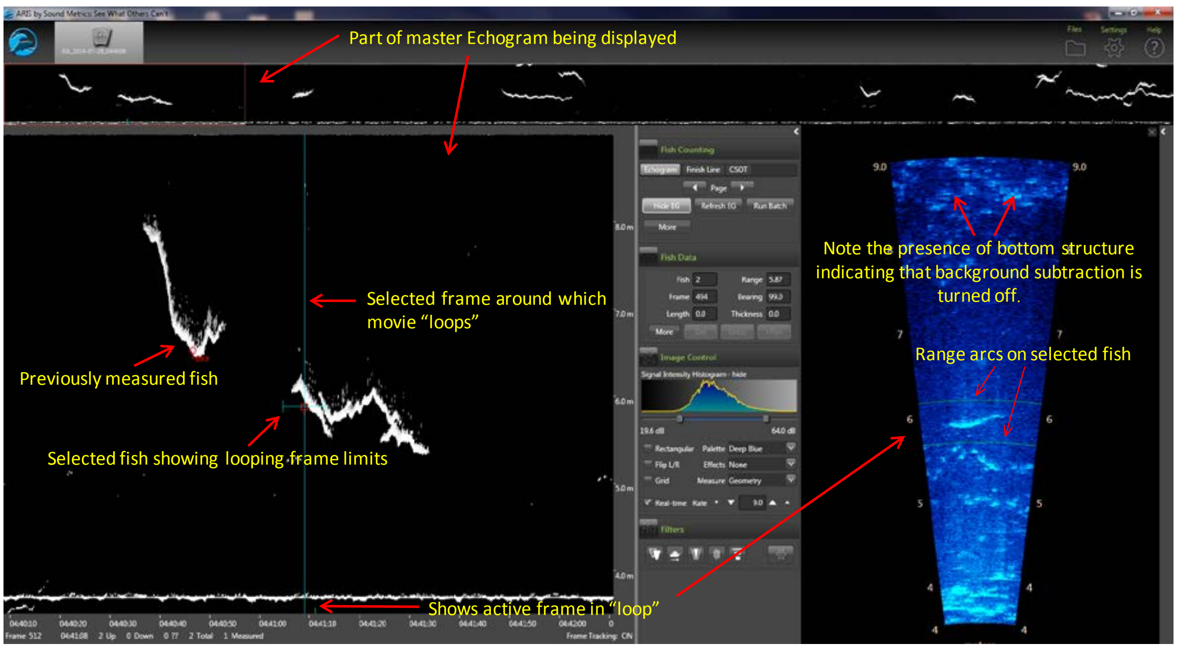
[6] Now that we use ARIS instead of DIDSON, most of the time we no longer use the background selection option while measuring fish image length. The ARIS background selection algorithm is more aggressive than the DIDSON selection and unless one is very careful in selecting a frame, it is easy to underestimate 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.

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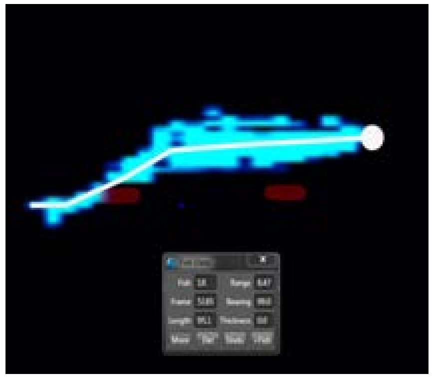
g) Measure fish image:

i. Fish traveling snout-first upstream or downstream - **<left click>** on the fish snout 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 tail.

ii. Fish backing downstream through the beam tail-first - **<left click>** on the fish tail 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 snout.

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.

-continued-

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

In order to optimize the aim of the sonar beams relative to the bottom of the river, the insonified zone is often divided into individual range strata that are sampled separately. In order to avoid over counting 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.

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).

