Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Eulachon Run Timing, Distribution, and Spawning in the Susitna River
Study Plan Section 9.16

Initial Study Report
Part A: Sections 1-6, 8-10

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

HDR, Inc. and LGL

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
CIBW	Cook Inlet Beluga Whales
cm	centimeter(s)
CPUE	catch per unit effort.
dB	decibel
DIDSON	Dual Frequency Identification Sonar
DO	Dissolved Oxygen
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
ft	feet
GIS	Geographic information system
GPS	global positioning system
ILP	Integrated Licensing Process
ISR	Initial Study Report
km	kilometer
kts	knots
m	meter(s)
m:f	male to female sex ratio
MHz	Megahertz

Abbreviation	Definition
mm	millimeter(s)
ms	millisecond(s)
m/s	meters per second
PAD	Pre-Application Document
PCE	primary constituent elements
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
RSP	Revised Study Plan
SPD	Study Plan Determination

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed its Revised Study Plan (RSP) with the Federal Energy Regulatory Commission (FERC or Commission) for the Susitna-Watana Hydroelectric Project (FERC No. 14241) which included 58 individual study plans (AEA 2012). Section 9.16 of the RSP described the Eulachon Run Timing, Distribution, and Spawning in the Susitna River Study. This section focuses on collecting baseline information regarding eulachon (*Thaleichtys pacificus*), which are an important prey species for the endangered Cook Inlet beluga whale (CIBW; *Delphinapterus leucas*). This study has been designed to support the CIBW Study (Study 9.17). RSP Section 9.16 provided goals, objectives, and proposed methods for data collection regarding eulachon in the Susitna River.

On February 1, 2013, FERC staff issued a study plan determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. RSP Section 9.16 was one of the 31 studies approved with no modifications.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule" (18 CFR 5.15(c)(1)). This Initial Study Report (ISR) on Eulachon Run Timing, Distribution, and Spawning in the Susitna River has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the RSP as approved by FERC's February 1 SPD (collectively referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The goal of the study is to collect baseline information regarding eulachon (*Thaleichtys pacificus*) run timing, distribution, and habitat use in the Susitna River in two years of study. Eulachon are an important prey species for the endangered CIBW; therefore, this study has been designed to support the CIBW Study (Study 9.17). Together with existing information, data collected as part of this study will provide necessary baseline information to address issues identified in the Pre-Application Document (PAD) and assess potential Project effects (AEA 2011).

The objectives of this baseline study are as follows:

1) Determine eulachon run timing and duration in the Susitna River in 2013 and 2014.
2) Identify and map eulachon spawning sites in the Susitna River.
3) Characterize eulachon spawning habitats.
4) Describe population characteristics of eulachon returning in 2013 and 2014.

3. STUDY AREA

As established in RSP Section 9.16.3, the eulachon study extends from the mouth of the Susitna River to the uppermost extent of spawning, which was determined by a combination of telemetry and acoustics to be approximately PRM 60 (Figure 3.1-1). This is within the area sampled daily in 1983 (ADF&G 1984), when few spawning locations were detected below PRM 10.

4. METHODS AND VARIANCES IN 2013

Eulachon field studies were conducted from ice out (May 28) through June 16 in 2013. Acoustic sampling was used at a fixed site in the Lower River to assess the timing and duration of the spawning migration, and assess relative abundance of eulachon. Active capture methods were used to confirm eulachon spawning concentrations, collect information on eulachon population characteristics, and document incidental observations of marine fish species. Telemetry and mobile acoustic surveys were used jointly to identify the distribution of spawning locations in the study area and to evaluate fish behavior on spawning sites. Physical habitat characteristics were measured at confirmed spawning sites.

4.1. Objective 1: Determine Eulachon Run Timing and Duration in the Susitna River

AEA implemented the methods as described in the Study Plan in 2013 with the exception of variances explained below (Section 4.1.3).

Tasks to address Objective 1 included:

- Obtaining indices of passage over time for migrating eulachon using multibeam dual frequency identification sonar (DIDSON) and splitbeam sonar.
- Confirming eulachon presence with active fish sampling.
- Processing multibeam sonar data to provide counts and relative abundance estimates of fish moving upstream over time.

4.1.1. Indices of Passage for Migrating Eulachon

4.1.1.1. Fixed Station Operation

Two types of acoustic equipment were positioned on the right bank at PRM 17.5 to detect migrating eulachon: a standard DIDSON imaging sonar and a BioSonics DTX system with a circular 6° 210 kHz splitbeam transducer (Figure 4.1-1). The site was selected because it was (1) upstream of tidal influence; (2) had a continuous slope of approximately 7 degrees, which provided an unobstructed view over a range of 10 m (32.8 ft); and (3) was near high ground where the acoustic surface units, laptop computer, 12-V battery bank supply, and generator could be placed.

The two transducers were mounted side-by-side on an H-type aluminum frame that allowed adjustments of the elevation and pitch angle for both transducers. The mount was placed in approximately 2.5 ft to 3 ft of water, with the center of the DIDSON lens 5 inches off the bottom, and aimed approximately perpendicular to the river channel. Because both the splitbeam and DIDSON were mounted on the same plate, pitch and elevation were identical for both sonars. The mount was moved with the water level (onshore when the water level was rising) and reset as necessary as the flood eroded and reshaped the sandbar.

A weir constructed of an aluminum frame with vexar plastic mesh was initially placed downstream of the transducer mount. The purpose of the weir was to guide eulachon so they would pass at least 0.7 m (2.3 ft) offshore from the transducer, where the acoustic beams have spread sufficiently to provide adequate coverage and reduce the chance of eulachon shadowing the entire sound field. However, the weir had to be removed for most of the sampling period because flood conditions made it too difficult to keep the weir clean. It also appeared that ripples created downstream of obstructions such as the weir tended to trigger the formation of spawning aggregations.

Data were collected at the fixed sonar station from May 28 through June 14. From June 1 through June 4, equipment was removed from the water because of unstable river conditions. The mobile DIDSON system (see Section 4.2.2.1) was used during this period to collect one or two samples per day from a boat held stationary at the fixed site. Continuous sampling with the stationary sonars was resumed on June 4 after the water level stabilized.

DIDSON data were recorded with DIDSON Viewer Version 5.25.43. After some experimentation with window length, focus, frame rate, and frequency settings, data were recorded with a systematic sampling scheme that cycled between 5 and 10 m (16.4 and 32.8 ft) window lengths, at 10 and 8 frames per second, respectively, 3 minutes each, every 15 minutes, providing a total sampling time of 24 minutes per hour. To assess the effect of frame rate and absorption, samples recorded with a 10-m (32.8-ft) window length alternated between high (1.8 MHz, 96 beams) and low (0.8 MHz, 48 beams) frequency modes. For the 5-m (16.4-ft) window, all data were recorded in high frequency mode (because over a short-range absorption frame rate limitations are negligible).

Splitbeam data were acquired with Visual Acquisition Version 6.0. Data were recorded continuously with a -70 dB threshold, 10 m (32.8 ft) maximum range, 20 pings per second, and a 0.2 ms pulse length.

4.1.1.2. Data Summary and Analysis

Raw DIDSON data were pre-processed in DIDSON Viewer 5.25.43, using its dynamic background removal function to remove static image background (i.e., reflections from the river bottom). Preprocessed files were loaded into Echoview for further image processing, target detection, and tracking. The images were smoothed with a 3x3 median convolution. The goal of the convolution was to join image pixels ("pixel" is used synonymously with acoustic data sample) that belong to one object (e.g., fish) into one contiguous group of pixels that are brighter than the surrounding background. To reduce problems with overlapping traces created by fish detected at the same range, the images were truncated to a 15° field of view. Targets were detected as contiguous samples with intensity >7 dB (low frequency images) or 9 dB (high frequency images). The detection threshold was chosen such that it produced detections whose outlines provide, on average, a good match with a visual perception of the outline of the fish image.

Next, the detected targets were filtered to eliminate as many false targets (e.g., noise created by forward scatter) as possible while retaining as many true fish targets as possible. The filter parameters differed depending on the final processing steps. Target tracking is more robust than density-based estimates with regard to gaps in the series of images that are produced by an individual fish over successive frames (as it moves through the 96 beams). Therefore, data files that were further processed with tracking used a target threshold of 14 cm (5.5 inches) (only targets estimated to be >14 cm (5.5 inches) are retained). For data files that were processed for density-based estimates a more liberal threshold of 11 cm (4.3 inches) was used, which also retains fish images that are artificially truncated (e.g., through shadowing or on the edges of the beam). The validity of this approach was empirically tested with a subset of the data that was processed both ways. Density and track-based estimates produced results that were in good agreement with one another and with a visual inspection of the tracking results (compared to a visual perception of individual fish passing through the beam).

The final DIDSON processing step involved one of two methods: fished tracking or density-based passage estimation (Table 4.1-1). For low to moderately high passage rates (<20,000 fish/hr) fish tracking was used. Fish echo traces were tracked with Echoview's implementation of an α-β-tracking algorithm, which tracks systematic movement of the target. The purpose of tracking is to group each series of echoes that has been returned by an individual fish. The total number of detected fish tracks thus equals the number of fish observed over the time period sampled. Tracking parameters (α, β, exclusion distance, weights and track acceptance criteria) were empirically adjusted to provide the best tracking performance for a given set of data files. Tracking results were exported and summarized in Excel. The number of fish tracked was expanded in proportion to the time sampled to provide estimated passage rates (fish/hr).

At very high passage rates fish are so densely spaced that the tracking algorithm tends to join adjacent fish, thus underestimating the total number of fish. The team therefore explored a density-based approach as an alternative for high passage rates (>20,000 fish/hr). To assess the accuracy of this alternative method the team examined a subset of the data, which spanned a range of passage rates and for which the team had good track estimates. For the density-based approach, fish passage was estimated as:

$$p = \frac{\sum_{i=1}^{n} x}{n} \times \frac{\bar{w}}{\bar{s}} \times 3600$$

Where

p is the estimated number of fish per hour

x is the number of targets detected on frame i

n is the number of good frames, i.e., frames that are not compromised by noise or fish blocking the image

$\bar{w}$ is the width (m) of the examined field of view at the average range of all targets detected in all good frames (in the given hour)

$\bar{s}$ is the average speed of a subset of fish tracked (m/s)

Splitbeam data were processed in Echoview 5.3. Data were edited to remove signals from the river bottom (i.e., stationary line on echogram) and salmon-sized fish. The edited data were analyzed with echo integration. Echo integration is a well-established fish quantification technique that is based on the concept that the total amount of echo energy is proportional to the density of targets in the ensonified volume of water (Simmonds and McLennan 2005). It is typically used for down-looking mobile surveys of schooling fish. The same principle can be applied to side-looking data.

Data were echo integrated with a -40 dB threshold, over cells spanning 1 hour periods and 5 m range strata, to generate areal backscattering coefficients (i.e., an unscaled, relative measure of fish density). To evaluate the echo integration results and determine an appropriate scaling factor, the team examined the relationship between the areal backscattering coefficients and density-based DIDSON estimates of data from a 4-day period (6/6 18:00 – 6/10 19:00) of high passage (20,000 – 100,000 fish/hour) that was not compromised by spawning and milling activity. The echo integration scaling factor was derived from the slope and intercept of a linear regression through the paired data points ($R^2 = 0.6$).

4.1.2. Active Fish Sampling

4.1.2.1. Standardized Dipnetting

Dip nets were used to collect eulachon in the lower Susitna River to (1) help verify species composition and overall representativeness of fixed-station sonar results, (2) collect fish for radio telemetry (Section 4.2.1), and (3) describe eulachon population characteristics (Section 4.4). Sampling sites ranged from PRM 11.0 to PRM 19.2 (Figure 3.1-1).

Because of the extremely late ice break-up in 2013 (officially May 20 at Sunshine Creek, but ice still covered most of the river upstream of PRM 15 on this date), limited opportunistic dip-net sampling was conducted when possible prior to and during break-up to detect any early-running eulachon. Sampling was conducted on May 9, May 20, May 22, and May 25 at a number of sites between PRM 11 and PRM 17.5 where ice was absent. This early sampling was not standardized; however, some sites were sampled on multiple days.

Standardized sampling was initiated on May 31 and initially was limited to the right bank at PRM 17.5 and the left bank at PRM 17.7 to be near the fixed sonar station. At each site, a 10-m by 20-m (32.8-ft by 65.6-ft) grid was established and divided into eight cells (5-m by 5-m [16.4-ft by 16.4-ft] each). Each cell was assigned a number and two cells at each site were randomly selected to sample each day. Cells were fished by one or two dipnetters using standard eulachon dip nets. Fishing duration often varied based on catch (high densities of eulachon sometimes resulted in large catches in a short time).

Sampling near the right bank at PRM 17.5 continued to track with sonar estimates through the end of the season, despite the presence of large aggregations of spawning eulachon early in the season. Sampling was terminated on June 15 when catches diminished. Sampling on the left bank at PRM 17.7 began June 1 and ceased after June 5 when this site also started being used by eulachon for spawning.

To continue daily sampling at a site not being used for spawning, the site at PRM 17.7 was replaced on June 6 by a site on the left bank at PRM 19.2. The bottom profile at this site was a steep drop-off along a cut bank, in contrast to a gradual slope at PRM 17.5 and PRM 17.7, and was not utilized by eulachon for spawning. A grid was not established at PRM 19.2, but a standard location was sampled daily.

Sex was determined and fork length (nearest mm) was measured from a subsample of eulachon captured each day throughout the run (Table 4.1-2). Otoliths were collected from a subsample of fish daily. Stomachs of fish sacrificed for otolith collection were examined, with some retained for subsequent analysis if not obviously empty. Fin clips for genetic analysis were also collected from a subset of these fish. Other fish species captured were identified, counted, and measured. Water temperature and water depth were recorded daily at each sampling location.

Beginning June 12, by which time catches at PRM 17.5 and PRM 19.2 had diminished, sites downstream from PRM 17.5 were sampled to determine if eulachon were still entering the river, and to identify potential sampling locations for the next year of study. Grids were not established.

4.1.2.2. Data Summary and Analysis

Daily CPUE from non-spawning sites along the left bank of the river was calculated for qualitative comparison of relative density to sonar findings. Species composition of the catch was summarized at each sampling location, including length, weight, and sex ratios. Daily sex ratios, mean length, and weight were also calculated to determine sex-specific differences, as well as differences in the run over time.

Catches of non-eulachon species were documented and sex and length were recorded when possible. Incidental catches of marine species were documented and measured for length (see Section 4.4.3.1).

4.1.3. Variances from Study Plan

RSP Section 9.16.4.1.1 provided that the study team would construct a blocking weir around the sonars to exclude eulachon from the 70–100 centimeter (27–39 inch) range in front of the sonar face. Instead, the weir had to be removed for most of the sampling period because flood conditions made it too difficult to keep the weir clean. It also appeared that ripples created downstream of obstructions such as the weir tended to trigger the formation of spawning aggregations. When flow conditions stabilized, useful information was collected by the sonar without the weir in place and the study team was able to meet the objective of using the sonar to develop indices of passage over time for migrating eulachon. Placement of the weir in the next year of study will depend on flow conditions.

RSP Section 9.16.4.1.3 provided that AEA would measure water velocity weekly at the fixed sonar site. Water velocity measurements have been used as a surrogate for the swim speed of downstream-migrating fish in conversions of density to flux (fish passing per unit time). However, in the case of upstream migrating eulachon, using water velocity in the density-to-flux conversion would not be appropriate. Because swim speed of individual eulachon as they were moving through the beam could be tracked, no surrogate was needed, and thus the study team did not collect water velocity measurements at the fixed sonar station. Indices of fish passage over time were developed without the use of this data in accordance with Objective 1.This change will continue in the next year of study.

RSP Section 9.16.4.1.2 provided that AEA would conduct standard sampling with dip nets and/or gillnets to assess representativeness of results from the fixed sonar site. This sampling was expanded in 2013 to include sampling before the fixed site could be installed due to ice and flow conditions. Also, during the operation of the fixed site, fish sampling in 2013 was not restricted to the fixed sonar station because that location became a spawning site. Other sites where fish did not seem to be spawning, but were passing through, were sampled to more effectively estimate run timing and CPUE. Study objectives to estimate run timing and passage indices were still achieved, as all sampling supported evaluation of the representativeness of the fixed sonar station results and the evaluation of run timing in the Susitna River. Sampling at multiple sites will continue in the next year of study.

RSP Section 9.16.4.1.1 provided that AEA would collect sonar data at the fixed site until after June 10, or no eulachon were detected at the fixed site, or during nearby sampling for five consecutive days. Given the peak estimates of passage from sonar (>100,000 fish per day) and CPUE (875 fish per minute of dipnetting), sampling for five consecutive days with zero catch would have been costly and uninformative. Instead, AEA discontinued sampling after June 15, by which time sonar detections had become minimal, and CPUE at PRM 17.5 had been below two fish per minute for five consecutive days. Sampling at alternative (non-spawning) sites also yielded less than two fish per minute on these days. Sampling in the next year of study will also cease after CPUE is below two fish per minute for five consecutive days as described in Section 7.1.1.

4.2. Objective 2: Identification and Mapping of Potential Eulachon Spawning Sites

Tasks to address Objective 2 included:

- Locating possible eulachon spawning sites using radio telemetry.
- Identifying likely eulachon spawning sites using multibeam sonar (DIDSON).
- Confirming the presence of spawning eulachon through active fish sampling methods.
- Mapping confirmed eulachon spawning sites.

Radio telemetry, visual observations, acoustics, and active fish sampling methods were used to identify eulachon spawning sites. Radio telemetry was used to follow tagged fish throughout the river, visual observations helped identify concentrations of fish, and acoustics were used to document fish behavior. Eulachon were tagged in the Lower River and then tracked with aerial surveys, using a similar approach to that described in Salmon Escapement Study, Section 9.7.

Initial and final distributions of tagged fish were calculated using the same approach and software as in the Salmon Escapement Study.

Prospective spawning sites were further investigated using a combination of multibeam sonar (DIDSON) and active sampling. DIDSON sonar was used to obtain video-type images of eulachon behavior and to observe fish passage at spawning sites. Fish sampling with dip nets confirmed that detections were eulachon and allowed for assessment of spawning condition, fish sex, and length.

4.2.1. Identifying Potential Spawning Locations Using Radio Telemetry

4.2.1.1. Fish Capture and Tagging, sample sizes

Eulachon to be radio-tagged were captured at different locations in the lower Susitna River to increase the chance of tagged fish representing different potential run components. All eulachon to be tagged were captured with a dip net constructed of 1/4-inch knotless nylon mesh with a 24-inch deep bag (Model 3544 made by Frabill, S. Plano, IL). Eulachon to be tagged were selected immediately upon capture and only tagged after found to be vigorous, free of obvious injuries, and in pre-spawning condition (Spangler et al. 2003).

For each tagged eulachon, time of fish capture, tagging start time, and time of release back into water were recorded. Each tagged eulachon was also measured for body length (nearest mm) and classified for sex. Presence of gametes (milt or eggs) was used to verify fish had not completed spawning. Fish processing time was considered the difference between the tagging start time and final release into water, and recorded in seconds (Figure 4.2-1). To reduce handling stress and aid recovery, fish were tagged as soon as possible after capture (not held and tagged in batches), and returned to the water at a site with velocity shelter.

In total, 207 eulachon were radio-tagged in 2013 (Table 4.2-1). Based on a preseason power analysis, a given spawning site containing 2.5 percent of the run would have a 97 percent likelihood of receiving one tag from a release group of 150 tags. For sites with 5 percent of the total run, this likelihood rises to >99 percent. The study team attempted to further increase these likelihoods by tagging 50 additional eulachon (to account for potential tag loss) and by tagging at different sites (to reduce the chance of over-tagging fish bound for only one area). It is important to note that the goal of this study component was to identify locations of the main spawning areas used in 2013.

Radio tags used were model MST-720, manufactured by Lotek Wireless Inc. (Newmarket, Ontario). Tags measured 7-mm by 18-mm (0.28-inches by 0.71-inches), weighed 1.3 g (0.46 oz), and had an estimated 29-d battery life at a pulse rate of 4.0 or 4.5 seconds. Radio tag codes were split evenly between two frequencies: 151.340 and 151.360 MHz. Tags were gastrically implanted into the eulachon without anesthetic, following the methods used by Spangler et al. (2003) when tagging eulachon on the nearby Twentymile River. Based on the 95 percent range of fish weights sampled in 1982 and 1983 (ADF&G 1984; Vincent-Lang and Queral 1984), the tag weighed 1.8 to 2.3 percent of the body weight of Susitna River eulachon.

Tag retention and mortality were also assessed by comparing a test group of tagged and a control group of untagged fish, each held for 48 hours in separate, adjacent totes submerged in the river. The test group of 12 radio-tagged fish was held from June 10 to 12, 2013. The control group of 17 untagged fish was held from June 11 to 13, 2013. All fish were checked for mortality and tag loss every 24 hours. An additional three radio-tagged fish were added to the test group for the last 24 hours.

4.2.1.2. Aerial Survey Operation

Aerial surveys were flown on 12 dates in 2013 to track tagged eulachon, starting on May 31 and ending on June 18 (Table 4.2-2). All surveys were conducted upstream of PRM 10 (the electrical power line crossing the river), and typically covered 25 to 35 river miles in a day. By mid-season, the spread of tag detection locations meant that two days were needed to survey potential tag locations; these surveys were typically split at PRM 10 through PRM 46.5 on the first day and from PRM 31 through PRM 57.5 on the second day. The Yentna River was surveyed up to the Yentna fixed telemetry station, and the mainstem Susitna River was surveyed to at least PRM 46.5 on all surveys (Table 4.2-2). All potential mainstem habitats (mainstem, side channels, and sloughs) were flown, including the West Channel (into which Alexander Creek drains), Kroto Slough, and several unnamed sloughs that are newly formed (Figure 4.2-2).

Aerial surveys ended following review of the data from the flight on June 18. This survey was flown to check for any fish moving undetected upstream of the Willow fixed station, and had complete coverage (including all side channels and sloughs) up to PRM 67, and partial coverage (main channel) up to PRM 98 (Talkeetna). No tags were detected.

For all surveys, a 4-element yagi antenna was externally mounted to the helicopter’s skid racks, then connected via coaxial cable and splitter to two Lotek SRX-400 telemetry receivers operated by a biologist inside the helicopter. Each telemetry receiver was programmed to a single frequency; receivers were monitored visually and via headphones. Tag frequency, tag code, signal power, and time of detection were automatically recorded by the SRX-400 for each tag detection, while the entire flight track was recorded with a global positioning system (GPS; Garmin model 590). Early in the season, a second biologist also recorded tag detection information in writing as backup to verify correct recording by the SRX-400. Radio detections were time-stamped, then later synced to the GPS to record position. The first survey was flown with a Robinson R44; all subsequent surveys were flown with a Jet Ranger. Surveys were typically flown at an altitude of approximately 200 to 300 ft and at a speed of 50 to 60 knots (kts). When a tag was detected, the area was re-flown with reduced speed and altitude lowered to attain a more precise detection location. Gain was adjusted throughout the survey though was typically 62 to 72. Radio interference in the lower river (likely originating from military sources) necessitated the gain be lower in the lower river, especially on frequency 151.340 MHz. Upstream of the confluence of the Deshka River, the gain was increased to extend survey detection range.

4.2.1.3. Fixed Telemetry Station Operation

Fixed telemetry stations were established at three sites to help detect any tagged fish moving out of the study area and to help guide aerial surveys. The first station (“Gateway”) was located at

PRM 17.5, which was the most downstream constriction of the mainstem river and captured all the river channel except for one side slough (Figure 4.2-2). The purpose of this station was to help document tags and to detect tagged fish dropping down out of the study area. The station was unable to fully serve this latter purpose because it could not simultaneously be located at the bottom of the spawning and tagging areas and still be in a part of the river where it covered the entire channel. The second fixed station ("Willow") was located at PRM 52.5, and was the most upstream station. The purpose of this station was to detect tags moving upstream of the expected range of spawning. The third fixed station ("Yentna") was 5.6 river miles up the Yentna River. The purpose of this station was to detect any fish migrating out of the study area via the Yentna River; the station needed to be as high up the Yentna River as it was because of a slough that connects the Yentna and Susitna rivers (Figure 4.2-2).

Each fixed telemetry station consisted of a receiver (Lotek model SRX-400), a power supply (a 12-volt battery charged by a 50-watt solar panel), and one or two antennas. Fixed stations were visited every 3–5 days to download tag data and maintain the station. One reference radio tag (frequency 151.380 MHz) was kept at each fixed station to maintain a record of operation and ensure that a lack of tag detections accurately reflected an absence of detectable tags. During fixed station installation at the Gateway station, tags along the opposite bank of the river were used to measure range of detectability and adjust gain settings. The resulting settings were used at all fixed telemetry stations.

4.2.1.4. Data Summary and Analysis

Aerial survey data were processed briefly during the season, then more extensively after the season. During the season, aerial survey data were imported into ArcGIS Explorer (ESRI, Redlands, CA) and plotted to help guide in-season aerial and mobile sonar surveys for eulachon. After the season, data were further analyzed to identify final destinations of tagged fish, which were taken as the best indication of potential spawning locations.

In-season, the telemetry crew was able to guide mobile sonar crews to locations of radio tag detections. After each survey, tag detections were discussed with the mobile sonar crew using ArcGIS Explorer and maps, and GIS maps were created to identify areas to explore further. During some surveys, the telemetry crew was also able to signal the mobile sonar crew when multiple fish were detected nearby.