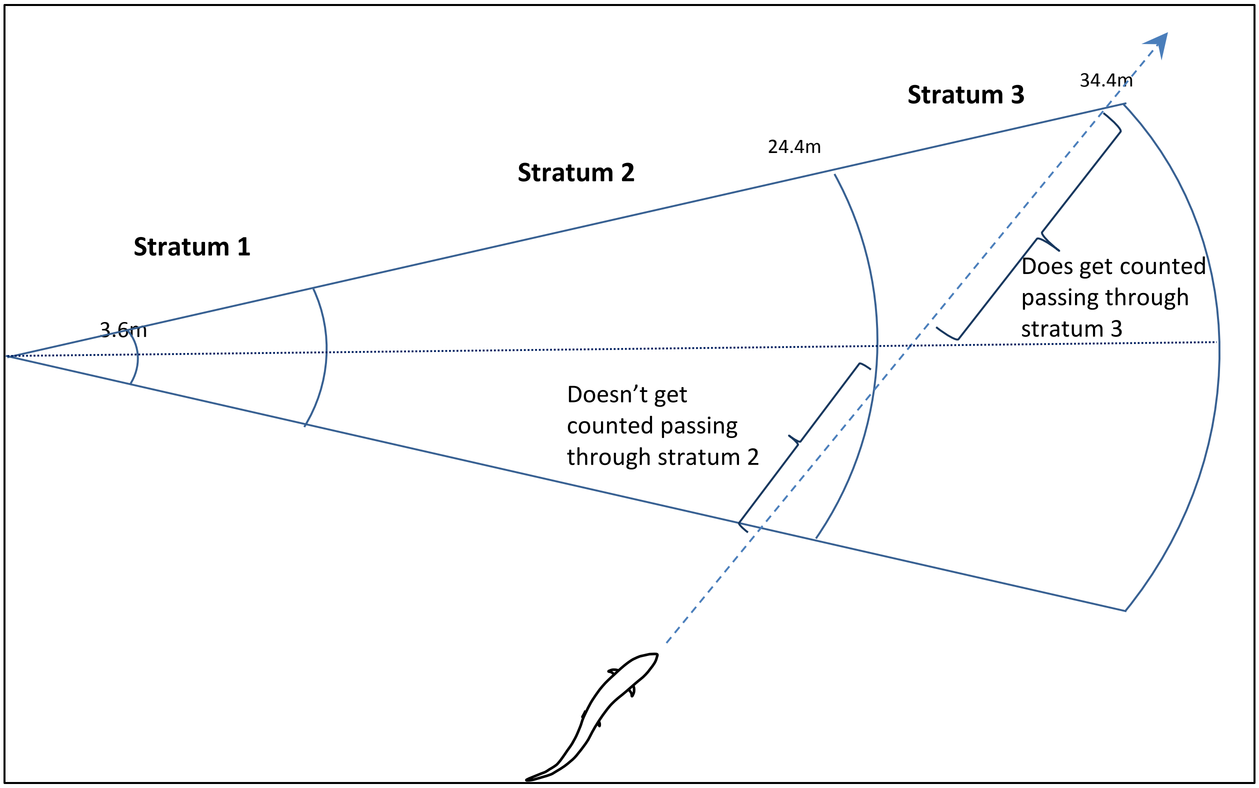
e) Exclude fish that enter the beam from downstream and then exit the beam downstream (do not measure even if they cross the centerline).

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.

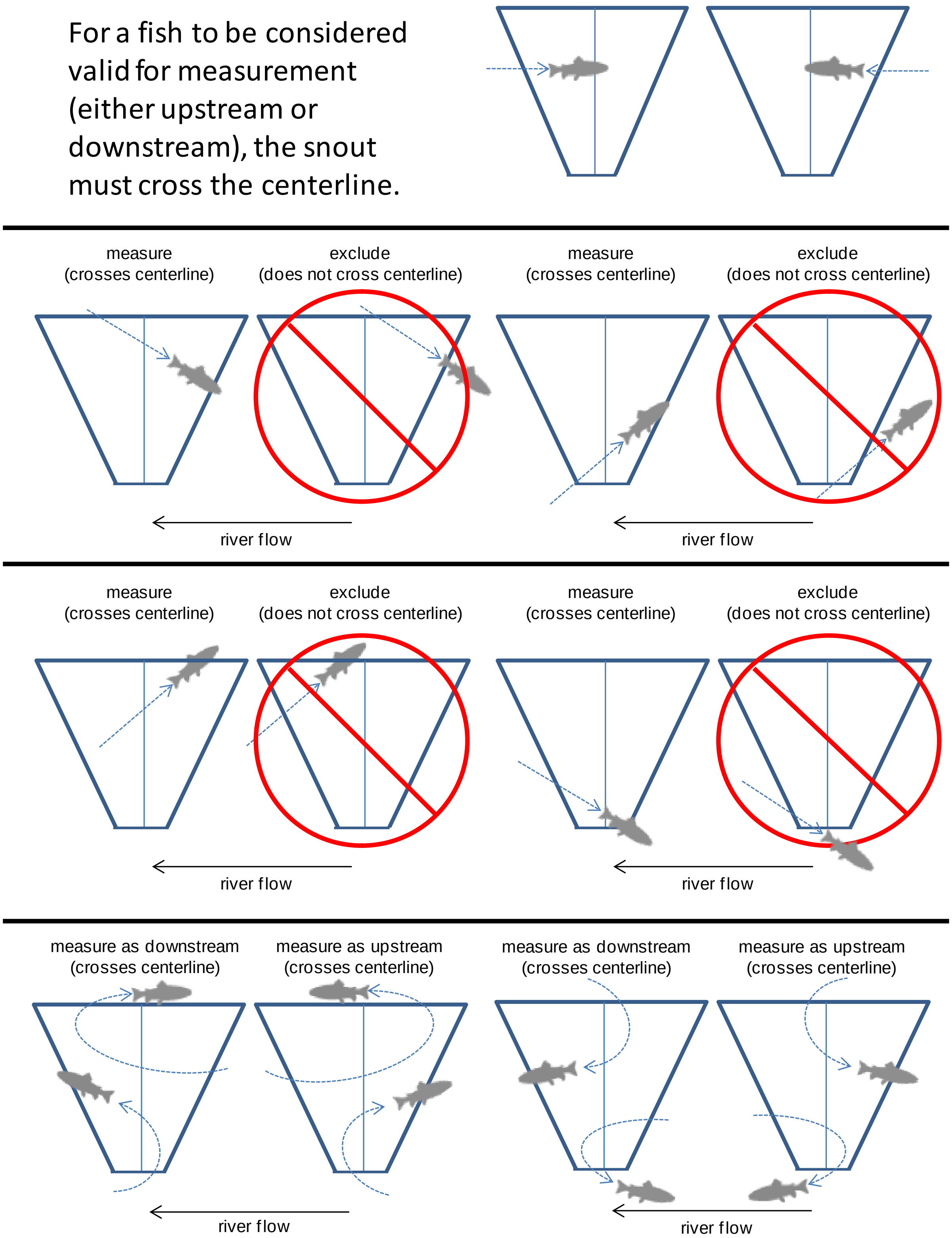
i) Consult with others if you come across a questionable fish image or are unclear of the rules listed above.