Postseason, Telemetry Assessor ™ (LGL Limited, Sidney BC) was used to screen all aerial tag detections and identify the highest-power detection of each tag during a given survey. Data were then imported into Microsoft Excel and visualized with ArcGIS Explorer. From there, tags were filtered based on upstream movement after tagging, number of surveys detected, repeat detections in the same location, and presence within clusters of other tags. All of these were used to identify final destinations of tagged fish and thus potential spawning sites.

The migration behavior of individual fish was the first way potential spawning locations were identified. Potential spawners were identified by filtering for only those fish detected upstream of their original tagging site. Then, each aerial detection of these fish was placed into one of three categories based on its movement since the previous detection: ascending for fish that had moved upstream, descending for fish that had moved downstream, or static for fish that remained within 500 m (1,640 ft) of their previous detection. The purpose of the static category was to allow some uncertainty before classifying a movement as ascending or descending. Locations classified as descending were then removed from the analysis. The study team also removed static locations that followed a descending detection, because these had an increased chance of being carcasses. Potential spawning locations were considered to be the most upstream of the ascending locations of each fish, plus any remaining location within 200 m (656 ft) of another (by that same fish) on other surveys. The final list of these locations was plotted as the potential spawning locations identified from the detection histories of individual fish.

The second approach to identifying potential spawning locations was based on spatial clustering of detections from all pooled fish (instead of separate detection histories of individual fish). As with the first approach, only fish detected upstream of their original tagging site were included. Detections of these fish were then classified as ascending, descending, or static, and detections that were descending and static following a descent were dropped from the analysis. All remaining ascending or static locations were then plotted for all fish combined, and a 100-m (328-ft) buffer was created around each point. All overlapping buffers were identified, and a polygon was created to capture each group of overlapping points and their 100-m (328-ft) buffers. The resulting polygon was considered a spawning cluster. Each spawning cluster was numbered and assigned a position based on its geographic center. The number of fish in each cluster and its location in the main channel or a side channel were reported. No attempt was made to differentiate whether fish within these polygons were spawning or just holding.

4.2.2. Confirming Spawning Locations

4.2.2.1. Mobile Sonar Surveys

At potential spawning sites, a boat-mounted DIDSON imaging sonar (standard model) was used to capture images of eulachon behavior. The DIDSON transducer was attached with an X2 dual axis rotator on a pole mount that allowed easy deployment over the side of the boat (Figure 4.2-3). The rotator provided control over the pan and tilt angle of the sonar. To have a sufficiently stable platform, data were collected with the boat anchored or tied off onshore. DIDSON was normally deployed for 10 minutes.

Depending on the physical characteristics of the site to be surveyed, the system was deployed in one of two configurations. At sites where the riverbank had a gentle slope, eulachon were typically spread out over several meters, which permitted observation with the DIDSON mounted on the offshore side of the boat looking out toward the river. However, at steep cut banks, the current typically forced eulachon to stay very close to shore (<1 m [3.28 ft]). In these situations, to view eulachon at a sufficient range (>0.5 m [1.64 ft]), the DIDSON transducer was lowered deep enough to aim back to shore underneath the hull of the boat. The rotator allowed a quick move through 360° of pan and 90° tilt to find the optimum aim for viewing.

Data were recorded with DIDSON Viewer Version 5.25.43. The startup range and window length were adjusted depending on the range interval where fish were seen; the frame rate was set to the maximum the system was able to maintain. A minimum of 5 minutes of data were collected at each site. All acoustic data were time-stamped and geo-referenced. Geo-referenced analysis results were provided in a format compatible with ArcGIS.

4.2.2.2. Fish Sampling

When acoustic surveys identified concentrations of fish that were likely to be spawning eulachon, dip nets were used to confirm species identification and assess spawning condition.

Criteria from ADF&G (1984) were used to confirm spawning sites:

1. Fish captured at the site freely expel eggs or milt.
2. Fish are in vigorously free-swimming condition.
3. Twenty or more fish are caught that meet criteria 1 and 2 above.

Station ID, location, date, time, eulachon presence/absence, and a description of fish behavior (i.e., moving in continuous band, discrete schools, milling, spawning) were collected at each site. In addition, eulachon were sexed and measured for fork length (mm).

4.2.2.3. Data Summary and Analysis

All acoustic data were geo-referenced and time-stamped. For each site, a qualitative description of fish behavior seen in the DIDSON footage was recorded, together with date, time, and coordinates of the sample, and some example video clips. Length and sex ratio were summarized for all fish caught during spawning site surveys and length was compared between sexes. Sex ratio was also calculated at each site to determine site-specific differences over time. Locations of confirmed spawning sites were compared to locations where radio telemetry tagged fish were observed.

Post season, the identification of potential spawning areas using radio telemetry (both cluster and individual sites) was assessed by examining how many areas in the Susitna River had been assessed by mobile sonar and visual surveys, and whether spawning was confirmed. Telemetry sites were considered to have been visited if surveyed to within 200 m. Conversely, the number of spawning sites confirmed by sonar and visual surveys at which radio-tagged eulachon had not been detected was summarized.

4.3. Objective 3: Eulachon Spawning Habitat Characteristics

Tasks to address Objective 3 included:

- Determining the feasibility of using acoustics to identify substrate composition at eulachon spawning habitats:
    - Estimating substrate composition using side scan sonar.
    - Verifying accuracy using bottom grab samples and visual surveys.
- Describing physical characteristics of spawning habitats, including water quality parameters, depth, and velocity.

4.3.1. Feasibility of Acoustics to Determine Substrate Composition

4.3.1.1. Side Scan Sonar

A boat-mounted EdgeTech 4125 600/1600 kHz high-resolution side scan sonar was used to provide images of the substrate and to test if it could detect migrating eulachon. Sites were surveyed with the towfish deployed on a davit off the shore-side of the boat, with the boat moving upstream, parallel to and approximately 20 m (65.6 ft) from the shoreline. Depending on image quality, data were collected either in low or high frequency mode.

4.3.1.2. Grab Samples and Visual Surveys

An Ekman Bottom Grab Sampler and visual surveys were used to classify substrate at each spawning site. Grab sampling was discontinued early because the sampler drifted downstream in the current, even in low flows, such that a reliable substrate sample could not be collected. Visual surveys were therefore the primary method used (Table 4.3-1). Overall substrate composition was recorded based on substrate characterization protocols of the Instream Flow Study (see RSP Section 8.5).

4.3.1.3. Data Summary and Analysis

Side scan data were reviewed in EdgeTech Discover 7.10. The fixed and time-varied gain of the side scan images were adjusted to provide the best contrast over the range sampled. Images were corrected for speed and slant range. Sites were categorized as sand or gravel based on their similarity to images collected at three sites of known substrate composition (submerged sandbar, sand waves, gravel).

Analysis of the side scan sonar data was limited to visual review, the preparation of sample images, and a qualitative description of each site because little variation in substrate type was found within sites. Preliminary acoustic substrate classifications were qualitatively compared to classifications from visual surveys.

4.3.2. Physical Characteristics of Spawning Habitats

4.3.2.1. Water Quality and Physical Habitat

A YSI® meter for pH, water temperature, dissolved oxygen, and specific conductance was used to assess water quality (Appendix Table A-1). Turbidity samples were collected in amber glass vials and analyzed every evening with a Hatch Turbidimeter. Water quality data were collected once at each spawning location for each survey (Table 4.3-1; Appendix Table A-2).

Aquatic habitat was recorded to the mesohabitat level based on the Project mesohabitat classification system. Water depth at spawning locations was measured with a metric stadia rod and water velocity was measured with a velocity flow meter (measured in feet per second). Water depth and water velocity were collected at three randomized locations along the length of the spawning habitat. Some spawning locations were not wadeable because of depth or current, so water quality measurements were taken from the boat in these conditions.

4.3.2.2. Data Summary and Analysis

Water quality parameters were summarized and compared among sites to facilitate description of preferred water quality characteristics. Water velocity and depth at each site were averaged from the three samples. Correlation analyses were used to evaluate the relationship between water temperature and run timing.

4.3.3. Variances from Study Plan

RSP Section 9.16.4.3.3 provided that AEA *may* use a grid system for the collection of water depth and water velocity data at confirmed spawning locations. At many sites, this was not feasible because of swift current, precarious boat anchoring, or the inability to wade the area safely (i.e., along a cut bank). Instead, these conditions necessitated that the study team collect measurements directly from the boat and a grid design was not used to sample spawning site water depth and water velocity. Depth and velocity measurements were taken at random from three areas of each spawning site. This randomized sampling approach still allowed characterization of spawning habitat in accordance with Objective 3 of the study, and will be used again in the second year of study.

4.4. Objective 4: Eulachon Population Characteristics

Tasks to address for Objective 4 included:

- Determining present baseline population characteristics.
- Collecting baseline genetic samples.
- Documenting incidental observations of marine fish species.

Describing baseline population characteristics was a main focus on 1980s studies; however, subsequent data indicate that population characteristics such as age may have changed since that time (Shields and Dupuis 2012). Additional data were collected to establish current baseline biological characteristics and archive genetic samples.

4.4.1. Baseline Population Characteristics

4.4.1.1. Fish Sampling

During active fish sampling to confirm presence of eulachon in the Lower Susitna River (Section 4.1), sex and spawning condition of all eulachon collected were documented. Fork length and weight were measured, and otoliths were collected from a maximum of 30 pre-spawn eulachon of each sex daily (Table 4.1-2). Stomach samples were collected from a subset of eulachon retained for otolith extraction. Stomachs were evaluated for fullness, and then for diet if feeding was suspected.

4.4.1.2. Data Summary and Analysis

Information on fork length, weight, and sex was used to build length and weight frequency distributions by sex for migrating fish. Sex ratios were determined for each sampling day. Two-sample t-tests were used to determine differences in length and weight between male and female eulachon.

Age data determined from otolith examination were used to assess age-length and age-weight relationships, track age classes throughout the run, and determine sex-specific age differences. Otoliths were aged following the protocol developed by Spangler et al. (2003) and Moffitt (1999). Otoliths were viewed with a stereomicroscope attached to a computer monitor, allowing several people to view otoliths at the same time. Otoliths were submerged in water to reduce glare and placed on a black background to improve contrast between the translucent and opaque zones. The age of fish was assigned by counting the translucent zones radiating out from the primordium. At least two regions on the otoliths were counted, and if the counts from the first two regions did not agree, a third was counted. If two of the three areas had the same count, this became the assigned age; otherwise, the process was repeated. Three individuals read all of the otoliths with the most common age assigned to each fish.

4.4.2. Baseline Genetic Samples

In support of the ADF&G's development of genetic baselines for various species, genetic samples from a subset of eulachon were collected (Table 4.1-2). Genetic samples consisted of anal fin clips cut from the fish with scissors. Tissue samples were preserved in ethyl alcohol in a 125–500 ml (7.6–30.5 in^3) bulk sample bottle for each site. Samples were delivered to the ADF&G Gene Conservation Laboratory for archiving and potential future analysis.

4.4.3. Marine Fish Observations

4.4.3.1. Fish Sampling

Because walleye pollock (*Theragra chalcogramma*), yellowfin sole (*Limanda aspera*), saffron cod (*Eleginus gracilis*), and Pacific cod (*Gadus macrocephalus*) are designated as primary constituent element (PCE) species for CIBWs, their occurrence in the Susitna River is of special interest to the Project for impact analyses. Marine fish caught while sampling for eulachon as described in Section 4.1 were identified, and any fish in question were photographed for later identification by a marine species expert. Marine fish were measured (either fork length or total length [tip of the snout to tip of the caudal fin]; nearest millimeter).

4.4.3.2. Data Summary and Analysis

The Study Plan required that marine fish caught while sampling for eulachon as described above and under Objective 1 would be identified, and any fish in question would be photographed and identified later by a marine species expert. All marine fish would be measured (either fork length or total length [tip of the snout to tip of the caudal fin]; nearest millimeter). Catch per unit effort would be calculated for all fish species. All information regarding marine fish species presence in the Lower Susitna River would be shared with the Fish Distribution and Abundance in the Middle and Lower River Study (Section 9.6).

As noted below in Section 5.4.2, there were no marine fish observations in 2013.

4.4.4. Variances from Study Plan

No variances to the Study Plan were implemented in 2013 for this objective.

5. RESULTS

Data developed in support of this study are available for download at http://gis.suhydro.org/reports/isr:

5.1. Objective 1 – Eulachon Run Timing and Duration

5.1.1. Fixed Sonar

Information from fixed-station sonar (and from dipnetting) indicated that the bulk of the eulachon run in the Susitna River occurred between May 28 and June 16 in 2013. The run peaked between June 6 and June 8.

Acoustic data collection at the fixed site began on the evening of May 28 and ended the morning of June 14. Data collection was temporarily impeded because of high water from June 1 through June 4 (Figures 5.1-1 and 5.1-2). Continuous sampling with the stationary sonars resumed on June 4 after the water level stabilized and began to recede. In addition, a high level of eulachon milling and spawning activity between May 31 and June 5 precluded meaningful passage estimates.

Even at very high passage rates (80,000 fish/hr), migrating eulachon were often sufficiently spaced to resolve individual fish on the DIDSON images and derived echograms (Figure 5.1-3). At low and moderately high densities (< 20,000 fish/hr) the echo traces tracked well (Figure 5.1-4). Splitbeam data show a meandering band of migrating eulachon (Figure 5.1-5.). The time series of the passage estimates (Figure 5.1-6) shows passage rates on the order of 1,000 fish/hr or less toward the beginning and the end of the sampling period, which is two orders of magnitude less than the passage rates observed June 6 through June 8 (approximately 40,000 – 100,000 fish/hr).

Comparison of the three types of acoustic estimates (track-based DIDSON, density-based DIDSON, and echo integration splitbeam estimates) showed good agreement between the methods over the overlapping range of passage rates for which they were suitable (Figures 5.1-7 and 5.1-8). The good match strengthens confidence in the estimates because each method is sensitive to different types of error. The echo integration results are scaled based on a regression against the density-based DIDSON estimates; however, the relative changes over time in the two data series are independent.

5.1.2. Active Fish Sampling

Opportunistic sampling by dip net prior to ice break-up yielded only one eulachon. A female was collected on May 25 at PRM 17.5. No fish were collected during sampling on May 9 (PRM 17.5), May 20 (PRM 10.5, PRM 14, and PRM 17.5), May 22 (three sites below PRM 15.0), or May 25 (PRM 11.0, PRM 14.0, and PRM 16.0). Sampling consisted of one or two dip nets at each site. Effort at all sites combined was 15 minutes on May 9, 110 minutes on May 20, and 134 minutes on May 25.

Eulachon were sampled at the fixed sonar location (PRM 17.5), as well as at four supplementary passage sites (PRM 11.0, 13.4, 17.7, and 19.2) on the left bank of the river from May 28 through June 15 (Figure 3.1-1). A total of 2,344 eulachon were collected (Table 4.1-2). Four incidental species were also caught, including undifferentiated lamprey, coho salmon, sockeye salmon, and three-spine stickleback (Table 4.1-2). All salmon sampled were juveniles.

Catch at PRM 17.5, which eulachon used for spawning, fluctuated throughout the run and exhibited a series of peaks (Figure 5.1-9). Eulachon daily CPUE at two non-spawning sites was low (<1 fish/min) at the beginning and end of sampling, and peaked on June 7 with a CPUE of 250 eulachon/min (Figure 5.1-9). Trends in CPUE at these two sites tracked closely with trends from the fixed station sonar. No correlation between run timing and water temperature was observed (Figure 5.1-9); however, CPUE began to increase at water temperatures above 7˚C.

Stomachs were examined for all eulachon sacrificed for otolith collection; however, only 11 stomachs were collected for subsequent analysis. All stomachs observed were empty, flaccid, and thread-like.

5.2. Identification and Mapping of Potential Eulachon Spawning Sites

5.2.1. Radio Telemetry

5.2.1.1. Eulachon Capture for Radio-tagging

Fish were tagged each day from May 29 through June 15, 2013, at one of nine different sites used over the course of the season. The number of tags placed daily was increased gradually until the end of historical runs, after which daily tag placements decreased (Table 4.2-1). The tagging team used a variety of information to assess run timing and guide tag placement: catch, effort, and aerial observations of eulachon by the tagging team, communication with the biosampling team, estimates of historical run timing, communication with fishery managers and the consequence of ending the season with tags left over vs. running out of tags before the run ended. Equal numbers of male and female eulachon were tagged on most days. In total, 207 eulachon were tagged (107 males and 100 females; Table 4.2-1). Tagging sites ranged from PRM 11 to 19.5. Eight tagging sites were in the main channel and one was in a side channel (Figure 4.2-2). All fish selected for tagging were vigorous, free of obvious injuries, and appeared to be pre-spawning in that they still contained milt or eggs; these characteristics were similar to those used by Spangler et al. (2003) when radio-tagging fish on the Twentymile River.

After tagging, each fish was inspected for proper tag placement and fish health before release, discarding fish that appeared stressed or with a poorly seated tag. No tagged fish showed signs of injury or tag regurgitation immediately after release. Mean tagging times were 42 seconds for females and 38 seconds for males, with times decreasing as the tagger gained experience (Figure 4.2-1). Fish measuring approximately 210 to 220 mm (8.3 to 8.7 inches) were not tagged early in the season due to the difficulty of keeping the tag from being regurgitated, but began to be tagged around June 5. One biologist tagged 203 of the 207 fish.

5.2.1.2. Tag Retention Testing

Tag retention and tagging effects were evaluated from June 10 to 13, 2013, using eulachon captured in the West Channel. All eulachon evaluated were captured approximately 500 feet downstream of site H5 and carried in buckets to the holding site. Eulachon were tagged identically to procedures during normal operations using the same tags and application procedures, with the exception of a longer transport (causing a longer period of time between capture and release). Sometime on June 9 or 10, fish became scarce in the West Channel and on June 10 most remaining fish had spawned. All fish used in the control group were thus spawned out, and unspawned fish in the test group appeared even more gravid than fish tagged to date in the main study.

Initially, 12 fish were used for the test (tagged) group starting on June 10. After 24 hours, this group was checked for mortality and tag retention, and another 3 tagged fish were added. The first group of 12 fish had one mortality and one tag regurgitation after 24 hours, then an additional three mortalities after 48 hours. The additional group of three fish all survived and retained their tags for the 24 hours tested.

The 17 fish in the control (untagged) group were held for 48 hours starting on June 11, with one check each 24 hours. Of these fish, 9 died after 24 hours and another two died after 48 hours.

5.2.1.3. Eulachon Tracking using Radio Telemetry

Of the 207 tagged fish released, 159 were detected during aerial surveys. Of these 159 fish, 125 moved at least 500 m (1,640 ft) upstream after tagging and were thus considered potential spawners. Tagged fish were detected during aerial surveys between PRM 10 and 44.5 in the mainstem Susitna River, and 3.5 miles up the Yentna River. For the remaining fish, it was impossible to determine the difference between downstream-moving spawners and any sulking or injured fish.

5.2.1.4. Fixed Telemetry Stations

The Gateway fixed telemetry station collected data from May 29 through June 10 and from June 13 through June 25. The station collected partial data on June 9 and 10. In total, 109 unique tags were detected at the Gateway fixed telemetry station. Ascending, descending, and stationary fish were detected.

The Willow fixed telemetry station collected data from June 6 through June 26, near PRM 57.5 on the mainstem river right bank. This station operated continuously with no known outages, and detected no tags.

The Yentna fixed telemetry station operated from May 31 through June 18, 2013, with no known outages. At this fixed station, four unique tags were detected, likely moving upstream and out of the study area. Of these four tags, two were not seen on subsequent aerial surveys and thus the fish likely spawned and died upstream of the Yentna fixed telemetry station. The remaining two tagged fish were later detected in the mainstem Susitna River during aerial surveys.

5.2.1.5. Identification of Potential Spawning Sites Using Radio Telemetry

A total of 130 potential spawning sites were identified using the individual detection history approach. These included one site from each of the 125 eulachon detected upstream of its tagging site, along with a possible second location for 5 of these fish. Five of the sites, representing five different fish, were in the Yentna River downstream of the Yentna fixed telemetry station. The remaining 125 sites, representing 120 different fish, were in the mainstem Susitna River and side channels (Figures 5.2–1a and b).

When these individual detections were integrated among all fish, the team identified 27 different clusters of ascending or static eulachon. All clusters were in the mainstem Susitna River or side channels, ranging from PRM 11.5 to PRM 29.7 (Figures 5.2-1a and b). Each cluster was composed of two to five individual tagged eulachon, except for one cluster of 11 tagged eulachon (Table 5.2-1). Of the 130 sites identified using individual detections, 79 sites made up these clusters.

5.2.2. Confirming Spawning Locations

Twenty-eight spawning locations were confirmed from PRM 10.5 to 50.3 during mobile acoustic and visual surveys. Spawning sites were easily identified by large aggregations of eulachon and confirmed by the presence of males and females in spawning condition sampled with dip nets (Tables 5.2-2 and 5.2-3; Appendix Table A-3). Males were more numerous at 18 of 28 sites sampled (Table 5.2-3). Males were more often observed in spawning condition than females; the proportion of females found in spawning condition increased as the season progressed (Table 5.2-3). Length for all fish sampled ranged from 187 to 247 mm (7.4 to 9.7 inches) (Table 5.2-4). Females were statistically smaller ($p<0.001$) than males at all spawning sites (Table 5.2-4 and Figure 5.2-2). No spawning was observed at three additional sites surveyed late in the season to assess fish presence.

5.3. Eulachon Spawning Habitat Characteristics

5.3.1. Feasibility of Acoustics to Determine Substrate Composition

Substrate type identified through visual surveys matched well to that identified by side scan sonar at all spawning sites (Appendix Table A-4). Side scan imagery showed differences between primarily sand/silt substrate river bottom and primarily gravel substrate (Appendix B). The brightness of the images distinguished between the soft, acoustically absorbent bottom indicative of sand/silt in contrast to a very bright, reflective bottom indicating harder, larger particle substrate. Photographs of the shoreline further confirmed the accuracy of side scan sonar in identifying substrate (Appendix C).

5.3.2. Physical Characteristics of Spawning Habitat

Twenty-eight spawning sites were surveyed from May 29 through June 13 (Figure 5.3-1). Overall spawning site characteristics included shallow water (<1 m (3.3 ft)), slow current (<1 m/s (3.3 ft/s)), and sandy/silty substrate (Table 5.3-1). Eulachon spawned at sites that were either entirely composed of silt/sand substrate, or were a mixture of various sizes of gravel/cobble and silt/sand (Appendix Table A-4). Water temperatures ranged from 5.2 to 10.29 ºC (41.4 to 50.5 ºF), with the warmest temperatures found during the latter part of the spawning season (Appendix Table A-2). Ranges for specific conductance and pH were relatively small, but dissolved oxygen and turbidity values fluctuated greatly (Table 5.3-1) and were site-specific.

5.4. Eulachon Population Characteristics

5.4.1. Baseline Population Characteristics

A total of 2,344 eulachon were sampled from sites located at PRM 11.0, 13.4, 17.5, 17.7, and 19.2 (Table 4.1-2). Males were more numerous than females and composed 54 percent of the catch; the overall male to female (M:F) sex ratio was 1.2:1.0 (Table 5.4-1). Sex ratio varied daily, and was nearly equal on June 6; however, males were more numerous for the duration of the season (Table 5.4-2). Lengths and weights for eulachon differed between sexes (Figures 5.4-1 and 5.4-2; Table 5.4-3). Male eulachon were longer at each age than females (Figure 5.4-3) but heavier than females at age 2 only.

Assigned ages based on examination of 272 otoliths ranged from 2 to 4 years (Table 5.4-4). The most common age class for both sexes was 3-year-olds, comprising nearly 68 percent of the catch. The proportion of 3-year-old males and females was similar; however, females were more often age 2. Both 3- and 4-year-old eulachon were numerous throughout the run (Figure 5.4-4). No 5-year-old eulachon were observed. No timing differences among age classes were observed, though there was a small peak of 4-year-olds on June 3.

5.4.2. Marine Fish Observations

No marine fish were observed.

6. DISCUSSION

6.1. Eulachon Run Timing and Duration

Despite the challenging river conditions, the beginning and the end of the run were captured and a sufficient amount of moderate and high passage data were recorded to confirm the feasibility of using sonar to estimate eulachon passage timing and duration. The three types of acoustic passage estimates (track based DIDSON, density based DIDSON, echo integration splitbeam) were in good agreement over the overlapping range of passage rates for which they are suitable. Each of the three methods is sensitive to different types of error; therefore, the good match increases confidence in the acoustic estimates. In addition, estimates of CPUE and run timing from dipnetting efforts matched well to estimates of fish passage calculated from splitbeam and DIDSON sonars.

The two-part run timing documented in previous studies (ADF&G 1984) could not be confirmed in 2013, although catches in dip nets at the fixed station sonar did have multiple peaks (Figure

6.1-1). Dip-net catches at this spawning site were subject to wide variation resulting from differences in fish behavior (milling, spawning, etc.) at any given time and specific location within the site. Catches at non-spawning sites did not exhibit a bi-modal appearance. Lack of acoustic data during a period of challenging environmental conditions may have precluded detection of two peaks in the eulachon run if these peaks occurred. If the run did lack two peaks, this may have been due to compressed run timing resulting from the late spring break-up. Lack of fish collected during opportunistic sampling prior to break-up reduces the likelihood that an early peak occurred prior to intensive sampling.

Observations made by ADF&G fishwheel crews located at PRM 33.5 support the contention that a late run of eulachon did not occur in 2013. Crews did not observe a second pulse of eulachon. Although migrating fish were observed as late as June 20, sightings were infrequent and included very small numbers (personal communication, Richard Yanusz, ADF&G).

Eulachon utilized a number of sites for spawning in 2013, including both sites initially selected to be sampled to collect migrating fish for confirmation of sonar findings and to obtain information on eulachon population characteristics. New sampling locations were established mid-season to allow collection of data on eulachon that were migrating, but not spawning.

6.2. Identification and Mapping of Potential Eulachon Spawning Sites

6.2.1. Radio Telemetry

The range of potential spawning locations identified by radio telemetry in 2013 matches relatively well with spawning distribution documented in the 1980s. In 2013, potential sites were as low as the study design would allow (~PRM 11.0) and as high as PRM 44.5. These appear similar to the range of historic river miles 8.5 to 50 reported in the 1980s (ADF&G 1984; Vincent-Lang and Queral 1984; personal communication from M. Bourdon, LGL GIS analyst, August 20, 2013). As in the 1980s, the team detected no potential sites upstream of Willow Creek in 2013, and the majority (117 of 130) was downstream from the Yentna River confluence. As in the 1980s, some eulachon moved into the Yentna River, including some that spawned in the lower section and others that moved higher up the Yentna River, out of the study area (ADF&G 1984; Vincent-Lang and Queral 1984).

The 125 radio-tagged fish used to identify potential spawning sites should be considered a minimum number of viable tags, a result of filtering to include those fish likely to give the most reliable information. Another 34 fish were detected but not used because they did not ascend the 500 m (1,640 ft) needed to qualify as an upstream movement. Some of these fish likely spawned within 500 m (1,640 ft) of their tag site based on how much spawning activity was documented in the reaches used for tagging.

Potential sites identified from radio telemetry in 2013 should also be considered a conservative estimate because the detections were filtered to include those most likely to represent spawning fish, and because the study team was restricted from sampling downstream from PRM 10 in 2013 to avoid potential harassment of Cook Inlet beluga whales. It is possible that some of the unused ascending and static tag detections included spawning fish mixed in with post-spawning fish and that some fish spawned downstream from PRM 10 before ever ascending upstream far enough to be tagged.

Radio detections indicate that eulachon migration and spawning behavior in the Susitna River may be more complex than directed linear movements to a spawning site. For example, one fish travelled over 20 miles up the Susitna River after tagging, and then dropped downstream and migrated up the Yentna River. Other eulachon were found twice in places identified as potential spawning sites for other fish, then migrated upstream to another potential spawning site. It is possible these detections represented two spawning events by one individual. Willson et al. (2006) report that individual eulachon may spawn more than once in a lifetime, but note that iteroparity (multiple reproductive events) is not well understood.

Radio telemetry proved to be a viable method for studying Susitna River eulachon. All eulachon tagging sites were on or near spawning sites, so many tagged fish may have had little or no reason to migrate upstream. Despite this, over half the eulachon moved greater than 500 m (1,640 ft) upstream after tagging and many of those moved over 20 km (12 miles). The study team also detected no major issues with tagging females vs. males, addressing a possible concern raised by Spangler et al. (2003) during telemetry studies on the Twentymile River.

The tag retention study provided only modest insight into tag retention and tagging effects because the only fish found near the holding site were noticeably less hardy than fish chosen for tagging. As evidence, there were more mortalities in the control group (11 of 17 untagged fish) than in the test group (4 of 15 tagged fish), suggesting that fish were simply too sensitive to handle at that point.

6.2.2. Mobile Sonar Surveys

The distribution of spawning sites confirmed by mobile sonar and visual surveys also matched well to that found by ADF&G (1984), and in some cases overlapped completely, indicating that eulachon may have some site fidelity over time. Sites ranged from historic RM 4.5 to 50.5 in 1984, compared to PRM 10.5 to 50.3 in 2013. Only 28 spawning sites were confirmed in 2013, whereas ADF&G (1984) found 57 sites. Most historical and current sites were located downstream from the Yentna River confluence, suggesting that eulachon may prefer habitat in this area.

6.3. Eulachon Spawning Habitat Characteristics

Early on, in the extremely muddy floodwater, the low-frequency side scan sonar mode provided good images of substrate because of the lower absorption compared to high frequency. As the silt load of the river started to decrease, the high-frequency mode was able to image the entire range sampled and high frequency became the mode of choice because it produced images with a higher resolution.

Although side scan sonar provided good images of substrate, visual surveys and side scan sonar output files produced similar substrate classifications for all sites. Side scan sonar was able to successfully distinguish between gravel and sand substrate, and in a few cases was able to provide information not obtained through visual assessments (i.e., gravel bar at base of cut bank).

In those cases, the fish were spawning along the cut bank, and not the submerged gravel bar. Side scan sonar is a useful tool to observe differences in river bottom topography; however, visual surveys obtained the same information where fish were actively spawning. Visual surveys should therefore be the primary method for characterizing substrate at spawning sites in the second year of study; however, side scan sonar may prove useful if any spawning sites are found at depths too great to be surveyed visually.

Spawning sites surveyed during this study were similar to those found by ADF&G (1984) in substrate type, velocity, and depth. Eulachon seemed to follow near-shore currents and prefer habitats with moderate flow (less than 1 m/s [3.3 ft/s]), spawn on mostly sand/silt substrate or mixed gravel, and in water less than 1 m (3.3 ft) deep. Crowding mortality occurred at almost every spawning site surveyed, particularly later in the season as more fished moved into areas where fish had previously spawned. This was exacerbated at very shallow sites where dead fish that had not yet spawned littered the shoreline.

6.4. Eulachon Population Characteristics

Eulachon age class composition was similar to that found by ADF&G (1984) in the 1980s; 3-year-olds were the dominant age class, followed by 4-year-olds. Mean length and weight of eulachon sampled during this study were larger than for eulachon sampled in 1984. Sex ratios were also similar, as males were the dominant sex. Males were more frequently observed in spawning condition than females, perhaps indicating that males mature earlier and remain in spawning readiness longer than females.

6.5. Relationship to Other Studies

The eulachon study is interrelated with a number of other studies (Baseline Water Quality – Study 5.5; Water Quality Modeling – Study 5.6; Geomorphology – Study 6.5; Fluvial Geomorphology – Study 6.6; Ice Processes – Study 7.6; Fish and Aquatics Instream Flow – Study 8.5; Salmon Escapement – Study 9.7; and CIBW Study – Study 9.17). In some cases, information from other studies was used to help guide 2013 efforts. In other cases, collaboration with related studies will begin in the second year of study.

7. COMPLETING THE STUDY

[Section 7 appears in the Part C section of this ISR.]

8. LITERATURE CITED

ADF&G (Alaska Department of Fish and Game). 1984. Susitna Hydro Aquatic Studies Report No. 1: Adult Anadromous Fish Investigations May–October, 1983. Anchorage, Alaska.

AEA. (Alaska Energy Authority). 2011. Pre-application document: Susitna-Watana Hydroelectric Project, FERC Project No. 14241. December 29, 2011.

AEA. 2012. Revised Study Plan: Susitna-Watana Hydroelectric Project FERC Project No. 14241. December 2012. Prepared for the Federal Energy Regulatory Commission by the Alaska Energy Authority, Anchorage, Alaska. http://www.susitna-watanahydro.org/study-plan.

Moffitt, S. 1999. *Commercial Fisheries*. Alaska Department of Fish and Game. 7 p. Cordova, Alaska.

Simmonds, J. and McLennan, D. 2005. *Fisheries Acoustics: Theory and Practice*. 2nd Ed. Blackwell Science Ltd., Oxford, UK.

Shields, P. and Dupuis, A. 2012. Upper Cook Inlet commercial fisheries annual management report, 2011. Alaska Department of Fish and Game, Fishery Management Report No. 12-25, Anchorage.

Spangler, E.A.K, Spangler, R.E., and B.L. Norcross. 2003. Eulachon subsistence use and ecology investigations of Cook Inlet. USFWS Office of Subsistence Management, Fisheries Resources Monitoring Program, Final Report No. 00-041, Anchorage, Alaska.

Vincent-Lang, D. and I. Queral. 1984. *Susitna Hydro aquatic studies. Report 3: Aquatic habitat and instream flow*. Chapter 5: Eulachon spawning habitat in the Lower Susitna River.

Willson, M. F, R. H. Armstrong, M. C. Hermans, and K Koski. 2006. Eulachon: a review of biology and an annotated bibliography. AFSC Processed Report 2006-12. NMFS, Juneau AK.

9. TABLES

Table 4.1-1. Methods used in 2013 for processing acoustic data collected at the fixed sonar station (Project River Mile 17.5).

Data Characteristics	DIDSON		Splitbeam
	Fish tracking	Density based	Echo integration
Strengths	Independent of fish speed; Provides information on direction of movement.	Can handle higher densities than fish tracking.	Can handle higher densities than density-based estimation; Does not require individual fish to resolve on the echogram.
Limitations	Breaks down when fish density is too high because the tracks of adjacent fish are more likely to be joined.	Requires information on fish speed; Requires individual fish to resolve on the image.	Requires scaling factor (e.g. derived from comparison with density-based estimates) More error at low densities; Presence of salmon inflates echo integration based estimate more than the other two methods.
Suitable passage rates (fish/hr in 5 m range interval)	< 20,000	< 100,000	20,000 - > 100,000

Table 4.1-2. Total number of fish by species sampled at dipnetting sites from Project River Mile 11.0–19.2 in 2013.

	Eulachon						Incidental Catch			
Date	No. collected	No. weighed/ measured	No. radio tagged	No. otolith samples	No. stomach samples	No. genetic samples	Lamprey (spp)	Coho salmon (*Oncorhynchus kisutch*)	Sockeye salmon (*Oncorhynchus nerka*)	Three-spine stickleback (*Gasterosteus aculeatus*)
May 31	828	738	10	53	11	61	0	1	0	2
June 1	67	67	10	20	0	20	0	0	0	1
June 2	217	217	10	19	0	20	1	0	0	0
June 3	200	200	10	20	0	20	0	0	0	2
June 4	166	166	14	20	0	20	0	0	0	25
June 5	165	156	14	20	0	20	0	0	5	15
June 6	168	93	14	15	0	15	0	0	0	43
June 7	142	142	16	15	0	15	0	0	0	1
June 8	139	139	10	10	0	10	0	0	0	0
June 9	123	123	20	10	0	10	0	0	0	0
June 10	32	32	14	8	0	8	0	0	0	1
June 11	25	25	14	9	0	9	0	0	0	1
June 12	40	40	14	11	0	11	0	0	0	1
June 13	15	15	10	13	0	13	0	0	0	1
June 14	16	16	5	15	0	11	0	0	2	2
June 15	1	1	2	14	0	1	0	0	0	1

Table 4.2-1. Daily tagging locations, numbers, and body sizes of male and female eulachon tagged with radio transmitters in 2013.

				Females			Males			Total
Date	Tag Site	Latitude	Longitude	*n*	Mean length (mm)	SD length	*n*	Mean length (mm)	SD length	*n*
May 29	H3	61.39087	-150.55200	3	225	7.2	3	231	1.0	6
May 30	H4	61.43192	-150.47890	7	228	6.6	7	224	5.7	14
May 31	H5	61.42680	-150.57963	6	222	7.5	4	227	2.8	10
June 1	H11	61.40823	-150.46727	5	227	8.0	5	225	1.6	10
June 2	H6	61.39640	-150.54680	5	228	5.4	5	225	5.1	10
June 3	H5	61.42680	-150.57963	5	224	4.9	5	223	5.0	10
June 4	H7	61.37352	-150.57295	7	226	6.3	7	228	8.1	14
June 5	H11	61.40823	-150.46727	7	225	4.8	7	226	5.9	14
June 6	H7	61.37352	-150.57295	7	226	5.4	7	226	2.9	14
June 7	H8	61.39520	-150.54868	8	228	7.1	8	230	7.2	16
June 8	H8	61.39520	-150.54868	5	228	1.7	5	228	4.8	10
June 9	H8	61.39520	-150.54868	10	222	4.5	10	228	6.2	20
June 10	H8	61.39520	-150.54868	7	219	6.6	7	227	8.4	14
June 11	H8	61.39520	-150.54868	7	222	2.8	7	225	5.0	14
June 12	H9	61.39422	-150.56020	7	223	5.4	7	226	3.9	14
June 13	H10	61.36550	-150.58837	3	214	2.5	7	224	5.2	10
June 14	H10	61.36550	-150.58837	0	NA	NA	5	224	6.3	5
June 15	H10	61.36550	-150.58837	1	213	NA	1	227	NA	2
Total				100	224	6.3	107	226	5.6	207

Table 4.2-2. Summary of aerial survey effort for telemetry component of Susitna River eulachon, 2013.

Survey Date	Aircraft	Start APRM	End APRM	Tags detected (n)	Running total of tags placed	Description
May 31	R44	10	46.5	24	30	Powerlines to Deshka Landing Slough
June 2	Jet Ranger	10	46.5	36	50	Powerlines to Deshka Landing Slough
June 4	Jet Ranger	10	46.5	58	74	Powerlines to Deshka Landing Slough
June 6	Jet Ranger	10	46.5	55	102	Powerlines to Deshka Landing Slough
June 8	Jet Ranger	10	46.5	62	128	Powerlines to Deshka Landing Slough
June 9	Jet Ranger	31	57.5	17	148	Susitna Station to Willow Fixed Station
June 11	Jet Ranger	10	46.5	75	176	Powerlines to Deshka Landing Slough
June 12	Jet Ranger	31	57.5	18	190	Susitna Station to Willow Fixed Station
June 14	Jet Ranger	10	46.5	58	205	Powerlines to Deshka Landing Slough
June 15	Jet Ranger	31	57.5	1	207	Susitna Station to Willow Fixed Station
June 17	Jet Ranger	10	46.5	46	207	Powerlines to Deshka Landing Slough
June 18	Jet Ranger	46.5	66.5	0	207	Deshka Landing Slough to Kashwitna River

[a] Running total of tags overestimates possible tag detections because it includes fish deceased or not in survey area.

Table 4.2-3. Spawning site acoustic surveys compared to potential sites identified from radio telemetry in 2013.

						Distance from nearest potential site identified from radio telemetry	
Spawning site ID	Latitude	Longitude	PRM	Sonar evaluation and active sampling date	Active Sampling Method	Distance (m)	Detection date
1	61.40717	150.46793	17.5	May 29	dip net	83	5-Jun
2	61.50188	150.55199	25.5	May 31	dip net	329	14-Jun
3	61.37842	150.51888	13.6	June 1	dip net	298	14-Jun
4	61.49334	150.57045	25.3	June 1	dip net	254	4-Jun
5	61.50088	150.57139	25.6	June 2	dip net	566	8-Jun
6	61.57277	150.42819	33.4	June 6	dip net	109	9-Jun
7	61.54682	150.53017	29.6	June 2	dip net	66	6-Jun
8	61.37302	150.57472	11.3	June 3	dip net	47	8-Jun
9	61.41581	150.46315	18.2	June 3	dip net	243	2-Jun
10	61.47063	150.51956	22.6	June 3	dip net	252	31-May
11	61.41152	150.46274	17.9	June 4	dip net	60	6-Jun
12	61.43274	150.47868	19.5	June 5	dip net	94	30-May
13	61.44718	150.48115	20.4	June 5	dip net	114	14-Jun
14	61.45693	150.49355	21	June 5	dip net	261	4-Jun
15	61.46864	150.50798	22.3	June 5	dip net	68	8-Jun
17	61.63331	150.36914	39.4	June 6	dip net	1,801	4-Jun
18	61.53751	150.54214	28.8	June 6	dip net	132	8-Jun
19	61.36883	150.59325	10.5	June 7	dip net	83	14-Jun
20	61.43238	150.48557	19.3	June 7	dip net	18	14-Jun
21	61.49193	150.57899	25.2	June 7	dip net	559	8-Jun
22	61.52616	150.56616	27.7	June 8	dip net	114	8-Jun
23	61.61289	150.36998	37.4	June 9	dip net	859	4-Jun
24	61.66857	150.31087	43.1	June 9	dip net	323	9-Jun
25	61.68623	150.30736	44.3	June 9	dip net	205	9-Jun
26	61.75748	150.25575	50.3	June 10	dip net	8,208	9-Jun
27	61.71187	150.27534	46.6	June 10	dip net	3,121	9-Jun
28	61.70347	150.28322	45.8	June 10	dip net	2,105	9-Jun
31	61.55201	150.49042	30.8	June 13	dip net	632	11-Jun

Table 4.3-1. Summary of spawning site habitat mapping effort in 2013.

Site ID	Date	Time	PRM	Maximum Mainstem Flow (cfs)	Survey Method	YSI Data	Turbidity grab sample	Depth & Flow
1	May 29	14:00	17.5	68,400	side scan sonar, visual survey	yes	yes	yes
2	May 31	15:00	25.5	80,300	side scan sonar, visual survey	no	no	yes
3	June 1	10:30	13.6	86,400	side scan sonar, visual survey	yes	yes	yes
4	June 1	14:08	25.3	86,400	side scan sonar, visual survey	yes	yes	yes
5	June 2	12:55	25.6	86,600	side scan sonar, visual survey	yes	yes	yes
6	June 2	11:00	33.4	45,800	side scan sonar, visual survey	yes	no	yes
7	June 2	15:17	29.6	86,600	side scan sonar, visual survey	yes	yes	yes
8	June 3	12:35	11.3	74,600	side scan sonar, visual survey	yes	yes	yes
9	June 3	14:29	18.2	74,600	visual survey	yes	yes	yes
10	June 3	15:17	22.6	74,600	side scan sonar, visual survey	yes	yes	yes
11	June 4	12:00	17.9	57,200	visual survey	yes	yes	yes
12	June 5	11:20	19.5	53,800	side scan sonar, visual survey	yes	yes	yes
13	June 5	12:20	20.4	53,800	side scan sonar, visual survey	yes	yes	yes
14	June 5	13:00	21.0	53,800	side scan sonar, visual survey	yes	yes	yes
15	June 5	13:50	22.3	53,800	side scan sonar, visual survey	yes	yes	yes
17	June 6	12:54	39.4	45,800	visual survey	yes	no	no
18	June 6	16:30	28.8	45,800	side scan sonar, visual survey	yes	yes	yes
19	June 7	10:15	10.5	39,400	side scan sonar, visual survey	yes	yes	yes
20	June 7	13:15	19.3	39,400	visual survey	yes	yes	yes
21	June 7	14:21	25.2	39,400	side scan sonar, visual survey	yes	yes	yes
22	June 8	12:48	27.7	41,200	side scan sonar, visual survey	yes	yes	yes
23	June 9	11:14	37.4	43,400	visual survey	yes	yes	yes
24	June 9	12:53	43.1	43,400	side scan sonar, visual survey	yes	yes	yes
25	June 9	13:40	44.3	43,400	visual survey	yes	yes	yes
26	June 10	12:37	50.3	42,400	visual survey	yes	yes	yes
27	June 10	13:22	46.6	42,400	side scan sonar, visual survey	yes	yes	yes
28	June 10	14:18	45.8	42,400	side scan sonar, visual survey	yes	yes	yes
31	June 13	12:34	30.8	33,000	visual survey	yes	yes	yes

Table 5.2–1. Number, group size, and location of potential clusters of eulachon identified by radio telemetry in the Susitna River, 2013. WGS84 datum. Clusters located within a side channel were not assigned a project river mile.

Cluster number	Project river mile	Latitude	Longitud e	Number of fish	Channel Type
Cluster1	11.5	-150.57558	61.37356	3	Mainstem
Cluster2	12.1	-150.56318	61.37857	2	Mainstem
Cluster3	13.4	-150.54655	61.39715	2	Mainstem
Cluster4	16.9	-150.47399	61.40080	3	Mainstem
Cluster5	14.8	-150.51801	61.40366	2	Mainstem
Cluster6	14.3	-150.53883	61.40374	11	Mainstem
Cluster7	17.1	-150.47066	61.40324	2	Mainstem
Cluster8	†	-150.57219	61.43347	3	Side Channel
Cluster9	19.4	-150.48815	61.43295	2	Mainstem
Cluster10	20.9	-150.49126	61.45314	2	Mainstem
Cluster11	21.4	-150.49471	61.46017	2	Mainstem
Cluster12	†	-150.53079	61.46355	2	Side Channel
Cluster13	21.9	-150.50057	61.46594	2	Mainstem
Cluster14	21.6	-150.48476	61.46556	2	Mainstem
Cluster15	22.3	-150.50968	61.46942	2	Mainstem
Cluster16	23.1	-150.53024	61.47310	4	Mainstem
Cluster17	22.6	-150.51276	61.47498	2	Mainstem
Cluster18	23.5	-150.54103	61.47646	4	Mainstem
Cluster19	24.0	-150.55433	61.48007	4	Mainstem
Cluster20	24.4	-150.56490	61.48268	2	Mainstem
Cluster21	24.4	-150.55574	61.48778	3	Mainstem
Cluster22	†	-150.53082	61.49112	2	Side Channel
Cluster23	26.6	-150.57277	61.51160	2	Mainstem
Cluster24	27.9	-150.54632	61.52863	2	Mainstem
Cluster25	28.7	-150.54356	61.53352	3	Mainstem
Cluster26	29.2	-150.53298	61.53621	4	Mainstem
Cluster27	29.7	-150.52747	61.54610	5	Mainstem
Total				79	

Table 5.2-2. Location, date, and number of fish sampled at spawning sites from May 29–June 13, 2013.

Site ID	Date	Latitude	Longitude	Project River Mile	Sex of sampled fish M	Sex of sampled fish F	M:F ratio
1	May 29	61.407170	150.467930	17.5	31	35	0.89
2	May 31	61.50188	150.55199	25.5	5	6	0.83
3	June 1	61.37842	150.51888	13.6	5	19	0.26
4	June 1	61.493340	150.570450	25.3	12	13	0.92
5	June 2	61.500880	150.571390	25.6	16	8	2.00
6	June 2	61.57277	150.42819	33.4	17	8	2.13
7	June 2	61.546820	150.530170	29.6	19	7	2.71
8	June 3	61.37302	150.57472	11.3	15	10	1.50
9	June 3	61.415810	150.463150	18.2	18	8	2.25
10	June 3	61.47063	150.51956	22.6	19	6	3.17
11	June 4	61.41152	150.46274	17.9	10	15	0.67
12	June 5	61.432740	150.478680	19.5	7	18	0.39
13	June 5	61.447180	150.481150	20.4	15	10	1.50
14	June 5	61.456930	150.493550	21	16	9	1.78
15	June 5	61.46864	150.50798	22.3	17	8	2.13
17	June 6	61.63331	150.36914	39.4	11	14	0.79
18	June 6	61.53751	150.54214	28.8	22	3	7.33
19	June 7	61.36883	150.59325	10.5	20	5	4.00
20	June 7	61.43238	150.48557	19.3	13	12	1.08
21	June 7	61.49193	150.57899	25.2	16	9	1.78
22	June 8	61.52616	150.56616	27.7	21	4	5.25
23	June 9	61.61289	150.36998	37.4	14	11	1.27
24	June 9	61.66857	150.31087	43.1	16	9	1.78
25	June 9	61.68623	150.30736	44.3	10	15	0.67
26	June 10	61.75748	150.25575	50.3	6	11	0.55
27	June 10	61.71187	150.27534	46.6	17	9	1.89
28	June 10	61.70347	150.28322	45.8	17	8	2.13
31	June 13	61.552010	150.490420	30.8	4	2	2.00

Table 5.2-3. Summary of spawning condition of eulachon sampled at each spawning site in 2013.

SITE ID	Date	Project River Mile	Males			Females		
			Pre-spawning	Spawning	Post spawning	Pre-spawning	Spawning	Post spawning
1	May 29	17.5	0	31	0	25	10	0
2	May 31	25.5	0	5	0	6	0	0
3	June 1	13.6	0	5	0	19	0	0
4	June 1	25.3	0	12	0	6	7	0
5	June 2	25.6	0	16	0	1	7	0
6	June 2	33.4	0	17	0	0	8	0
7	June 2	29.6	0	19	0	6	1	0
8	June 3	11.3	0	15	0	3	7	0
9	June 3	18.2	1	17	0	2	6	0
10	June 3	22.6	0	19	0	1	5	0
11	June 4	17.9	0	10	0	6	9	0
12	June 5	19.5	0	7	0	7	11	0
13	June 5	20.4	0	15	0	4	6	0
14	June 5	21.0	0	16	0	2	7	0
15	June 5	22.3	0	17	0	2	6	0
17	June 6	39.4	0	11	0	3	11	0
18	June 6	28.8	0	22	0	0	3	0
19	June 7	10.5	0	20	0	2	3	0
20	June 7	19.3	0	13	0	3	8	1
21	June 7	25.2	0	16	0	4	5	0
22	June 8	27.7	0	21	0	0	4	0
23	June 9	37.4	0	14	0	5	6	0
24	June 9	43.1	0	16	0	4	5	0
25	June 9	44.3	0	10	0	5	9	0
26	June 10	50.3	0	6	0	1	10	0
27	June 10	46.6	0	16	1	1	8	0
28	June 10	45.8	0	17	0	2	6	0
31	June 13	30.8	0	2	2	0	2	0

Table 5.2-4. Summary of length (mm) of eulachon sampled at each spawning site in 2013.

Sex	Mean	SD	Minimum	Maximum	*N*
Male	226.6	± 7.06	193	247	402
Female	219.8	± 8.21	187	238	292
All fish	223.7	± 8.31	187	247	694

Table 5.3-1. Summarized water quality parameters collected at 28 spawning sites in 2013.

Water Quality Parameter	Min	Max	Range	Mean
DO (mg/l)	6.64	20.75	14.11	12.21
Conductivity (µscm)	41	90	49	63.14
Turbidity (NTU)	116	586	470	331.68
pH	5.87	7.59	1.72	6.7
Temperature (C°)	5.2	10.29	5.09	7.54
Depth (m)	0.15	1.5	1.35	0.42
Velocity (m/s)	0.05	0.72	0.67	0.48

Table 5.4-1. Sex ratio for all fish caught during dipnetting at sites from Project River Mile 11.0 to 19.2 from May 28–June 16, 2013.