Appendix A2.–Illustration of how the problem of double-counting is avoided.

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.



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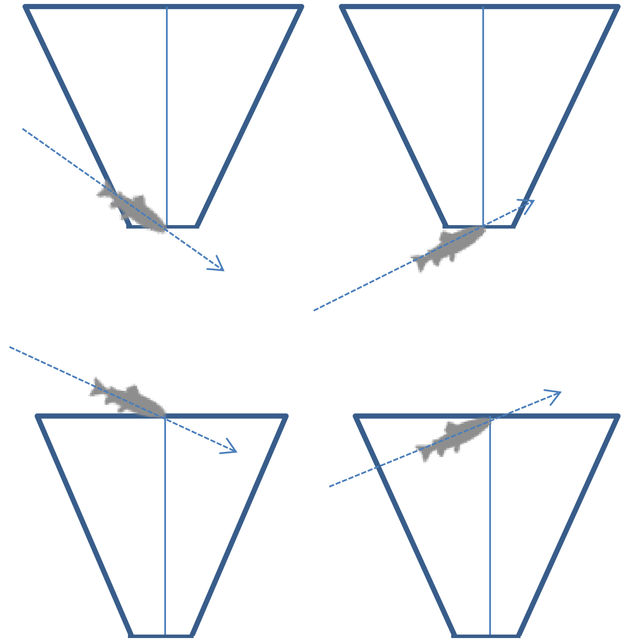
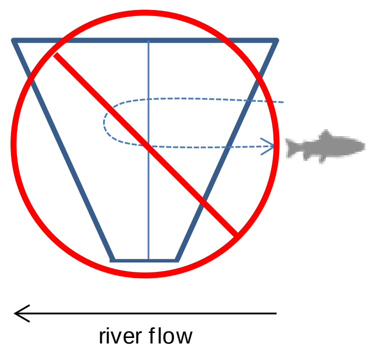
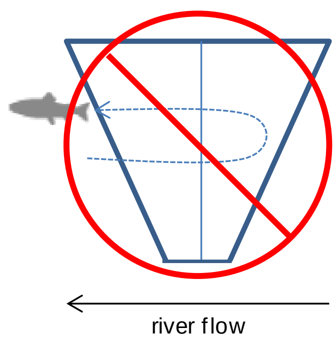
If the snout of the fish enters the near- or far-range boundary right on the centerline, the fish should be considered valid for measurement.



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



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



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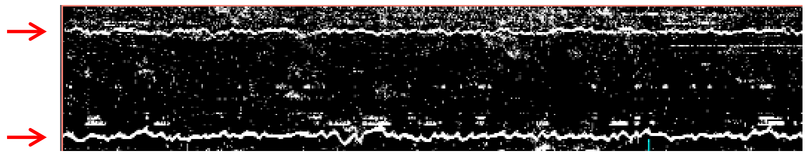
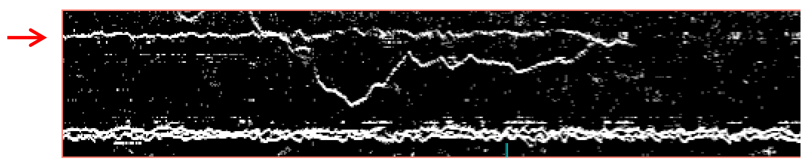
Exclude fish that hold throughout the length of the sample.

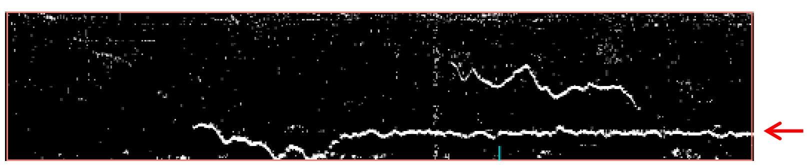


Two fish hold throughout the entire file.
Exclude both fish.

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

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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.