Sex	Number of fish	Percent
F	1,107	45
M	1,327	54
U	13	1
Total	2,447	100
Overall M:F	1.20	

Table 5.4-2. Eulachon sex ratio (M:F) by date from fish caught during dipnetting at sites from Project River Mile 11.0-19.2 in 2013.

Date	Eulachon	Males	Females	Undetermined	M:F Ratio
May 31	828	446	384	1	1.16
June 1	67	31	37	0	0.84
June 2	217	96	121	1	0.79
June 3	200	114	88	0	1.30
June 4	166	80	111	0	0.72
June 5	165	65	115	0	0.57
June 6	168	102	103	6	0.99
June 7	142	85	58	0	1.47
June 8	139	108	31	0	3.48
June 9	123	91	32	0	2.84
June 10	32	25	8	0	3.13
June 11	25	25	0	1	25.00
June 12	40	32	8	1	4.00
June 13	15	9	6	1	1.50
June 14	16	16	3	1	5.33
June 15	1	1	0	1	--

Table 5.4-3. Mean lengths and weights for eulachon sampled during dipnetting at sites from Project River Mile 11.0-19.2 in 2013.

	Length			Weight		
Sex	Mean (mm)	SD	*N*	Mean (g)	SD	*N*
M	217.38	30.18	1,234	82.24	14.24	554
F	212.95	27.15	1,008	76.06	14.33	389
All fish	215.39	28.99	2,258	79.69	14.59	943

Table 5.4-4. Overall age composition for eulachon sampled at dipnetting sites from PRM 11 to 19.2 during 2013.

Age	Sex	Sample Size	Length (mm)		Weight (g)	
			Range	Median	Range	Median
2	M	3	189-225	219	60-80	70
3	M	80	187-238	223	40-100	80
4	M	44	215-241	228	65-100	80
2	F	15	165-219	198	30-60	35
3	F	93	200-233	220	58-100	80
4	F	37	202-250	224	60-100	80

10. FIGURES

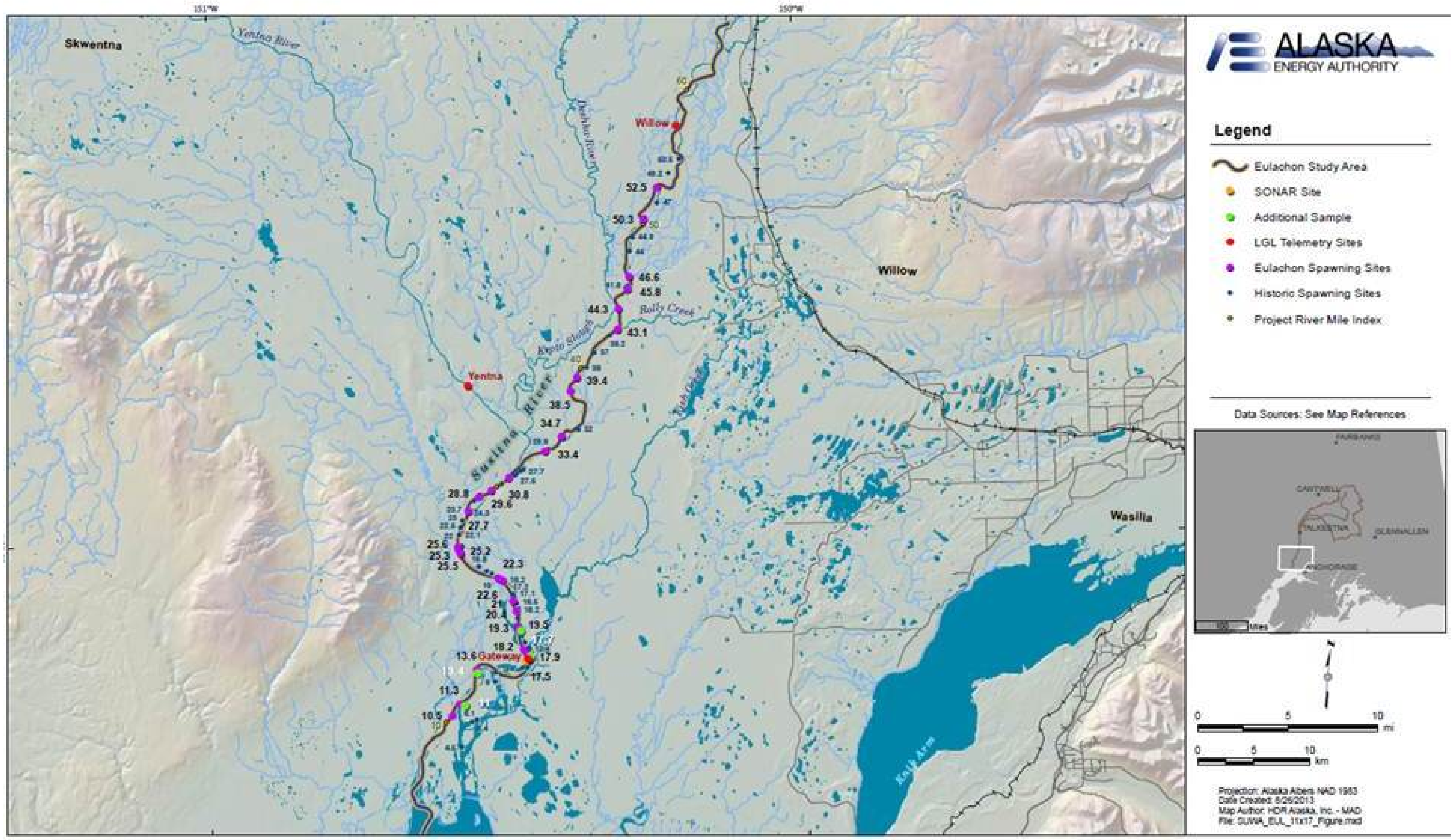


Figure 3.1-1. Map of eulachon project study area in 2013 from Project River Mile 0–60.

Figure 4.1-1. Acoustic equipment deployed at the fixed site on May 30, 2013 at Project River Mile 17.5.

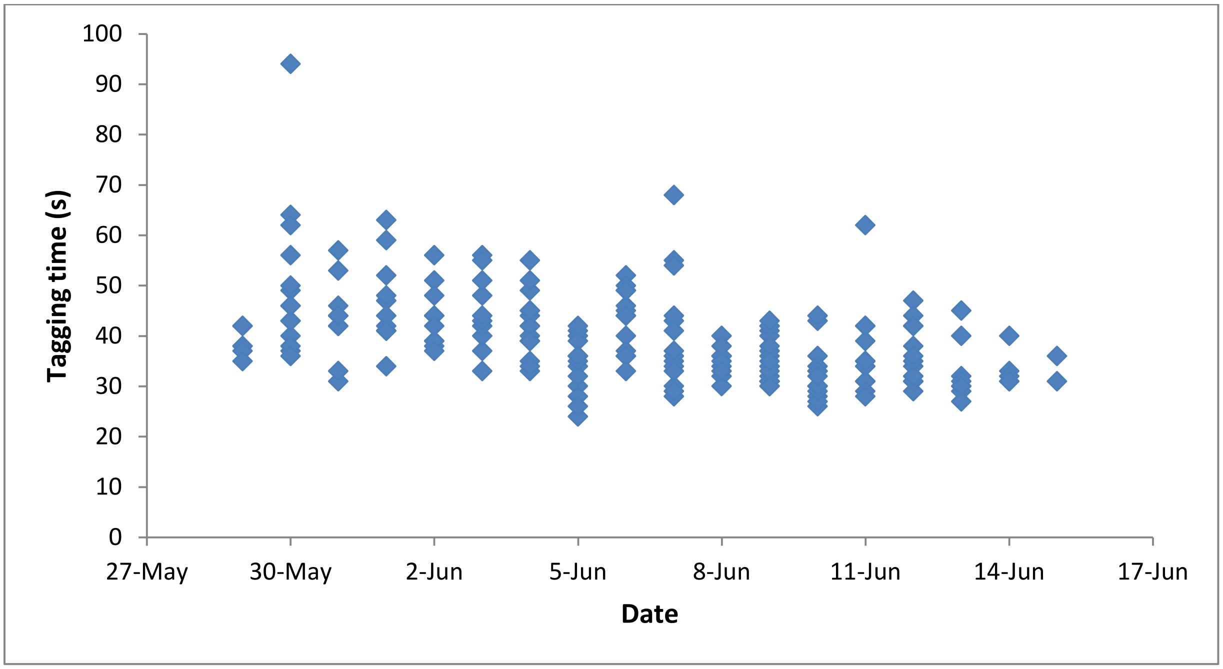


Figure 4.2-1. Processing time (seconds) by date for eulachon radio tagged in 2013.

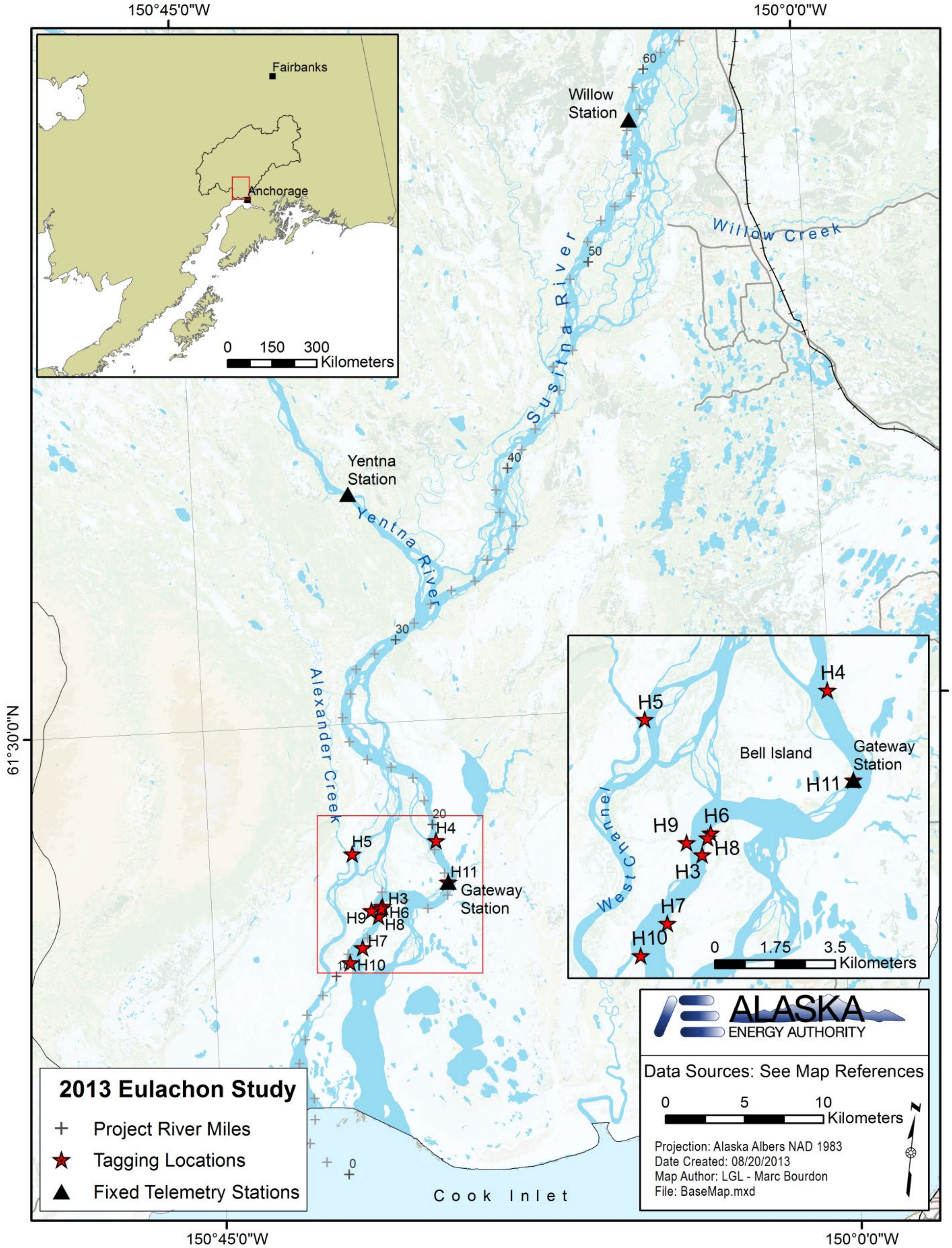


Figure 4.2-2. Map of radio telemetry area of study in 2013, showing location of fish tagging site and fixed station telemetry receivers.

Figure 4.2-3. DIDSON imaging sonar and X2 rotator deployed over the side of the boat in 2013.

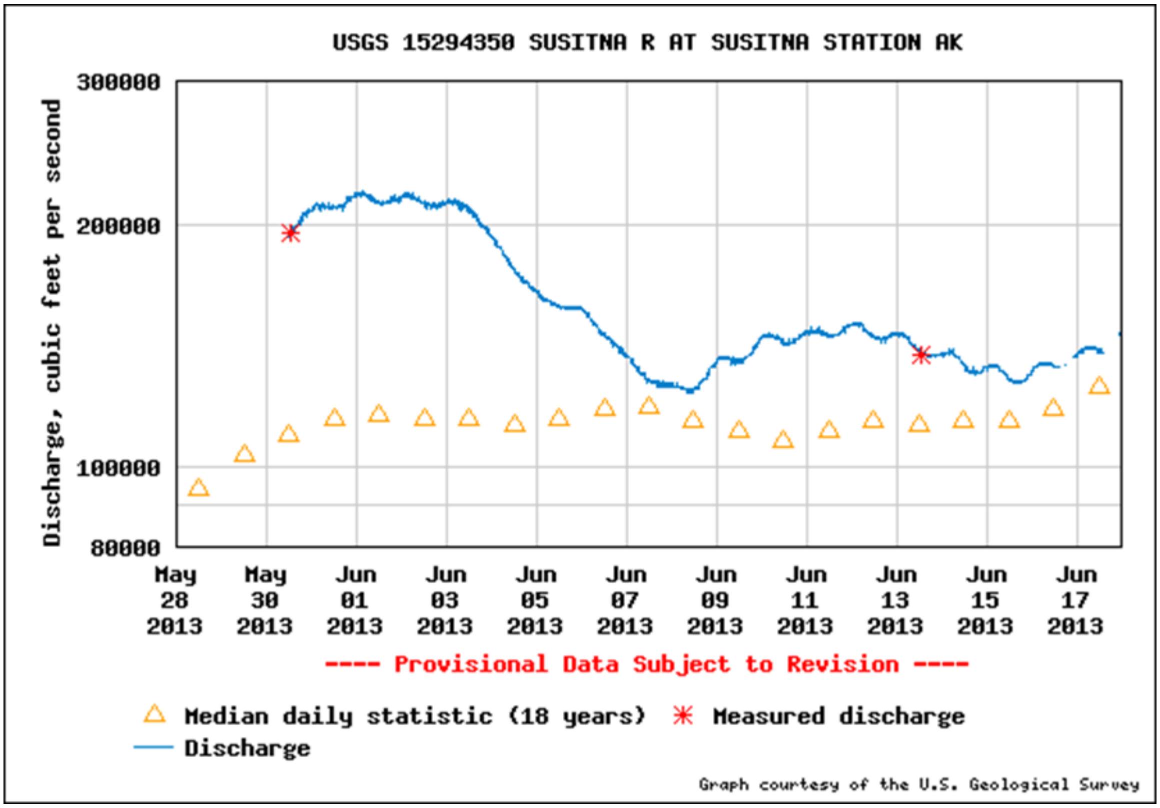


Figure 5.1-1. River discharge measured on the Susitna River at Susitna Station from May 28–June 17, 2013.

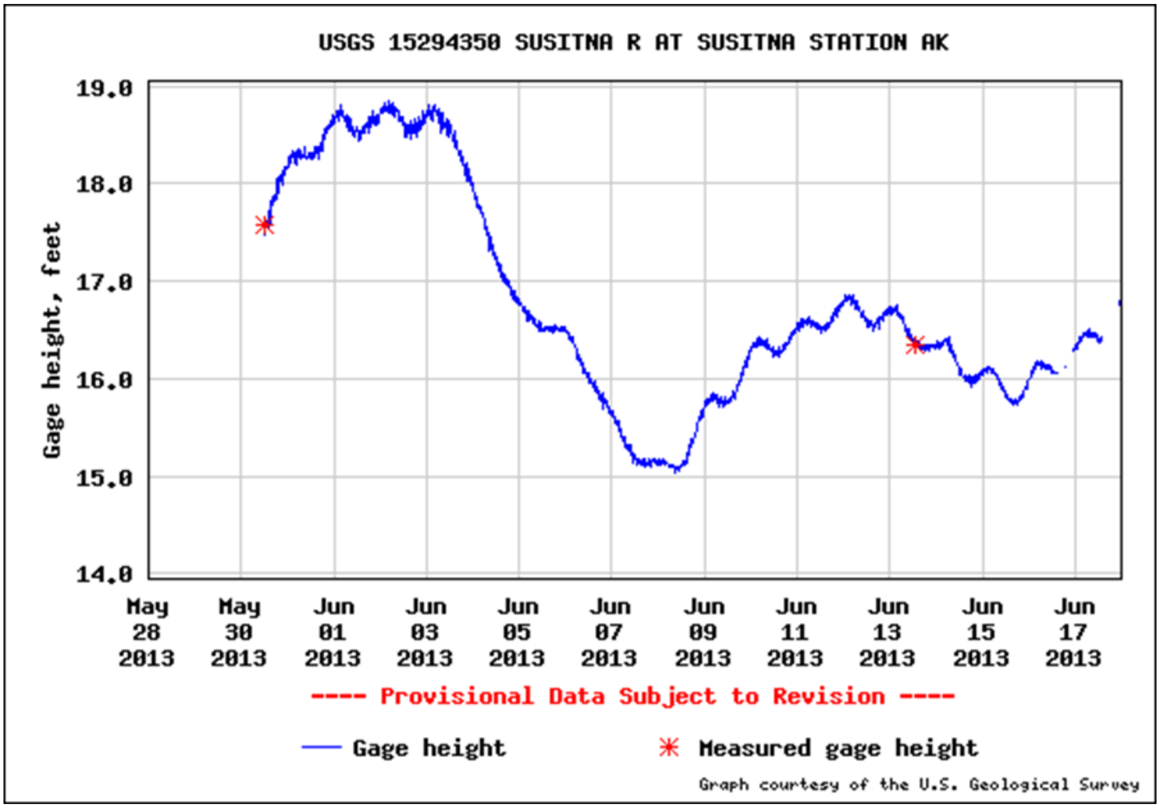


Figure 5.1-2. River height measured on the Susitna River at Susitna Station from May 28–June 17, 2013.

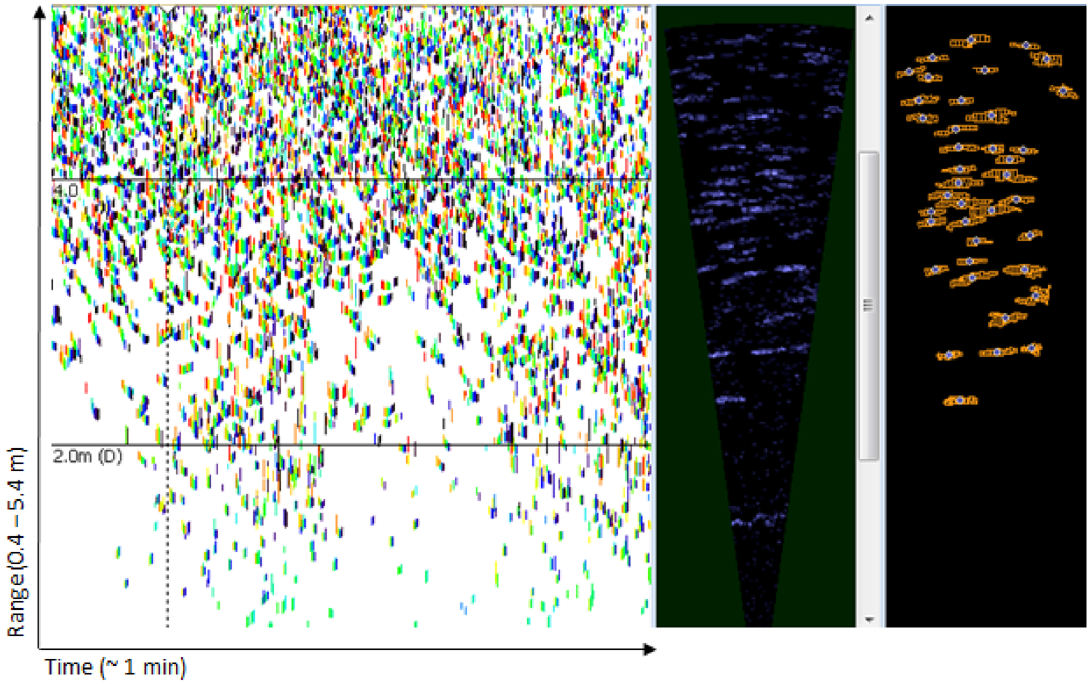


Figure 5.1-3. DIDSON images of eulachon passing upstream in 2013. Angle echogram (left), 15° subset of background subtracted DIDSON image (center) and corresponding view of detected targets (right). Echo traces progressing from red to blue indicate upstream moving fish. Dashed vertical line on the echogram marks frame shown on DIDSON image

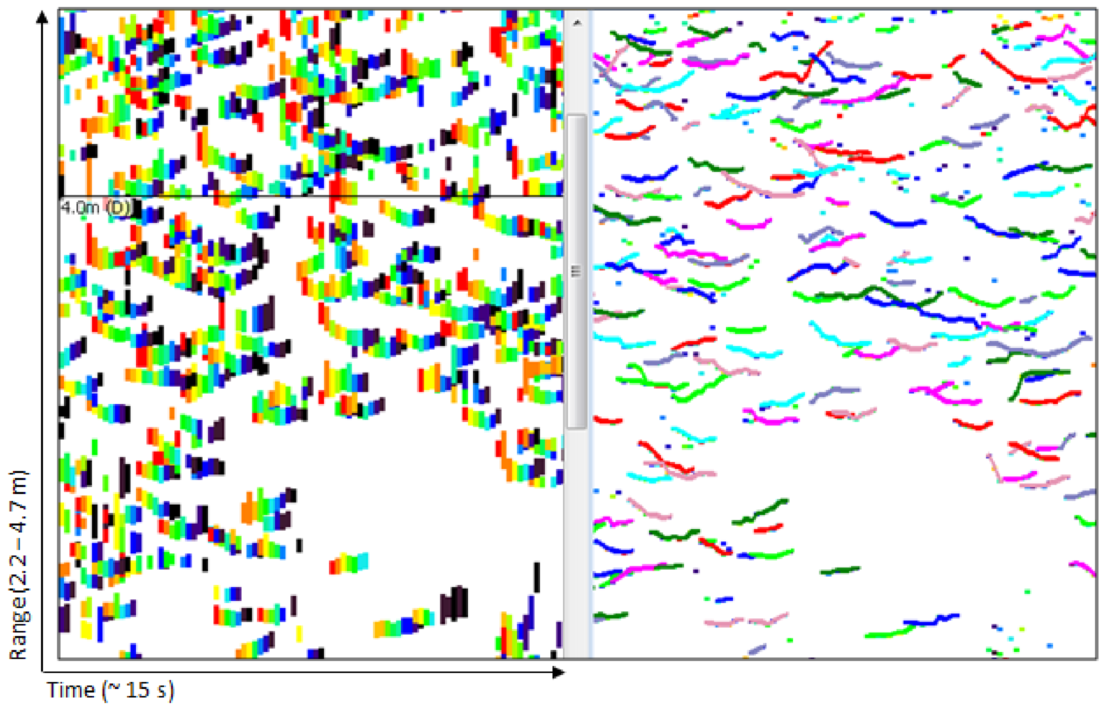


Figure 5.1-4. Zoomed view of DIDSON angle echogram and corresponding fish tracks in 2013. Echo traces progressing from red to blue indicate upstream moving fish. Each colored line represents a tracked fish.

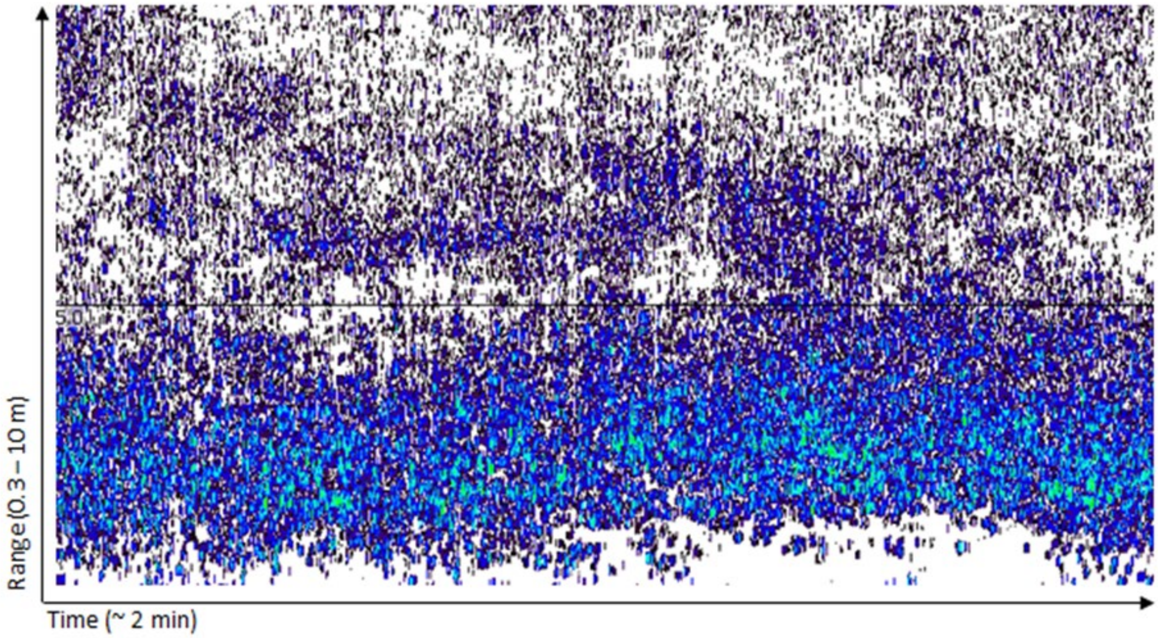


Figure 5.1-5. Splitbeam echogram of eulachon passing the fixed sonar site (Project River Mile 17.5) in 2013.

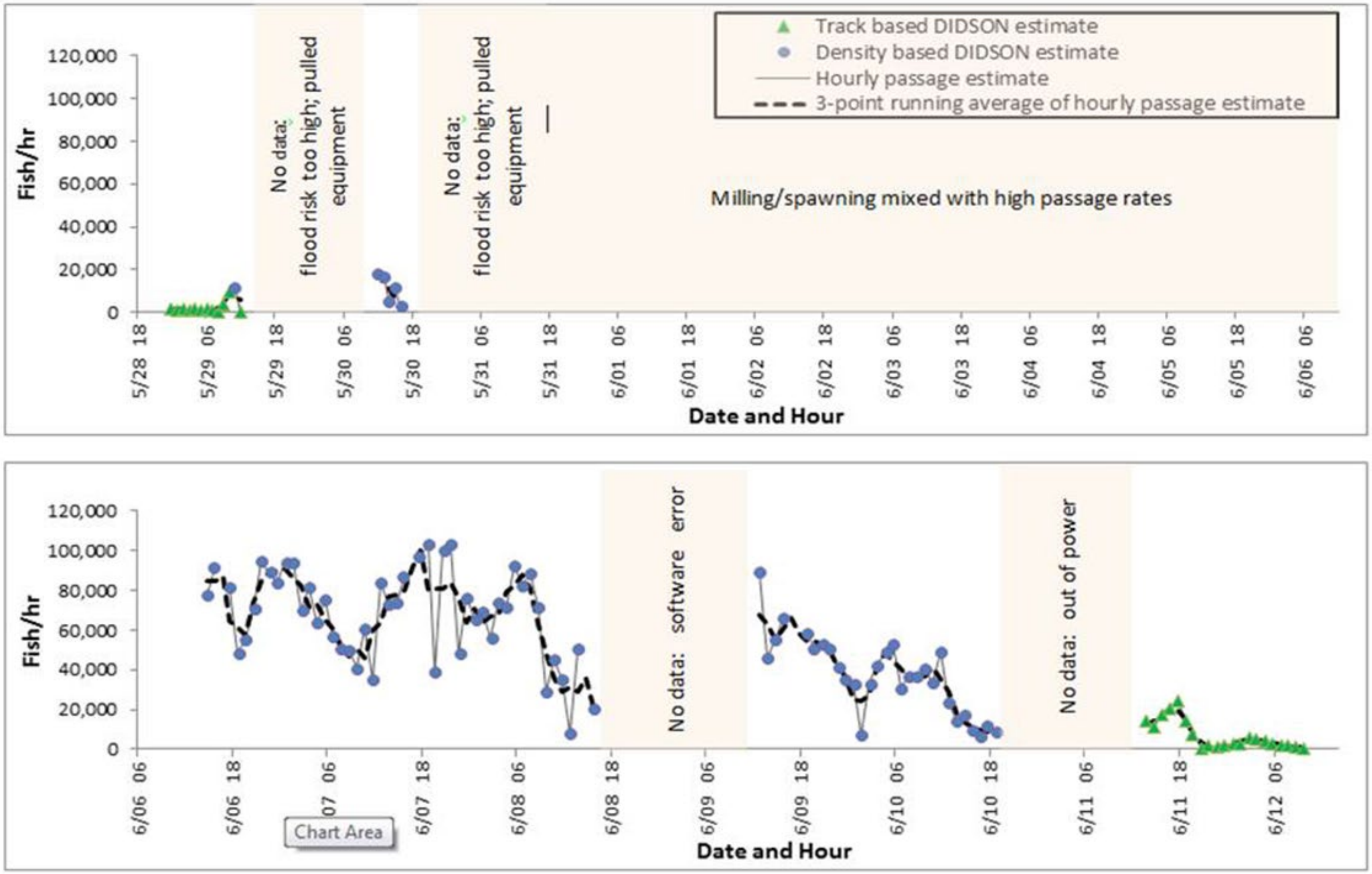


Figure 5.1-6. Time series of track and density-based DIDSON estimates of eulachon passage at the fixed sonar site (Project River Mile 17.5) in 2013.

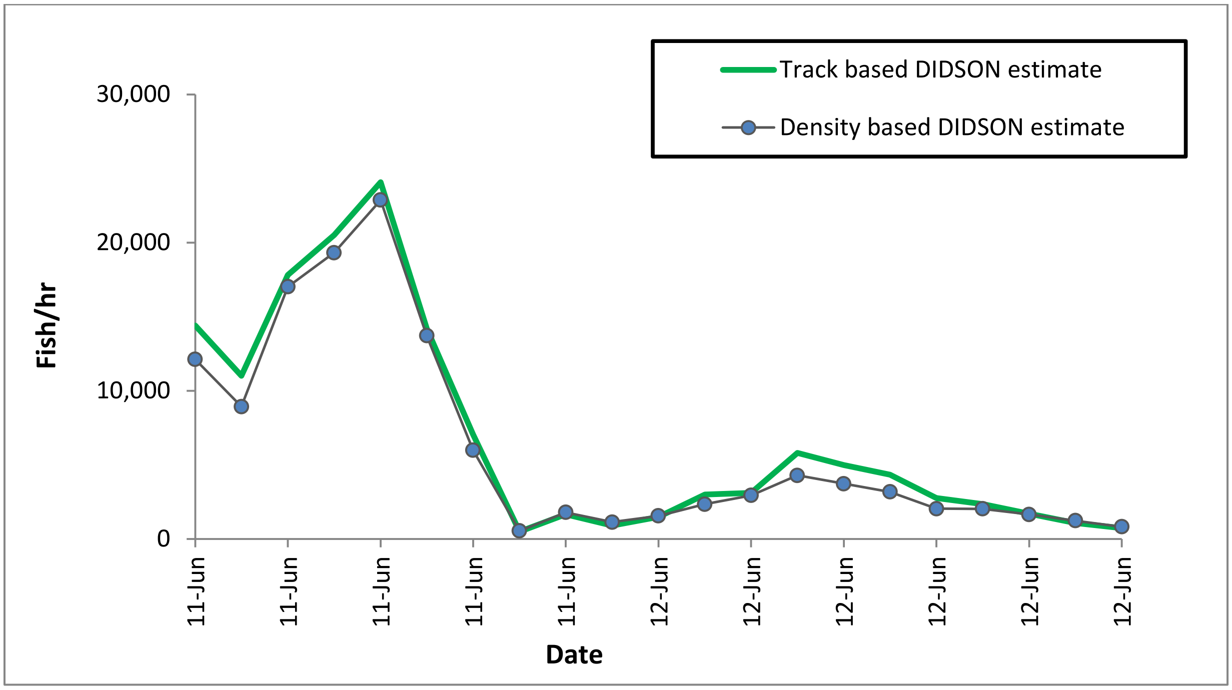


Figure 5.1-7. Comparison of track and density based DIDSON estimates of eulachon passage at the fixed sonar site (Project River Mile 17.5) in 2013.

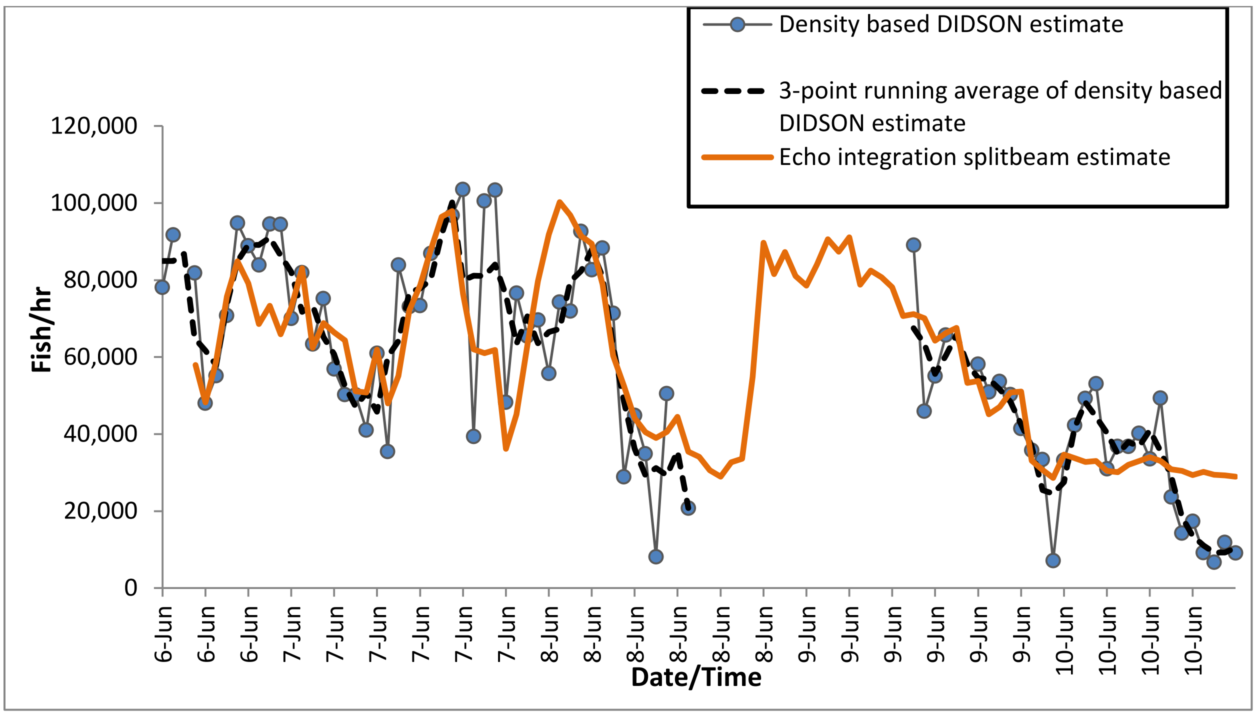


Figure 5.1-8. Comparison of density-based DIDSON and echo integration splitbeam estimates of eulachon passage at the fixed sonar site (Project River Mile 17.5) in 2013.

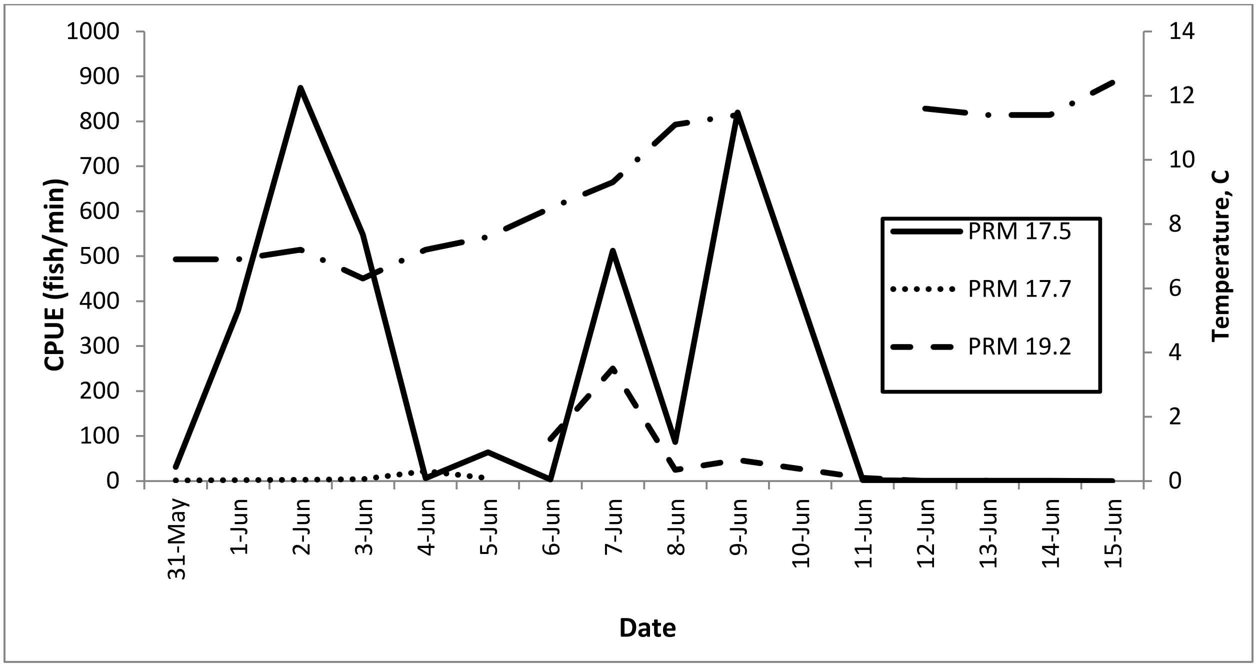


Figure 5.1-9. Eulachon CPUE (fish/min) in 2013 by day at one spawning site (PRM 17.5) and two non-spawning sites compared to daily water temperature at the fixed sonar site (PRM 17.5). PRM = Project River Mile.

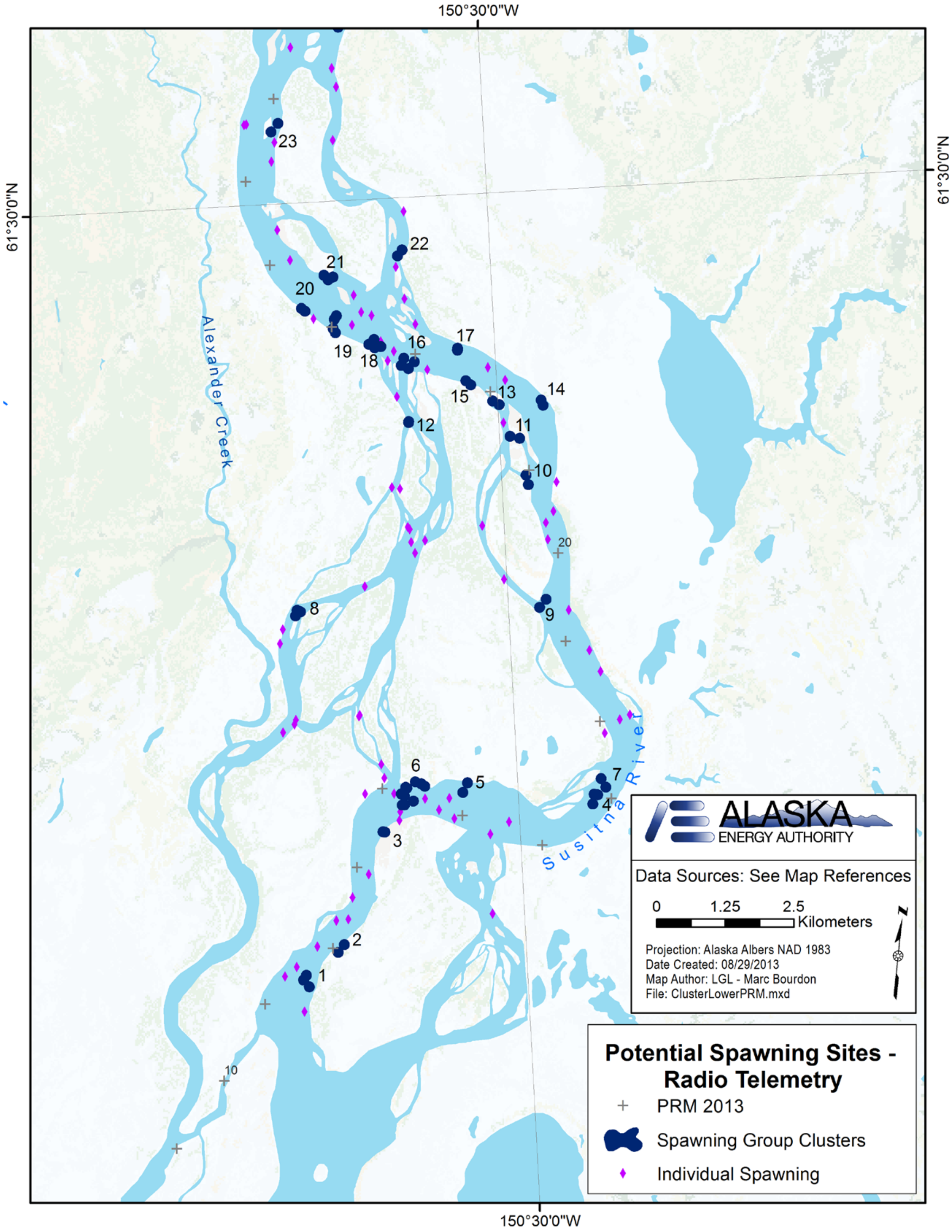


Figure 5.2 – 1a. Potential spawning sites of eulachon in the Susitna River in 2013, based on radio telemetry detections, Map 1 of 2.

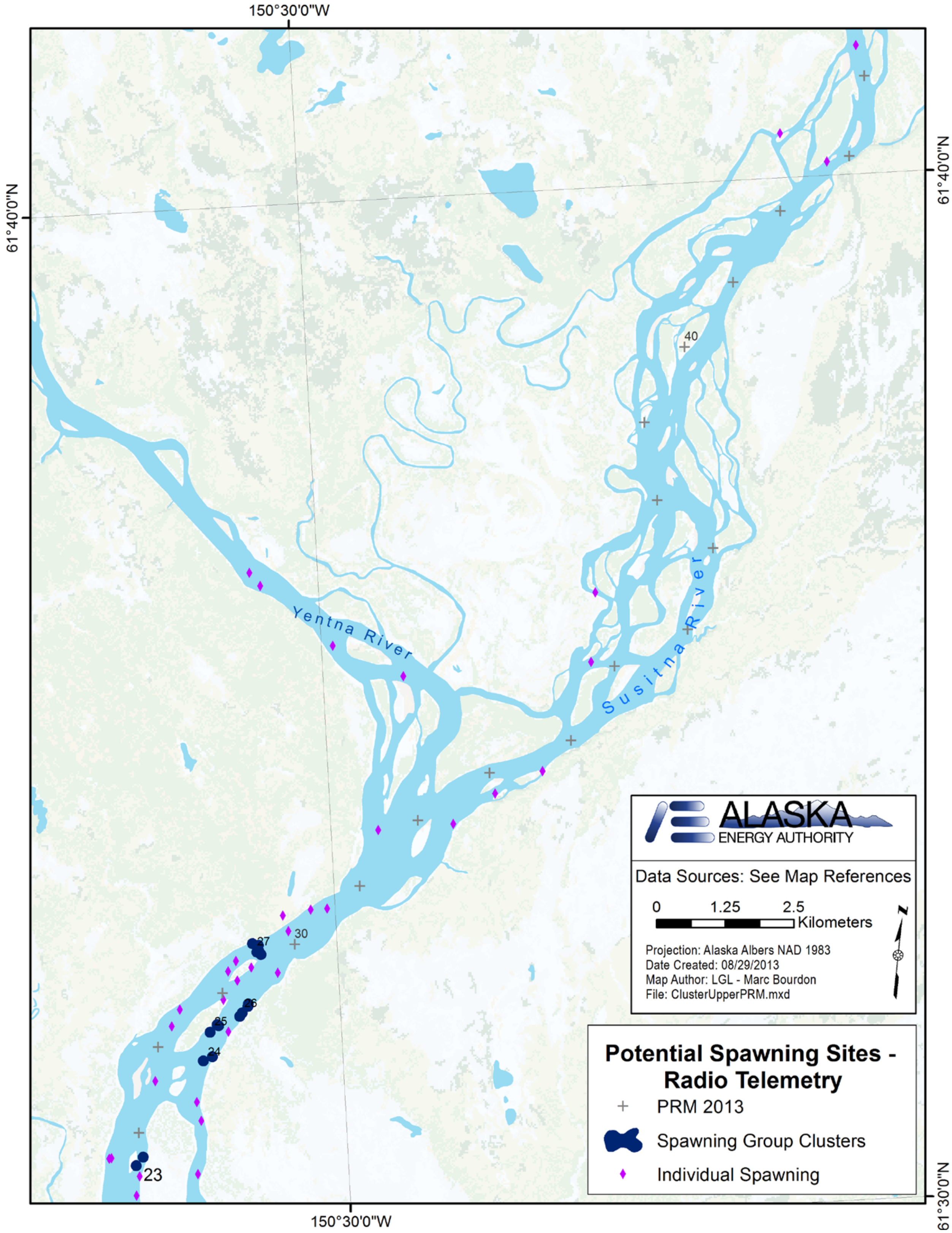


Figure 5.2 – 1b. Potential spawning sites of eulachon in the Susitna River in 2013, based on radio telemetry detections, Map 2 of 2.

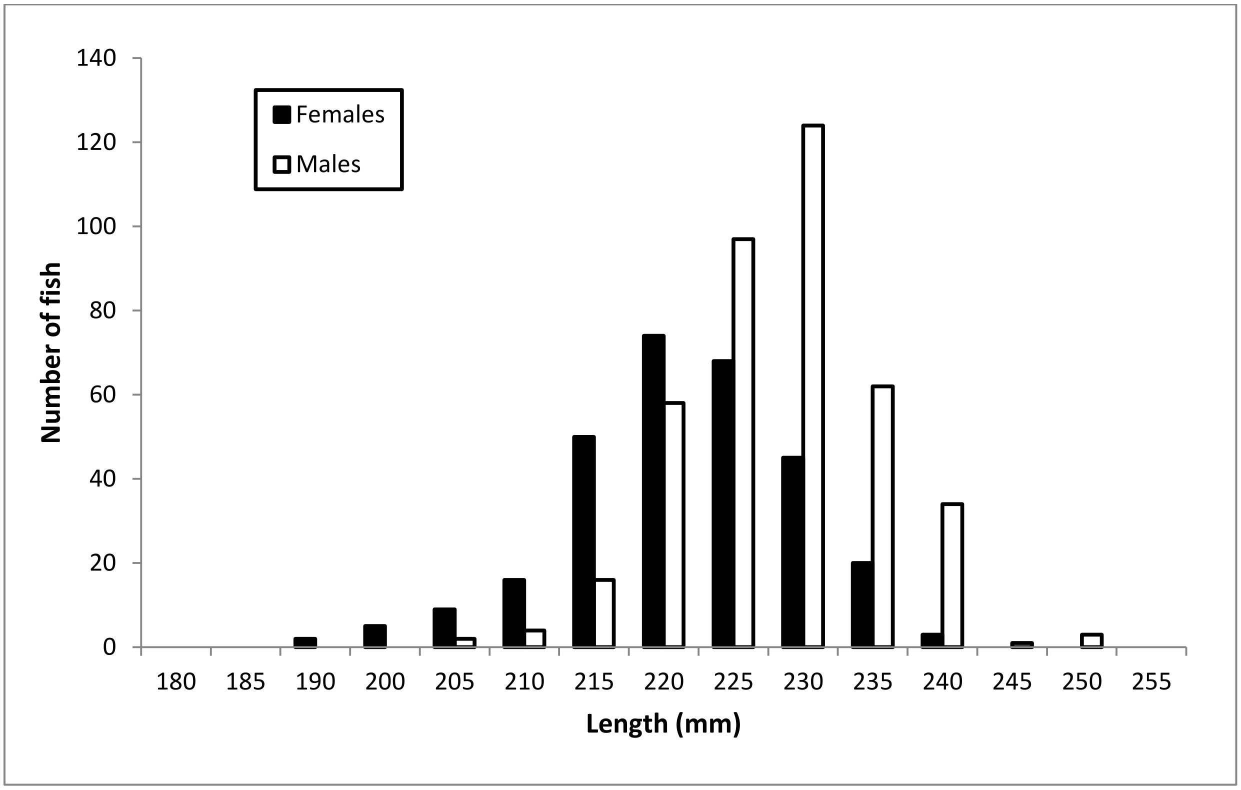


Figure 5.2-2. Length frequency by sex for eulachon sampled at 28 spawning sites from Project River Mile 10.5 to 50.3 in 2013.

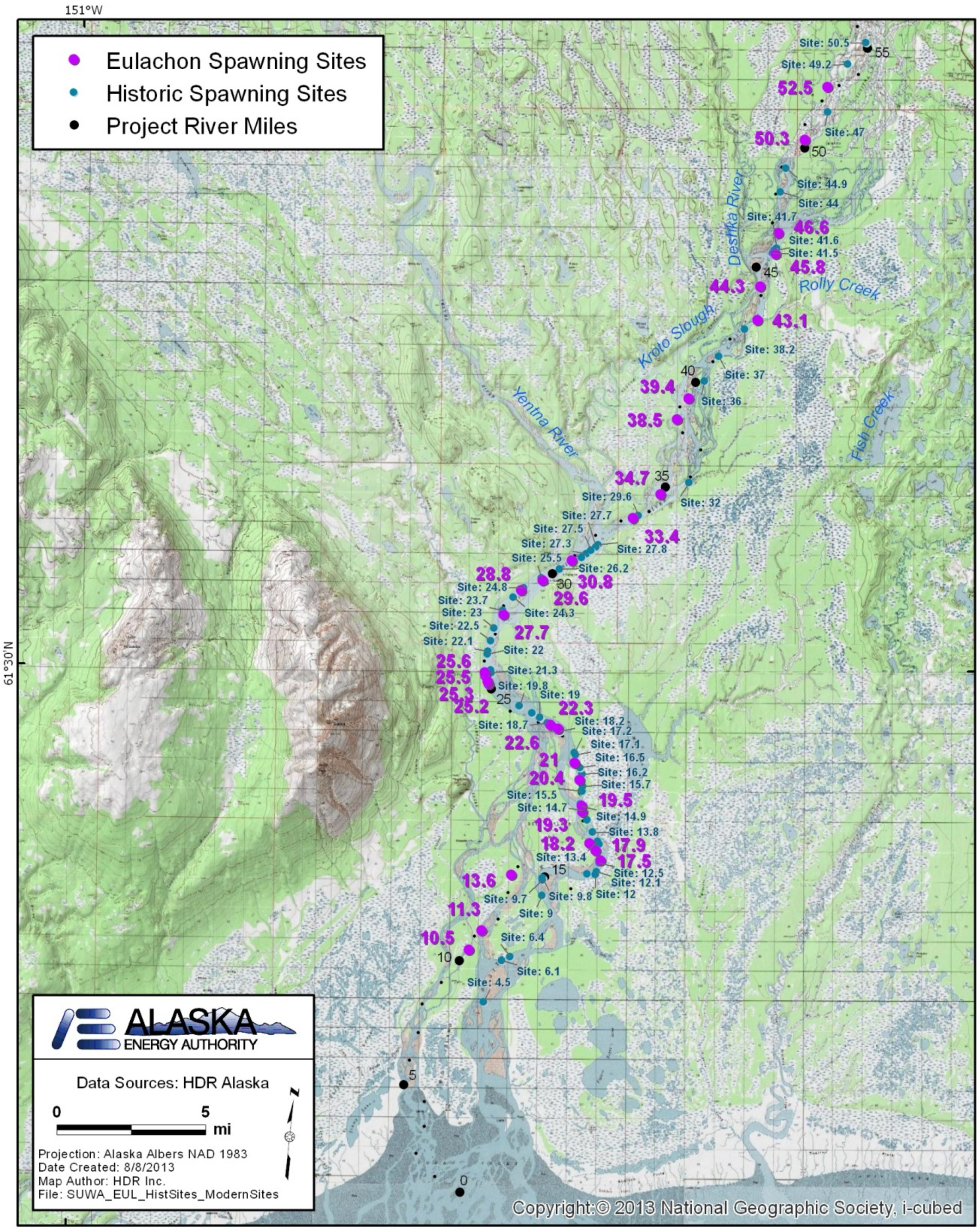


Figure 5.3-1. Location of historic eulachon spawning sites (blue) and spawning sites surveyed in 2013 (purple) by Project River Mile.

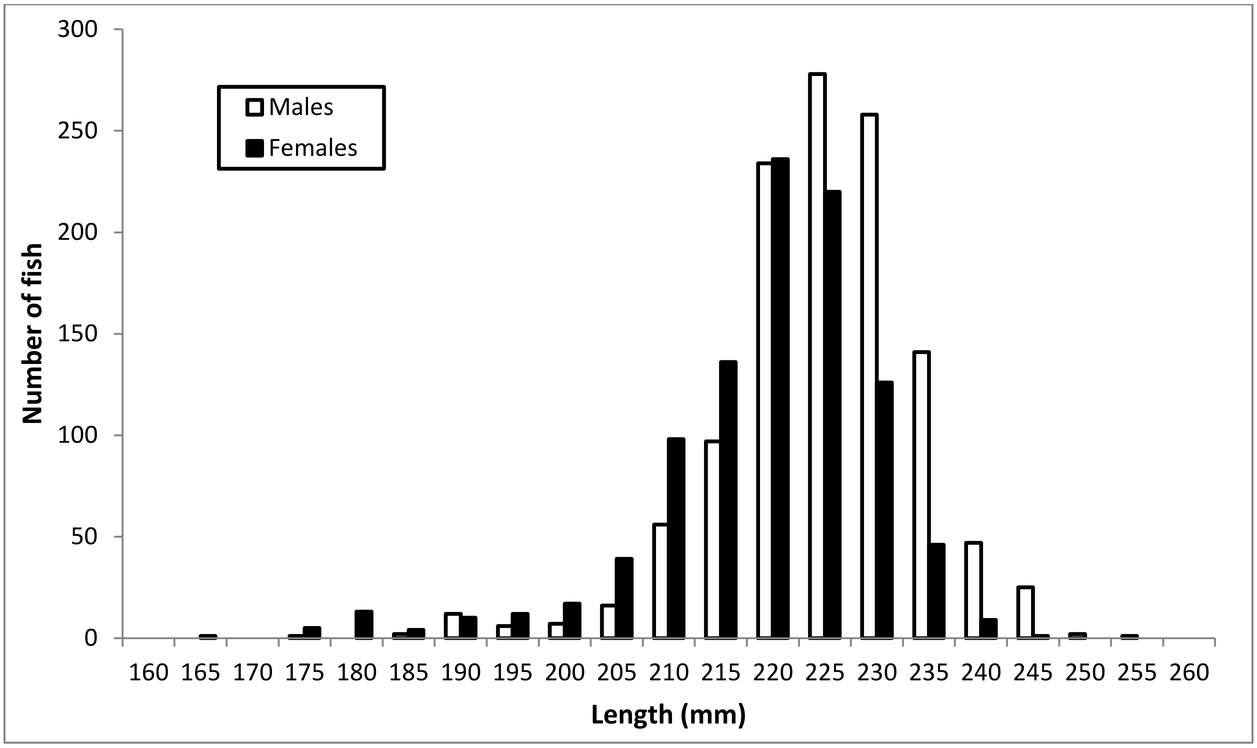


Figure 5.4-1. Length frequency by sex for eulachon sampled at the fixed site (Project River Mile 17.5) from May 31–June 15, 2013.

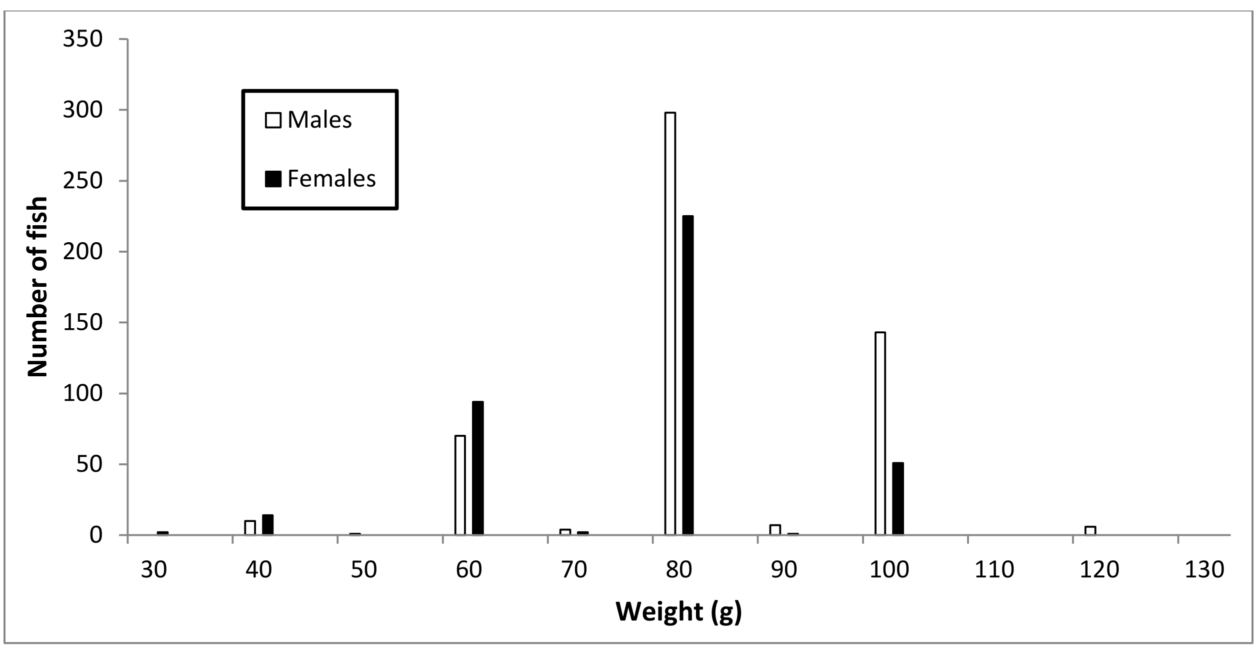


Figure 5.4-2. Weight frequency by sex for eulachon sampled at the fixed site (Project River Mile 17.5) from May 31–June 15, 2013.

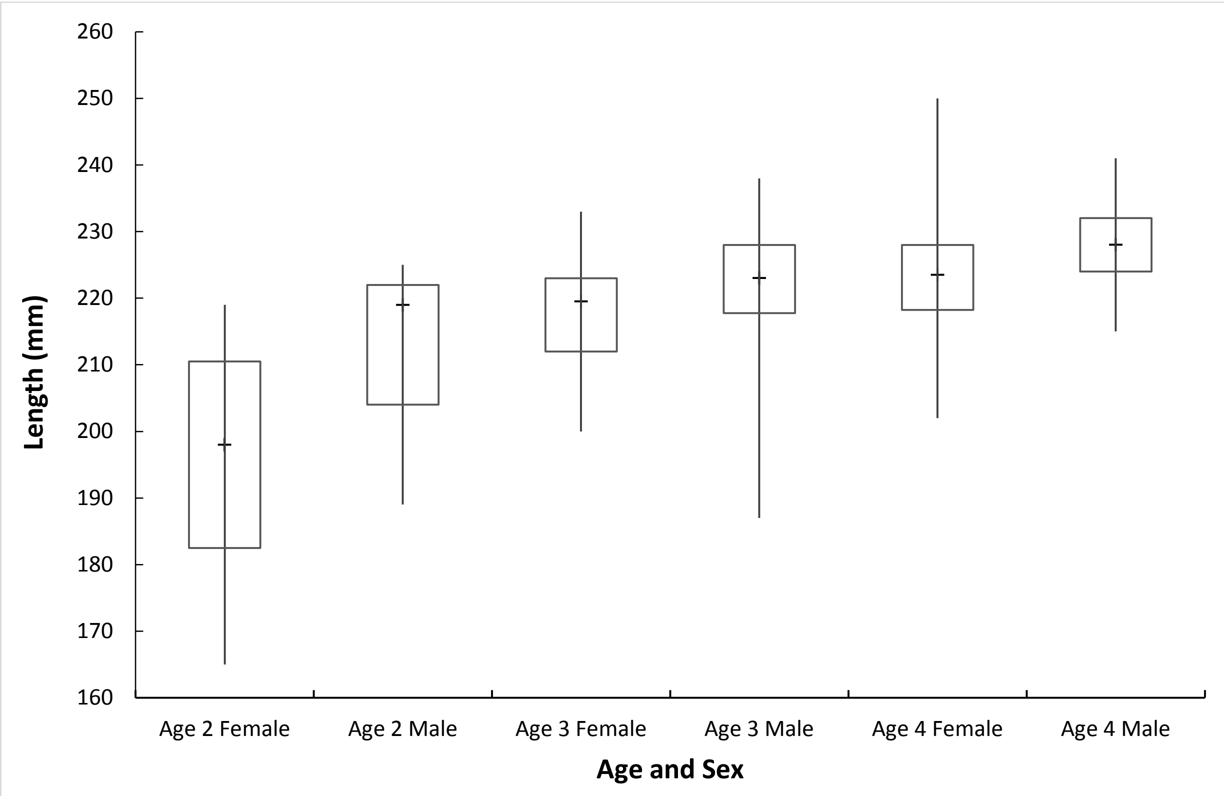


Figure 5.4-3. Length, age and sex of eulachon sampled at non-spawning sites, 2013. Boxes bracket the 25th and 75th percentile length values. Hash mark in the middle of the box denotes the median length value. The top of the vertical line indicates maximum values and bottom indicates minimum values.

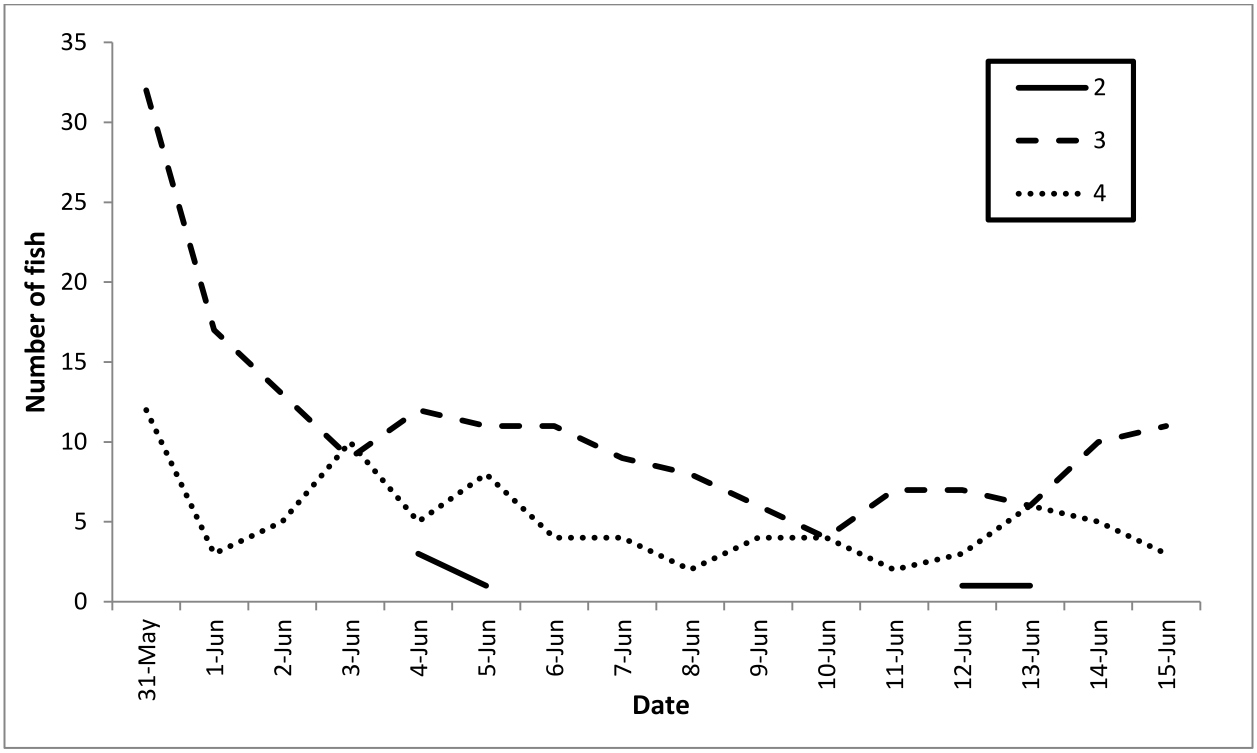


Figure 5.4-4. Ages of eulachon caught per day during sampling near the fixed site from May 31-June 15, 2013.

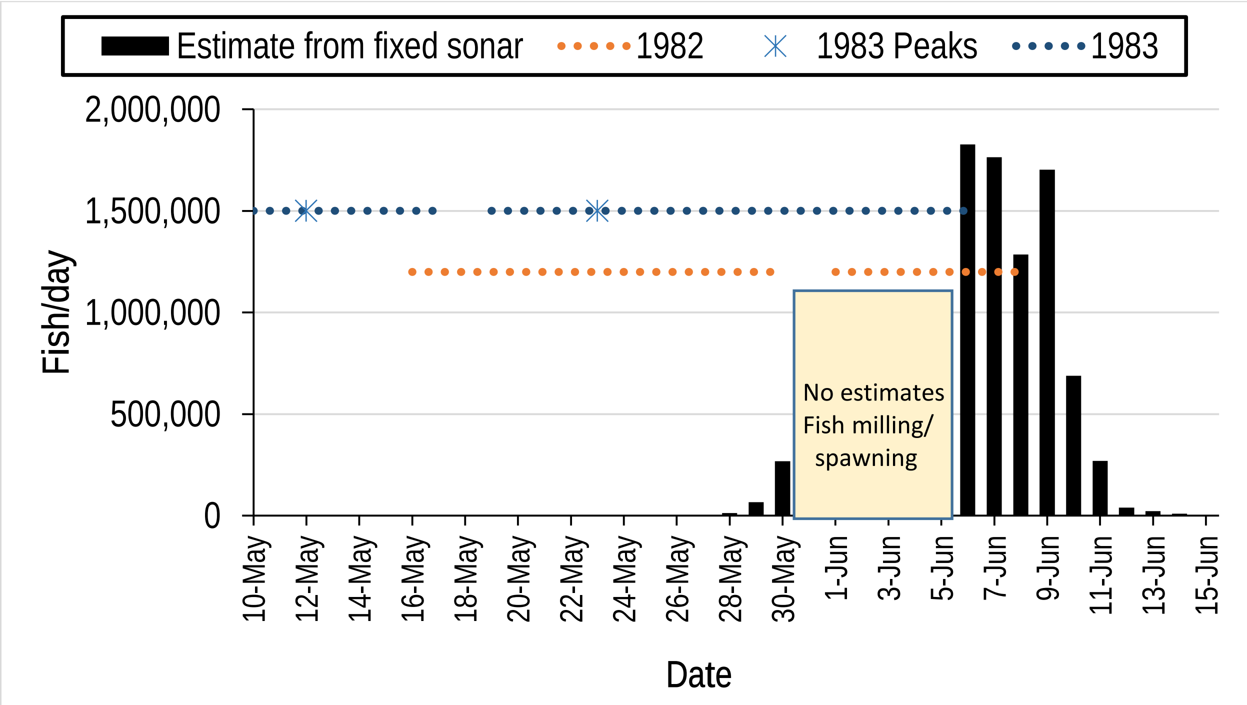


Figure 6.1-1. Eulachon run timing in 2013 from the fixed station as compared to counts from 1982 and 1983 studies.

PART A - APPENDIX A: EULACHON SPAWNING HABITAT TABLES

Appendix Table A-1. Summary of water quality probe specifications in 2013.

Parameter	Instrument	Units	Range	Accuracy	Precision
Temperature	YSI	˚C	0-85	±0.2 ˚	0.01 ˚
Dissolved oxygen	YSI	mg/L	0-50	±0.2	0.01
pH	YSI		0-14	±0.2	0.01
Specific conductance	YSI	us/cm	0-200	±0.5%	0.01
Water velocity	Marsh-McBirney Flo-Mate	m/s	-0.5 - 20	±2%	--
Turbidity	Hach 2100P Turbidimeter	NTU	0-1000	--	0.01

Appendix Table A-2. Instantaneous water quality parameters and water depth at spawning sites sampled from May 28–June 13, 2013.

Site ID	Project River Mile	Dissolved Oxygen (mg/l)	Specific conductance (µscm)	Turbidity (NTU)	pH	Water Temp (C°)	Water Depth (m)	Velocity (m/s)
1	17.5	15.50	52	554	6.75	5.64	0.50	0.38
2	25.5	16.94	41	367	6.88	5.72	0.30	0.43
3	13.6	11.10	48	314	6.10	6.02	0.22	0.43
4	25.3	18.50	43	506	6.60	5.98	0.22	0.59
5	25.6	20.75	47	500	6.40	5.61	0.85	0.22
6	33.4	11.48	58	Not recorded	7.48	6.46	0.25	0.55
7	29.6	12.77	74	536	6.67	7.51	0.60	1.00
8	11.3	14.75	56	746	6.75	5.20	0.23	0.65
9	18.2	9.45	51	495	6.06	5.28	0.46	0.28
10	22.6	13.05	69	586	6.85	5.83	0.28	0.46
11	17.9	12.15	58	346	5.87	6.42	0.20	0.35
12	19.5	14.45	58	316	6.30	6.49	0.25	0.50
13	20.4	11.80	58	340	6.40	6.65	1.50	0.45
14	21	11.43	76	270	6.49	7.28	0.46	0.54
15	22.3	12.30	78	308	6.46	7.53	0.48	0.71
17	39.4	13.15	58	Not recorded	6.56	6.73	Not recorded	Not recorded
18	28.8	11.52	62	305	7.07	7.33	0.75	0.53
19	10.5	9.23	71	116	6.67	8.27	0.23	0.55
20	19.3	10.71	85	171	6.76	8.90	0.30	0.44
21	25.2	9.10	90	233	7.02	9.05	0.22	0.52
22	27.7	7.15	78	263	6.93	9.81	0.23	0.54
23	37.4	10.97	71	143	7.29	8.96	0.46	0.61
24	43.1	10.08	62	117	6.88	9.00	0.15	0.72
25	44.3	6.64	78	206	7.59	10.11	0.35	0.56
26	50.3	12.50	69	251	7.56	10.01	0.75	0.15
27	46.6	11.98	49	148	6.32	9.29	0.40	0.43
28	45.8	11.84	55	155	6.18	9.73	0.30	0.43
31	30.8	13.90	73	Not recorded	6.71	10.29	Not recorded	0.05

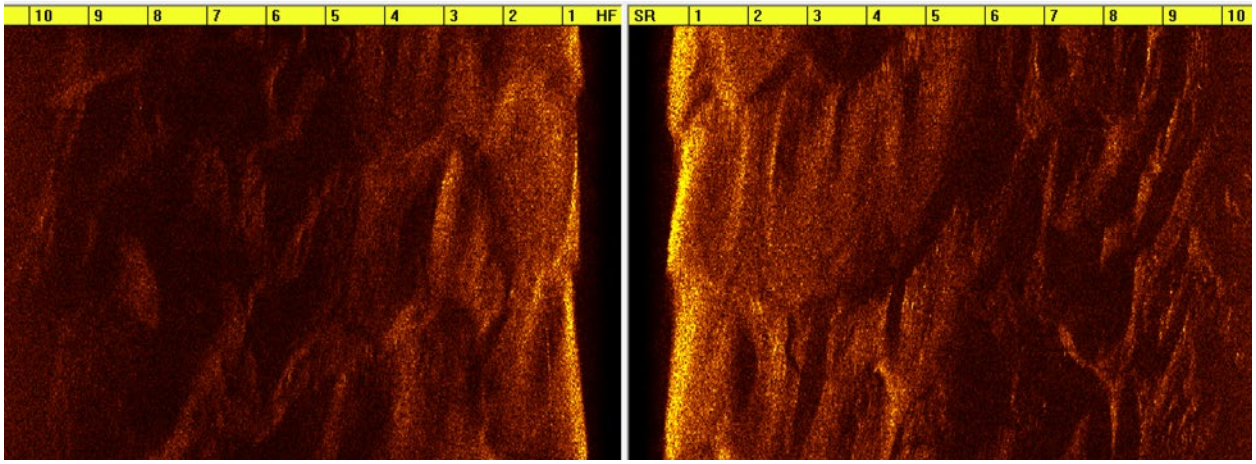
Appendix Table A-3. Summary of 2013 spawning site identification and confirmation surveys.

Site ID	Date	Time	PRM	Method	Eulachon presence	Dominant Behavior	Dominant Condition	Egg Release
1	May 29	14:00	17.5	dip net	yes	spawning	spawning	yes
2	May 31	15:00	25.5	dip net	yes	spawning	spawning	no
3	June 1	10:30	13.6	dip net	yes	spawning	spawning	no
4	June 1	14:08	25.3	dip net	yes	spawning	spawning	yes
5	June 2	12:55	25.6	dip net	yes	spawning	spawning	yes
6	June 2	11:00	33.4	dip net	yes	milling	spawning	yes
7	June 2	15:17	29.6	dip net	yes	spawning	spawning	yes
8	June 3	12:35	11.3	dip net	yes	spawning	spawning	yes
9	June 3	14:29	18.2	dip net	yes	spawning	spawning	yes
10	June 3	15:17	22.6	dip net	yes	spawning	spawning	yes
11	June 4	12:00	17.9	dip net	yes	spawning	spawning	yes
12	June 5	11:20	19.5	dip net	yes	spawning	spawning	yes
13	June 5	12:20	20.4	dip net	yes	spawning	spawning	yes
14	June 5	13:00	21	dip net	yes	spawning	spawning	yes
15	June 5	13:50	22.3	dip net	yes	spawning	spawning	yes
16	June 6	12:25	34.7	dip net	no	-	-	-
17	June 6	12:54	39.4	dip net	yes	spawning	spawning	yes
18	June 6	16:30	28.8	dip net	yes	spawning	spawning	yes
19	June 7	10:15	10.5	dip net	yes	spawning	spawning	yes
20	June 7	13:15	19.3	dip net	yes	milling	spawning	yes
21	June 7	14:21	25.2	dip net	yes	spawning	spawning	yes
22	June 8	12:48	27.7	dip net	yes	milling	spawning	yes
23	June 9	11:14	37.4	dip net	yes	milling	spawning	yes
24	June 9	12:53	43.1	dip net	yes	passing by	spawning	yes
25	June 9	13:40	44.3	dip net	yes	spawning	spawning	yes
26	June 10	12:37	50.3	dip net	yes	milling	spawning	yes
27	June 10	13:22	46.6	dip net	yes	spawning	spawning	yes
28	June 10	14:18	45.8	dip net	yes	milling	spawning	yes
29	June 11	10:49	38.5	dip net	no	-	-	-
30	June 12	14:04	52.5	dip net	no	-	-	-
31	June 13	12:34	30.8	dip net	yes	spawning	spawning	yes

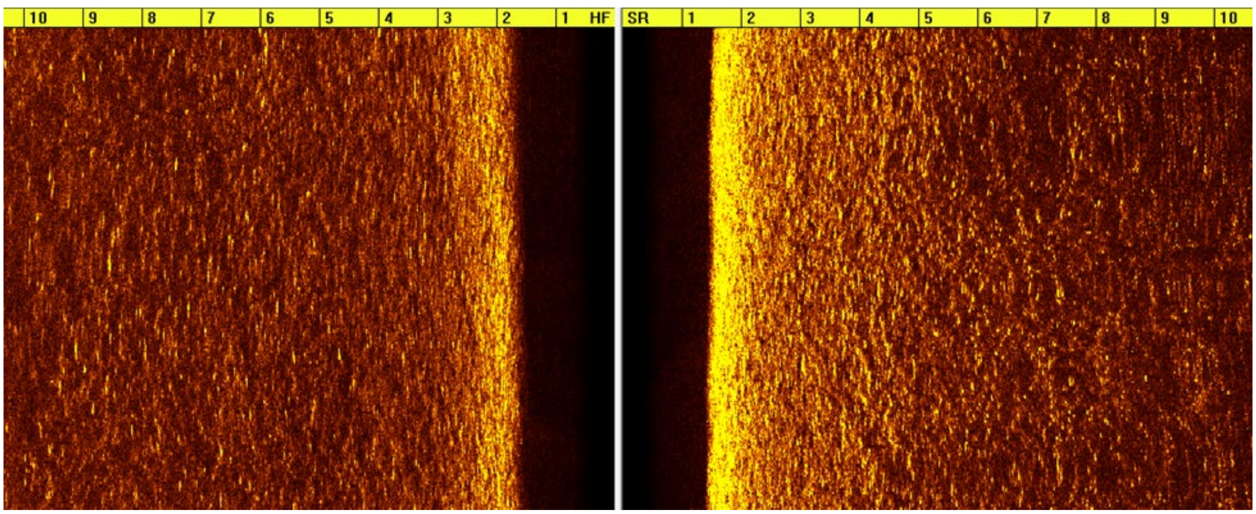
Appendix Table A-4. Location, mesohabitat type, and substrate description at 28 spawning sites and three additional sites surveyed in 2013.

Site ID	Date	Project River Mile	Mesohabitat	Substrate Classification	
				Acoustic Description	Visual Survey
1	May 29	17.5	run	sand	100 % sand/silt
2	May 31	25.5	run	sand	100 % sand/silt
3	June 1	13.6	run	sand/silt	100 % sand/silt
4	June 1	25.3	shallow riffle	sand	100 % sand/silt
5	June 2	25.6	run	sand	100 % sand/silt
6	June 2	33.4	run	gravel bar, finer sediment over gravel	25% sand/silt, 75% mixed gravel
7	June 2	29.6	run	gravel and sand	100 % sand/silt
8	June 3	11.3	run	sand	100 % sand/silt
9	June 3	18.2	run	no side scan sample	100 % sand/silt
10	June 3	22.6	run	gravel and sand	25% sand/silt, 75% mixed gravel
11	June 4	17.9	run	no side scan sample	100 % sand/silt
12	June 5	19.5	run	sand	100 % sand/silt
13	June 5	20.4	run	sand	100 % sand/silt
14	June 5	21	shallow riffle	sand	100 % sand/silt
15	June 5	22.3	shallow riffle	sand	50% sand/silt, 50% mixed gravel
16	June 6	34.7	--	no side scan sample	100 % sand/silt
17	June 6	39.4	run	no side scan sample	50% sand/silt, 50% mixed gravel
18	June 6	28.8	shallow riffle	sand bank	100 % sand/silt
19	June 7	10.5	shallow riffle	sand	100 % sand/silt
20	June 7	19.3	run	sandbar	100 % sand/silt
21	June 7	25.2	run	peat over clay base	100 % silt/clay and peat
22	June 8	27.7	run	gravel bar	20% sand/silt, 80% mixed gravel
23	June 9	37.4	run	no side scan sample	100 % sand/silt
24	June 9	43.1	run	--	100 % sand/silt
25	June 9	44.3	shallow riffle	gravel	25% sand/silt, 75% mixed gravel
26	June 10	50.3	run	no side scan sample	100 % sand/silt
27	June 10	46.6	shallow riffle	gravel	20% sand/silt, 80% mixed gravel
28	June 10	45.8	run	sand	100 % sand/silt
29	June 11	38.5	--	no side scan sample	100 % sand/silt
30	June 12	52.5	--	no side scan sample	30% sand/silt, 70% mixed gravel
31	June 13	30.8	run	no side scan sample	100 % sand/silt

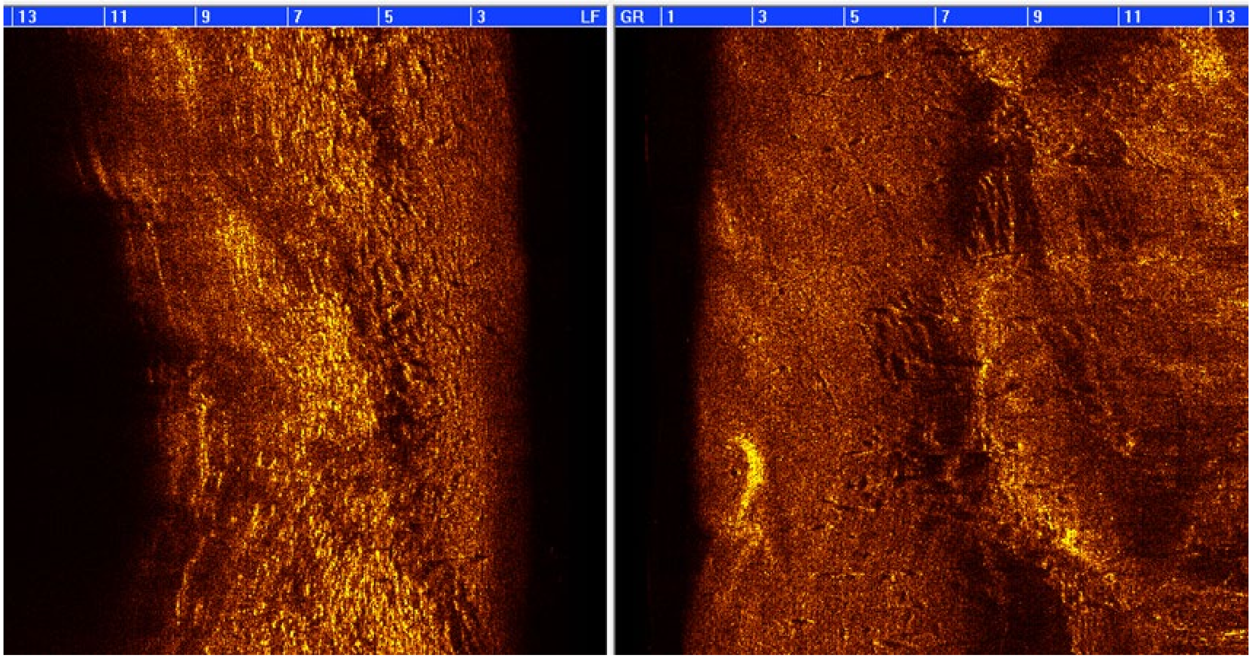
PART A - APPENDIX B: SIDE SCAN SONAR IMAGES



Appendix Figure B-1. Sand waves visible at mobile acoustic site 2 (Project River Mile 25.5) using side scan sonar in 2013.

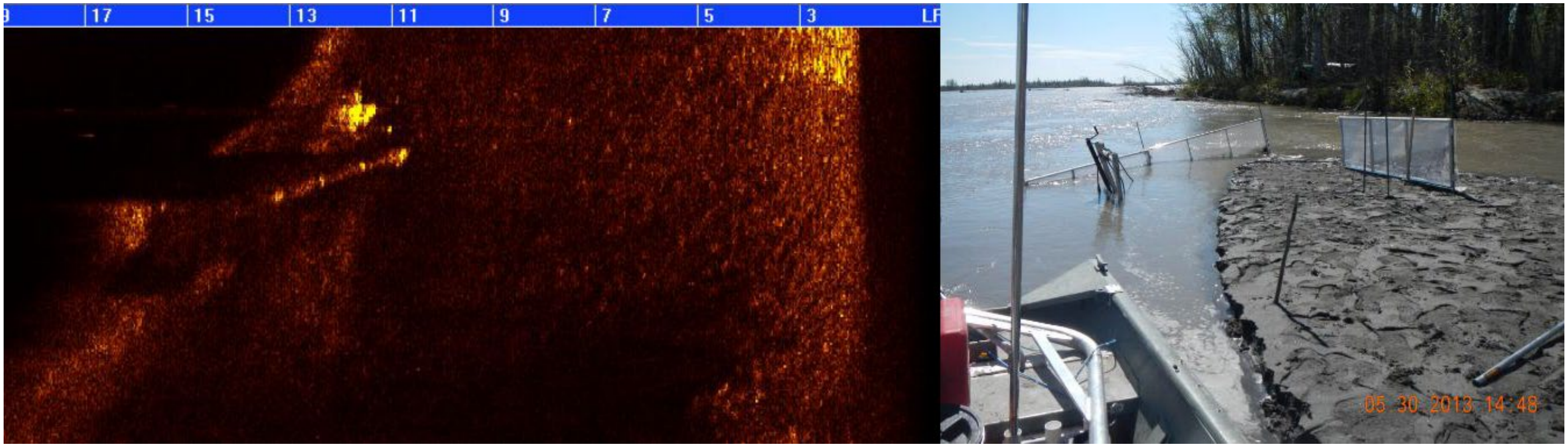


Appendix Figure B-2. Side scan sonar showing the gravel bar at mobile acoustic site 6 (Project River Mile 33.4) in 2013.

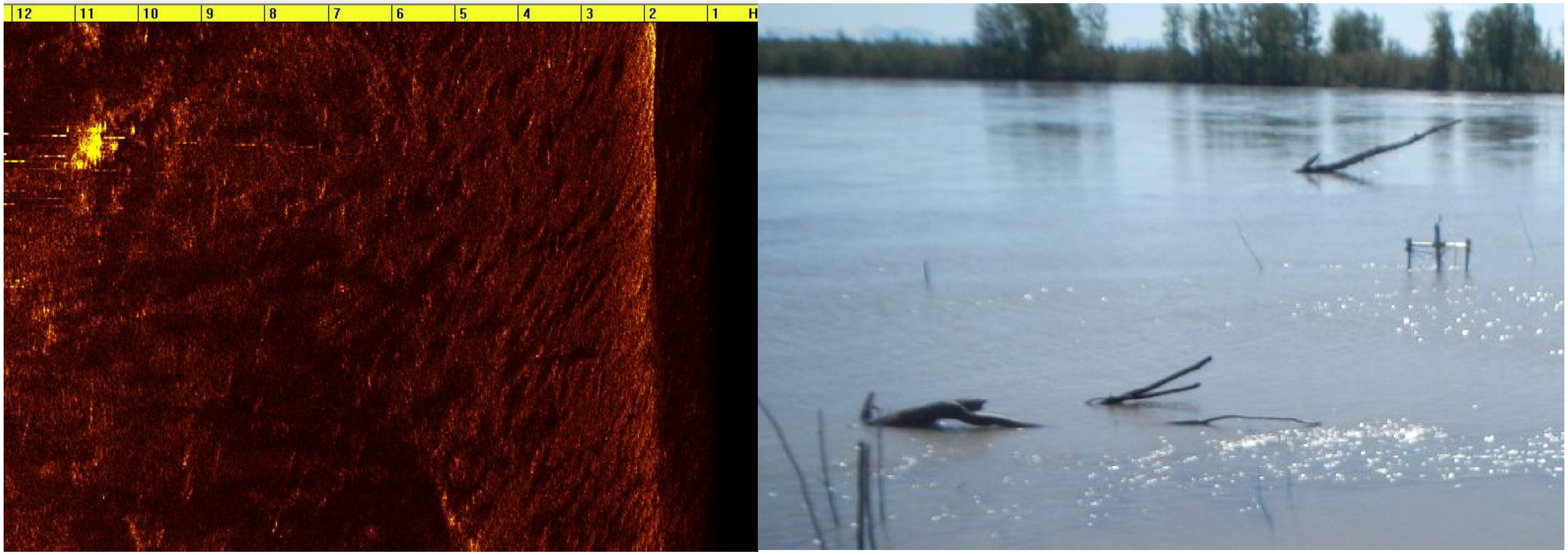


Appendix Figure B-3. Side scan sonar imagery of substrate at mobile acoustic site 10 (Project River Mile 22.6) in 2013 showing mixed gravel and sand/silt substrate.

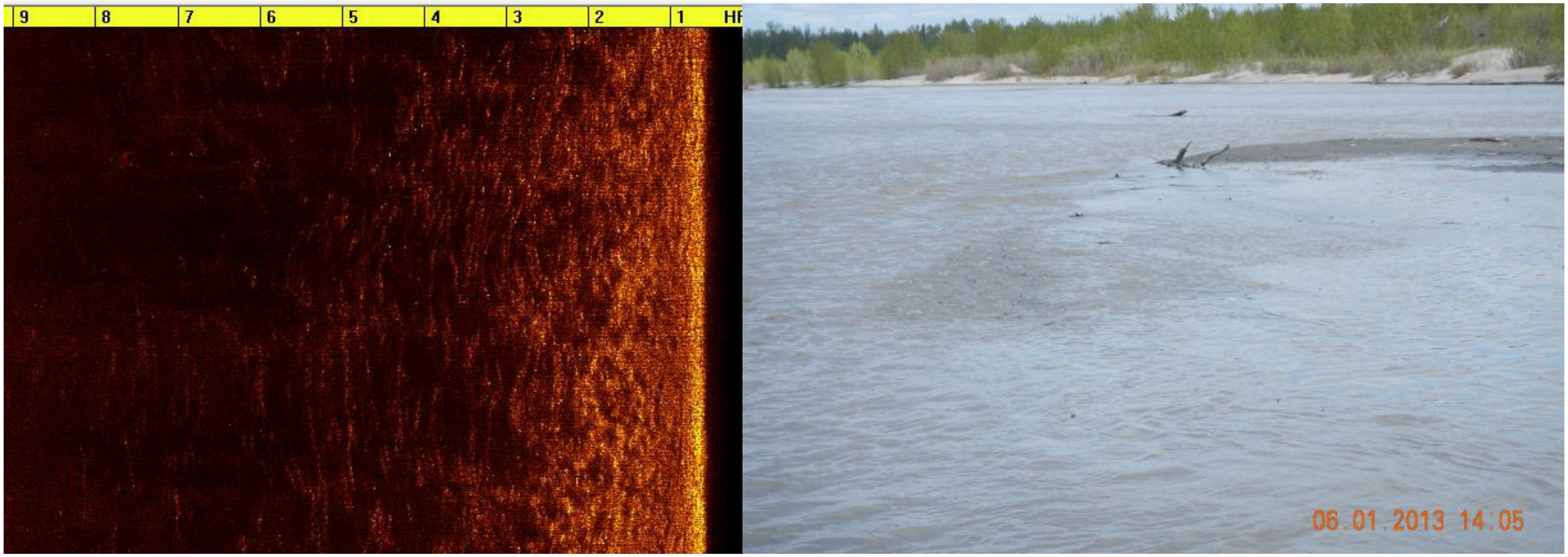
PART A - APPENDIX C: SIDE SCAN SONAR IMAGES COMPARED TO PHOTOGRAPHS



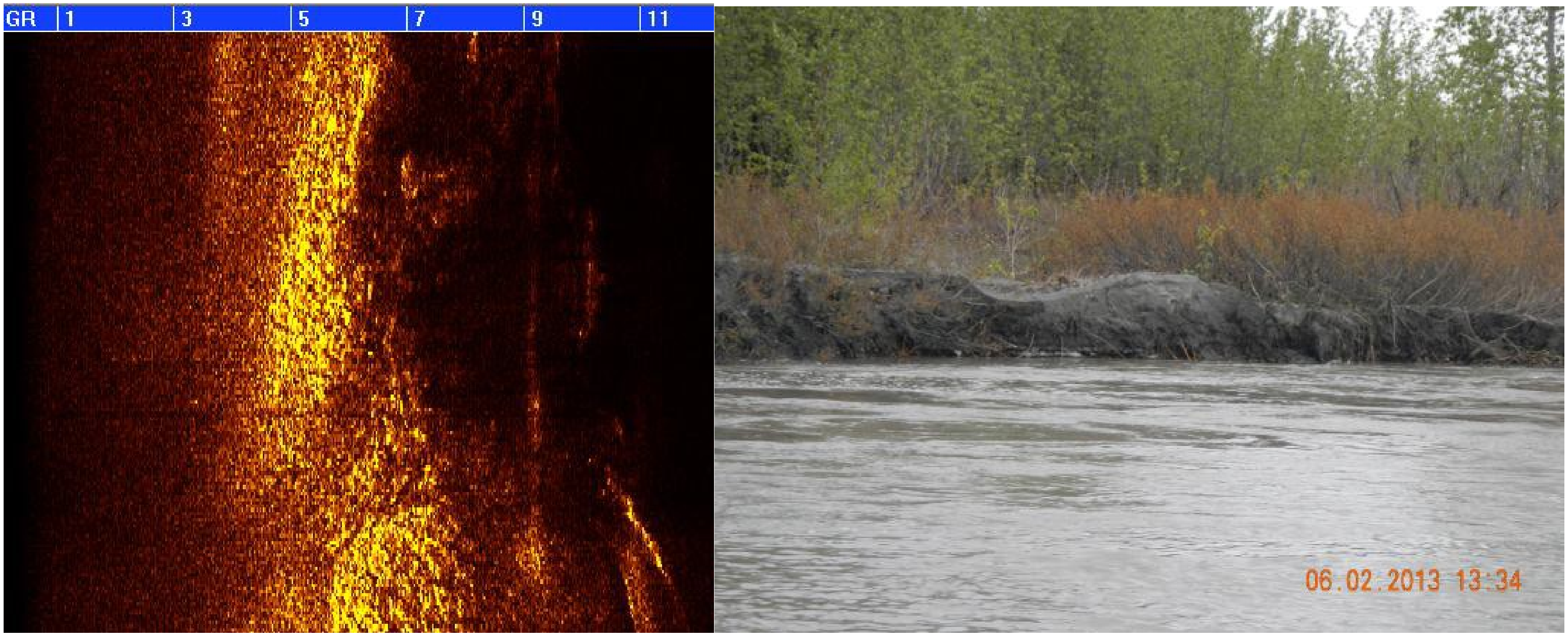
Appendix Figure C-1. Side scan image and photograph of sand bar, weir and fixed transducer at Site 1 on May 30. Weir and fixed transducer mount visible as bright reflections.



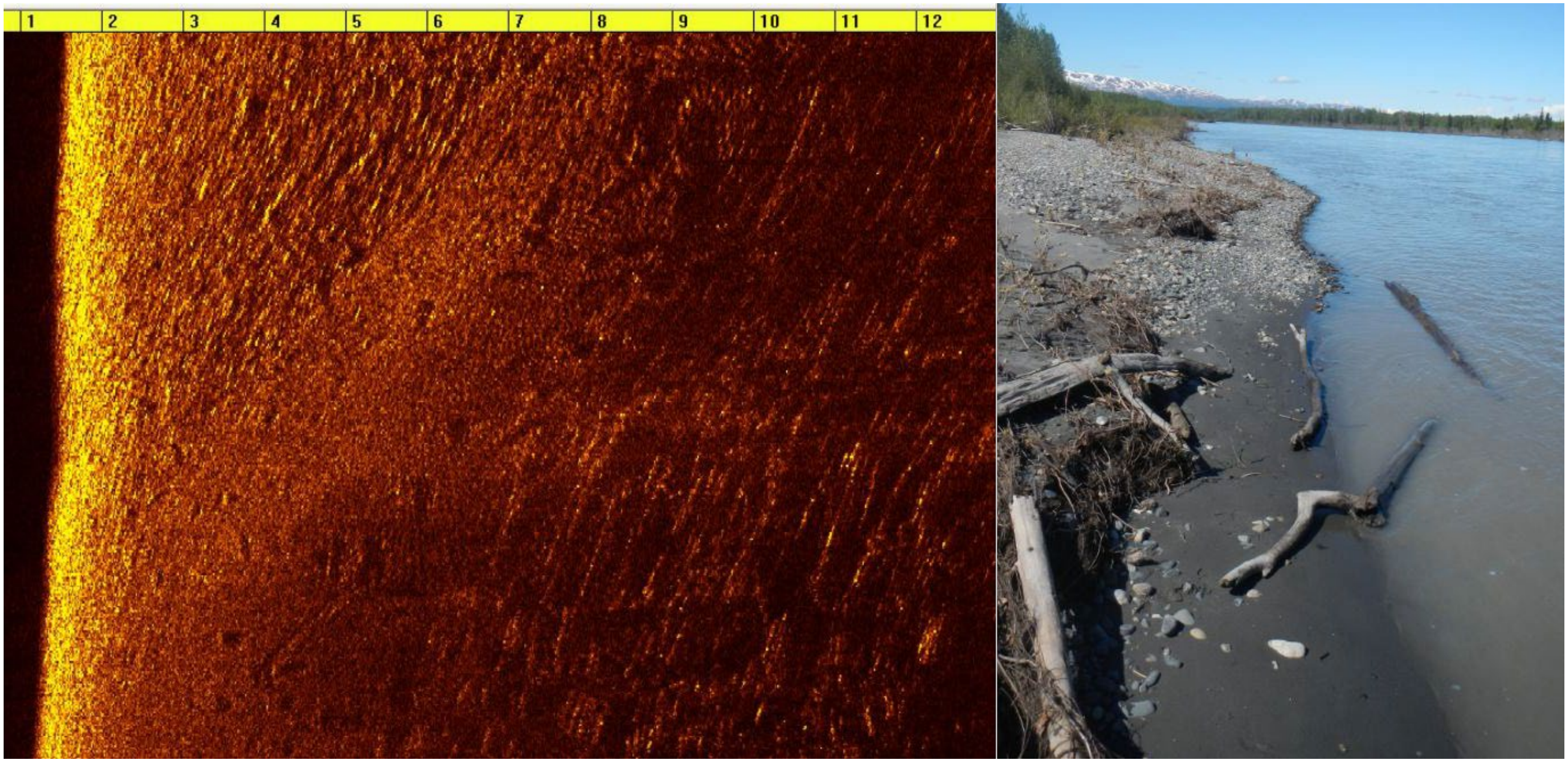
Appendix Figure C-2. Side scan image and photograph of submerged sand bar and the fixed transducer mount at Site 1. Large number of eulachon present on June 8.



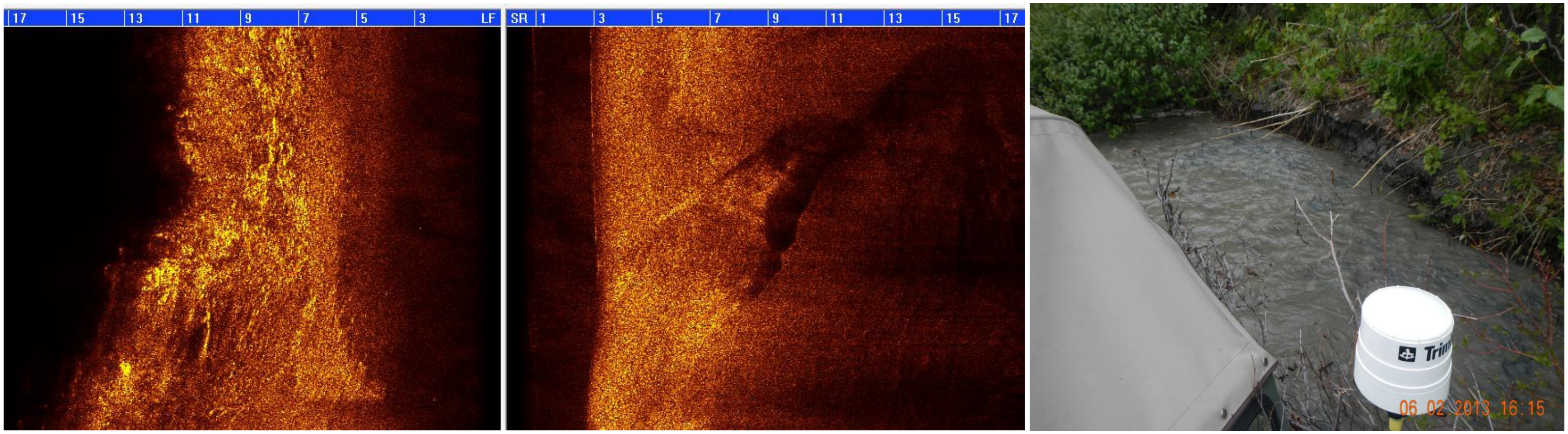
Appendix Figure C-3. Side scan image and photograph at shoreline of sand bar with eulachon spawning activity at Site 4. “Striations” appear to be related to the presence of a large number of eulachon on June 1.



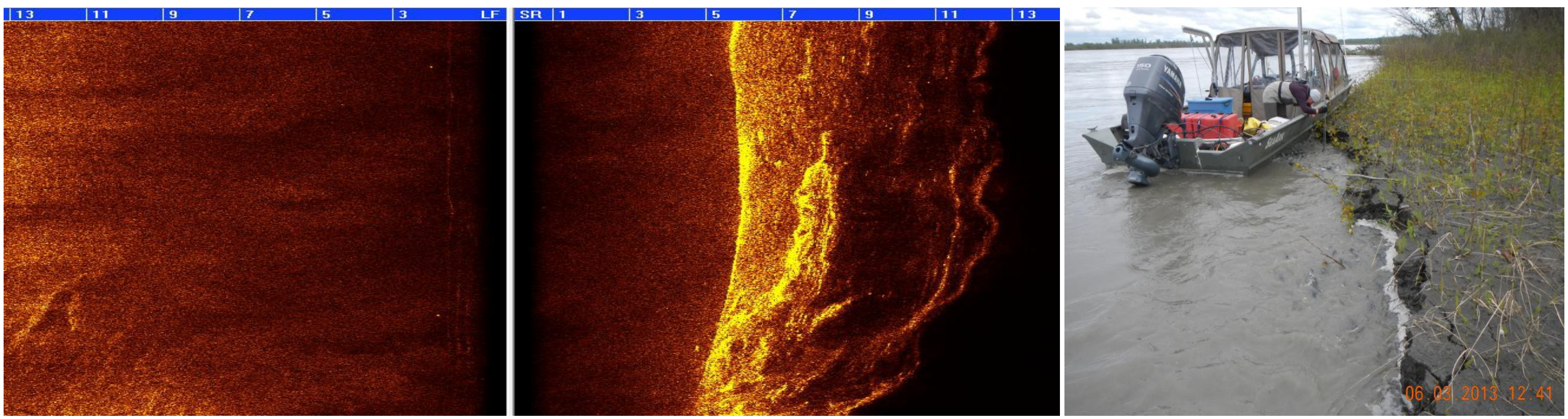
Appendix Figure C-4. Side scan image and photograph of cut bank along the shoreline at Site 5 on June 2. Side scan image suggests gravel base under sand.



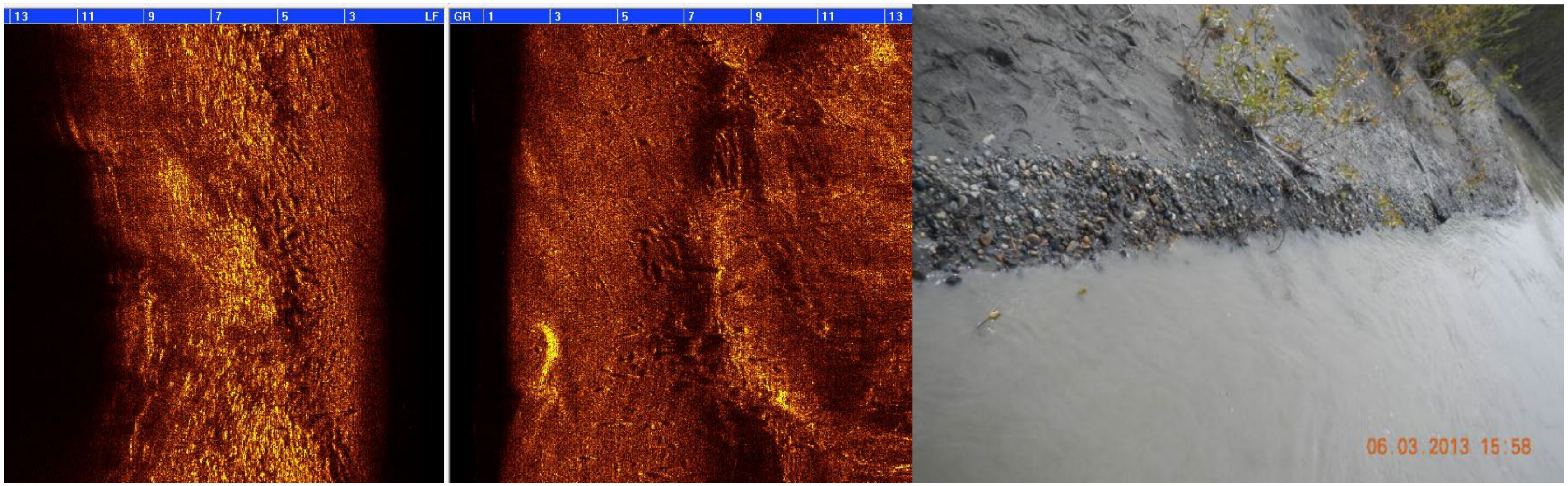
Appendix Figure C-5. Side scan image and photograph of the shoreline at Site 6 showing mixed gravel and sand on June 8.



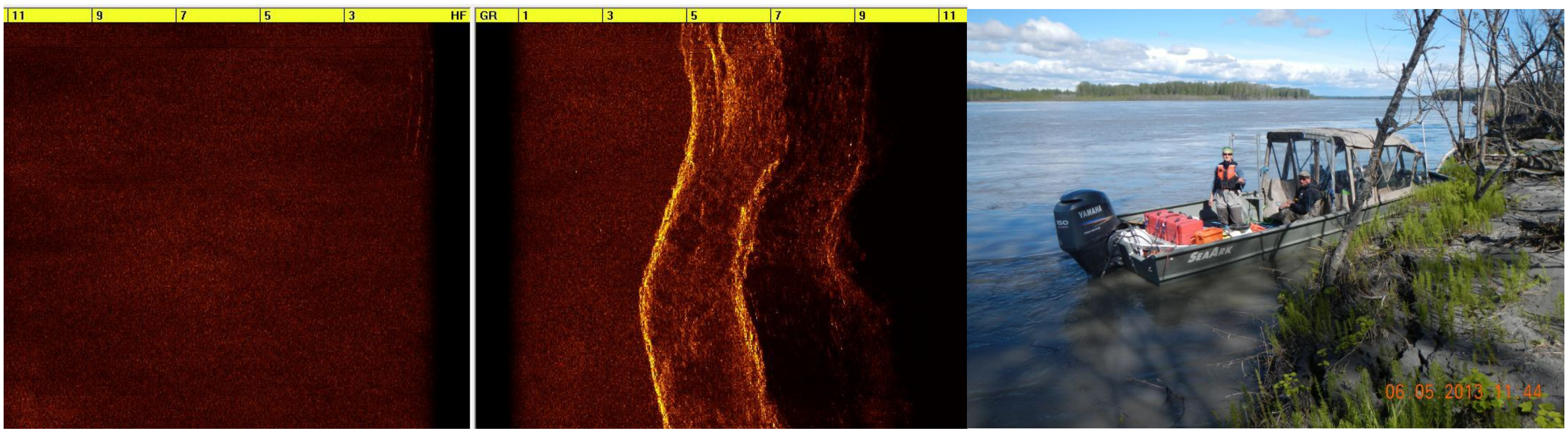
Appendix Figure C-6. Side scan image and photograph of site showing sand/silt low cut bank under alders, with some gravel along the shore at Site 7 on June 2.



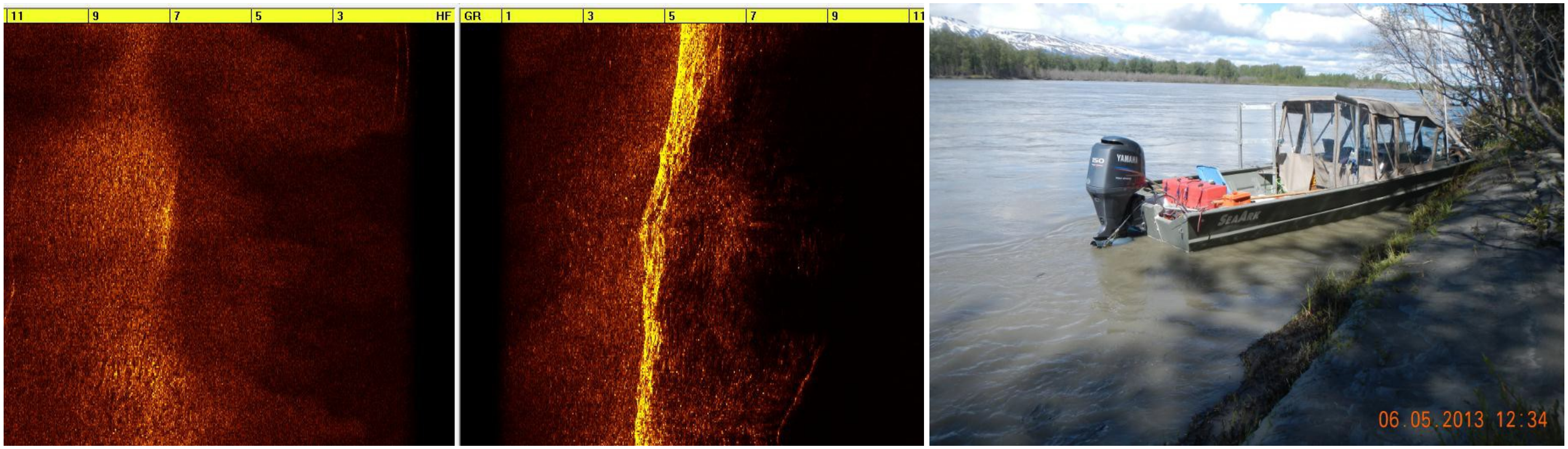
Appendix Figure C-7. Side scan image and photograph of sand stepped low cut bank at Site 8 on June 3.



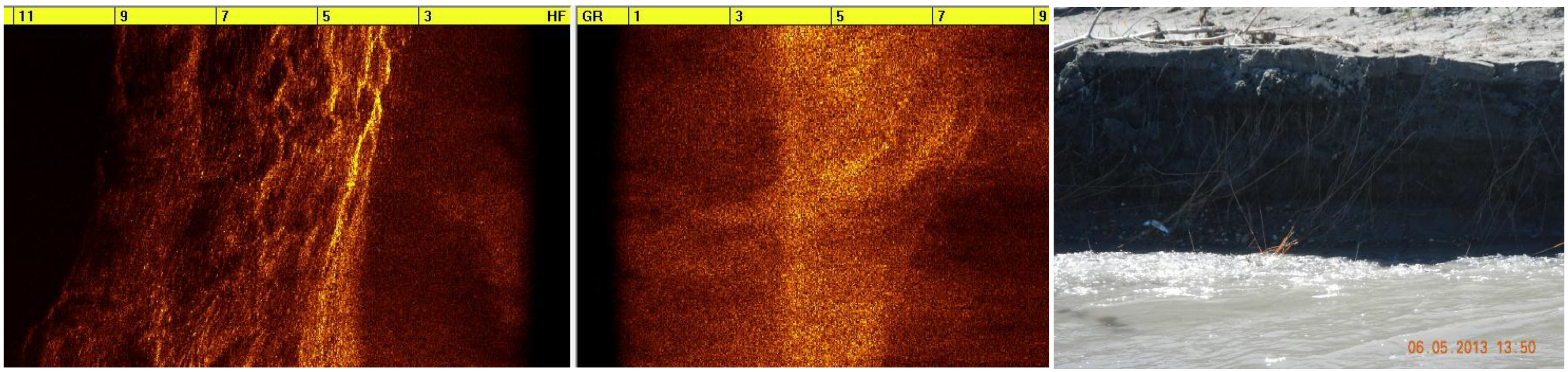
Appendix Figure C-8. Side scan image and photograph of gravel and sand along the shoreline at Site 10 on June 3.



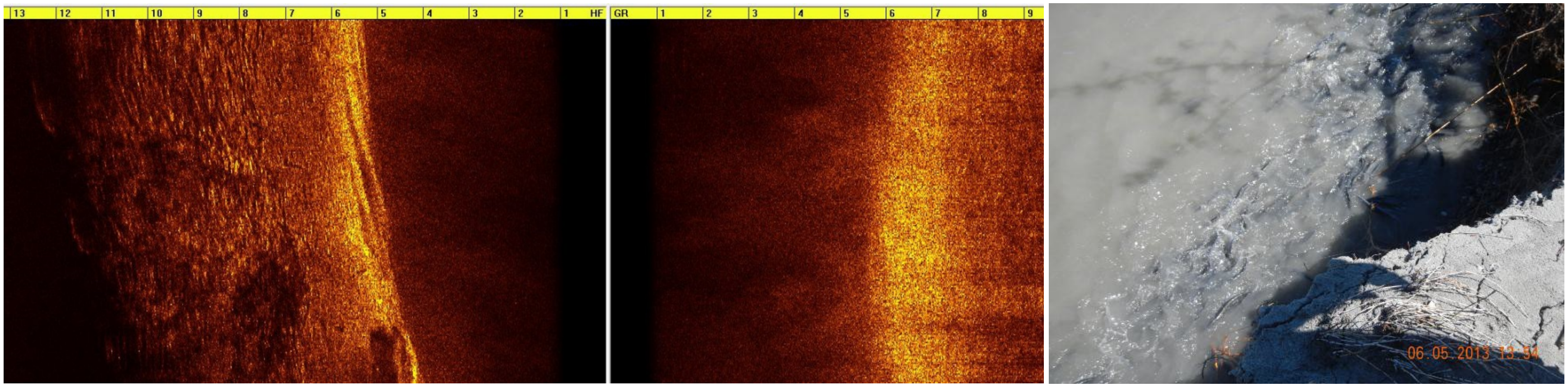
Appendix Figure C-9. Side scan image and photograph showing sand and high cut bank along the shoreline at Site 12 on June 5.



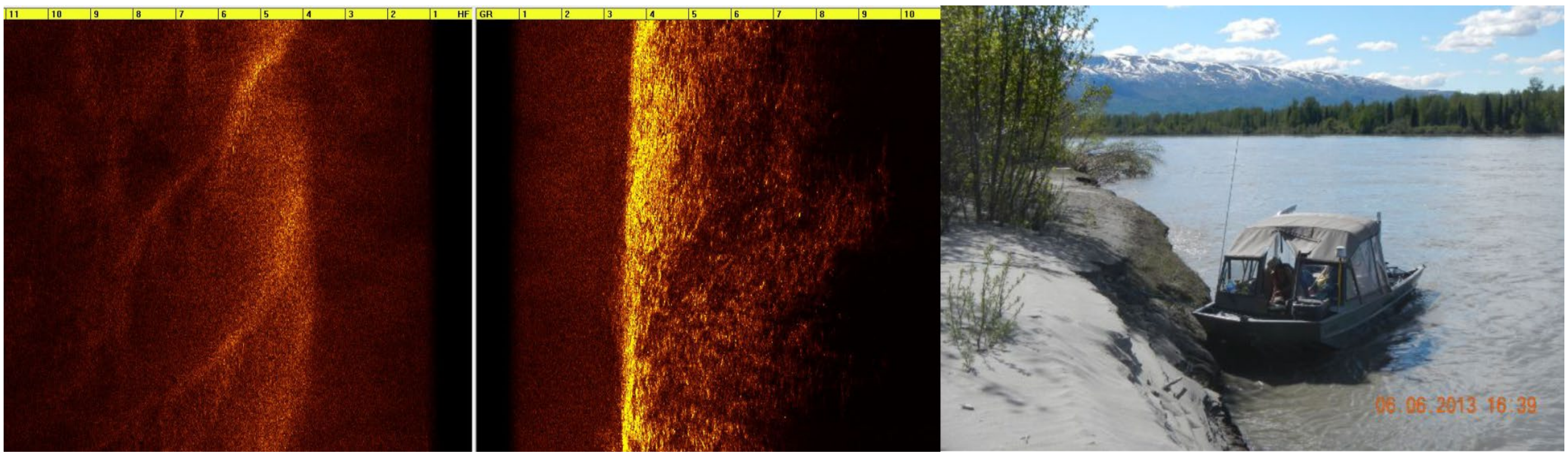
Appendix Figure C-10. Side scan image and photograph of shoreline at Site 13 showing sand and high cut bank on June 5.



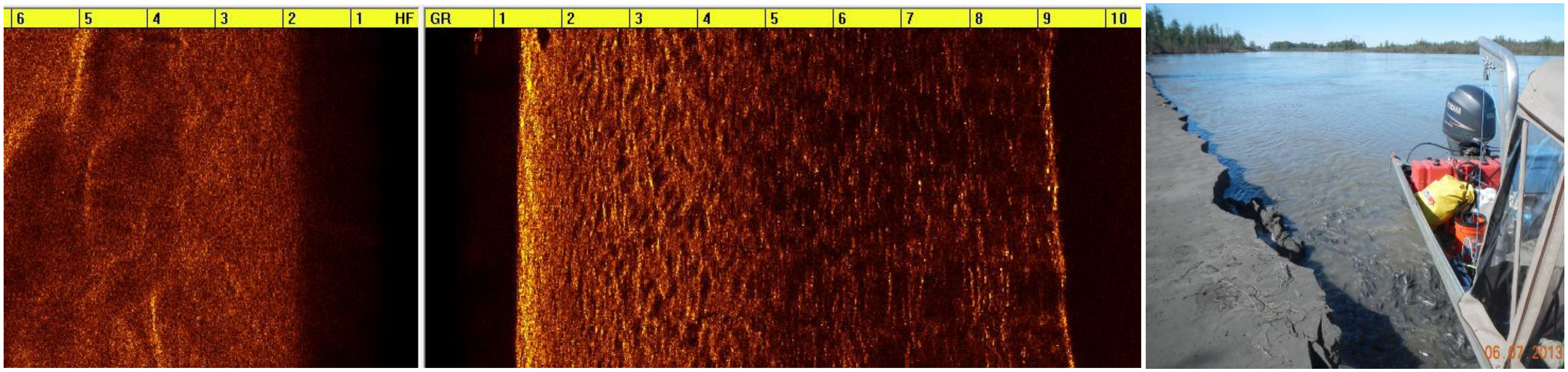
Appendix Figure C-11. Side scan image and photograph of sand, some gravel, and stepped cut bank at Site 14 on June 5.



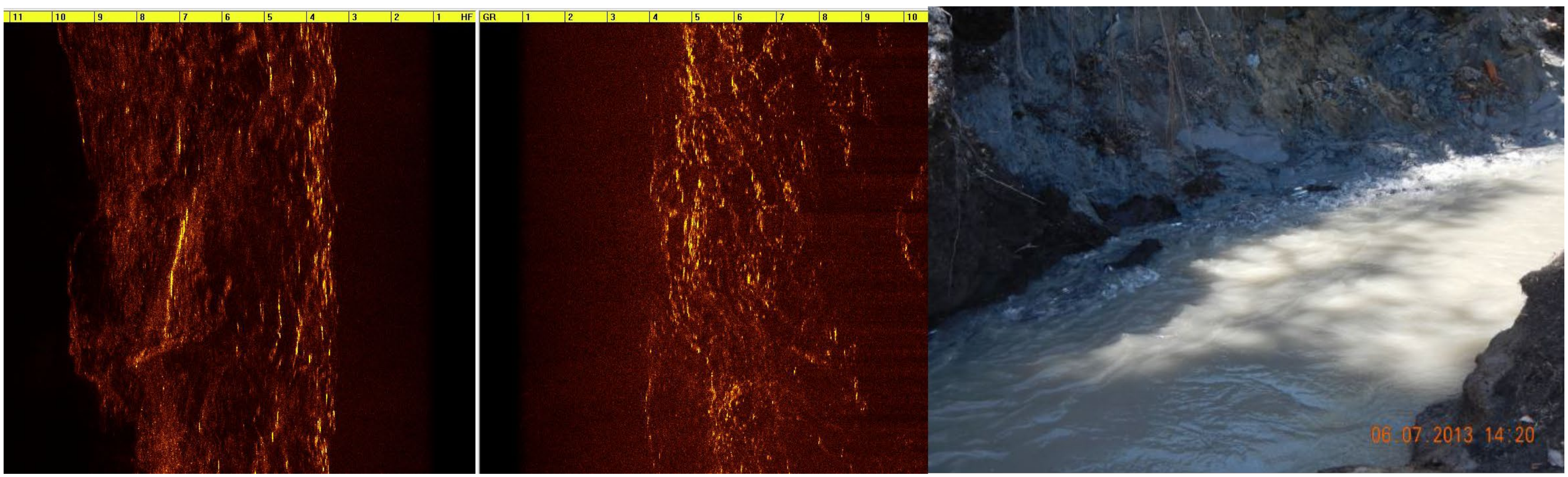
Appendix Figure C-12. Side scan image and photograph of sand stepped cut bank at Site 15 on June 5.



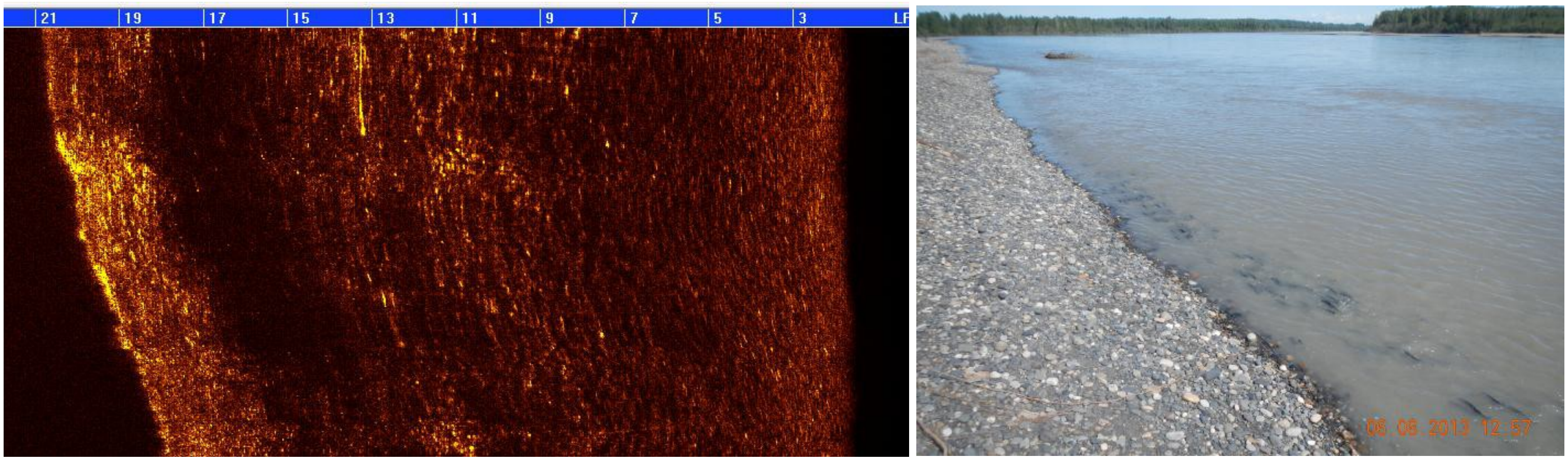
Appendix Figure C-13. Side scan image and photograph along shore showing sand bank, possibly with harder substrate at its base at Site 18 on June 6.



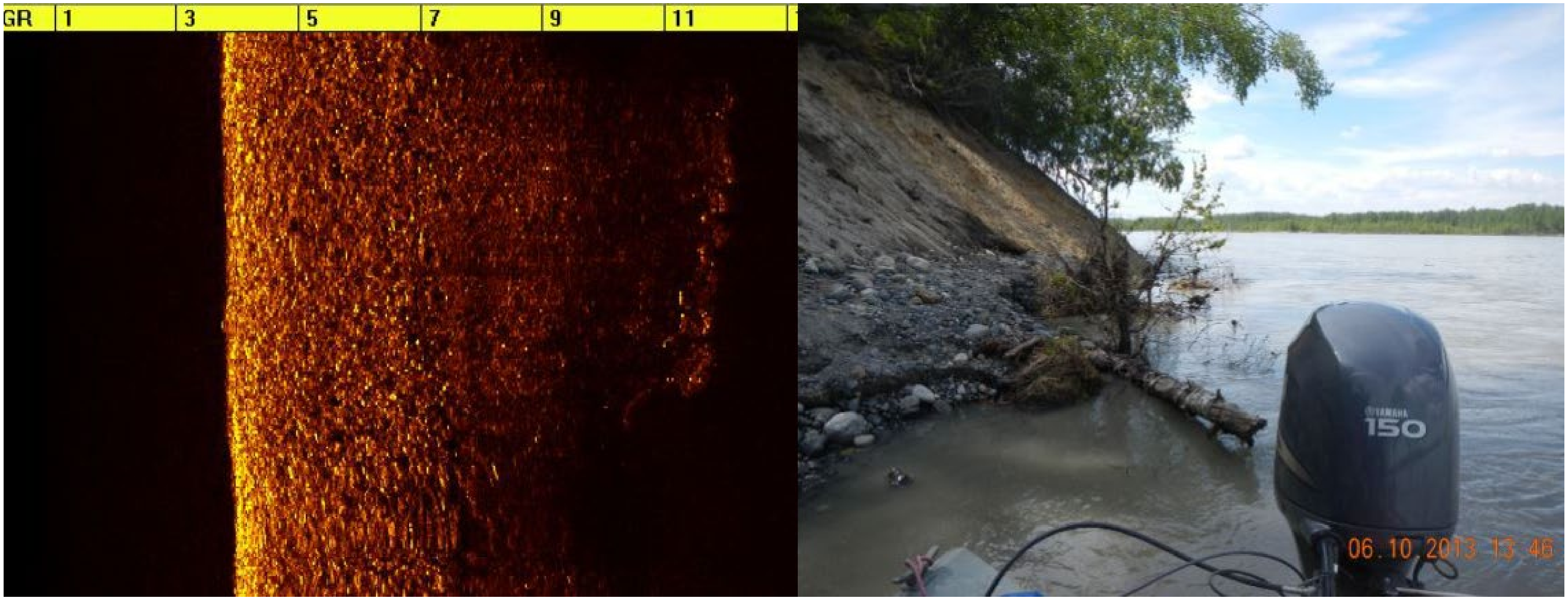
Appendix Figure C-14. Side scan image and photograph showing sand and a low cut bank at Site 19 on June 7. Eulachon reflections and shadows are visible in the side scan image.



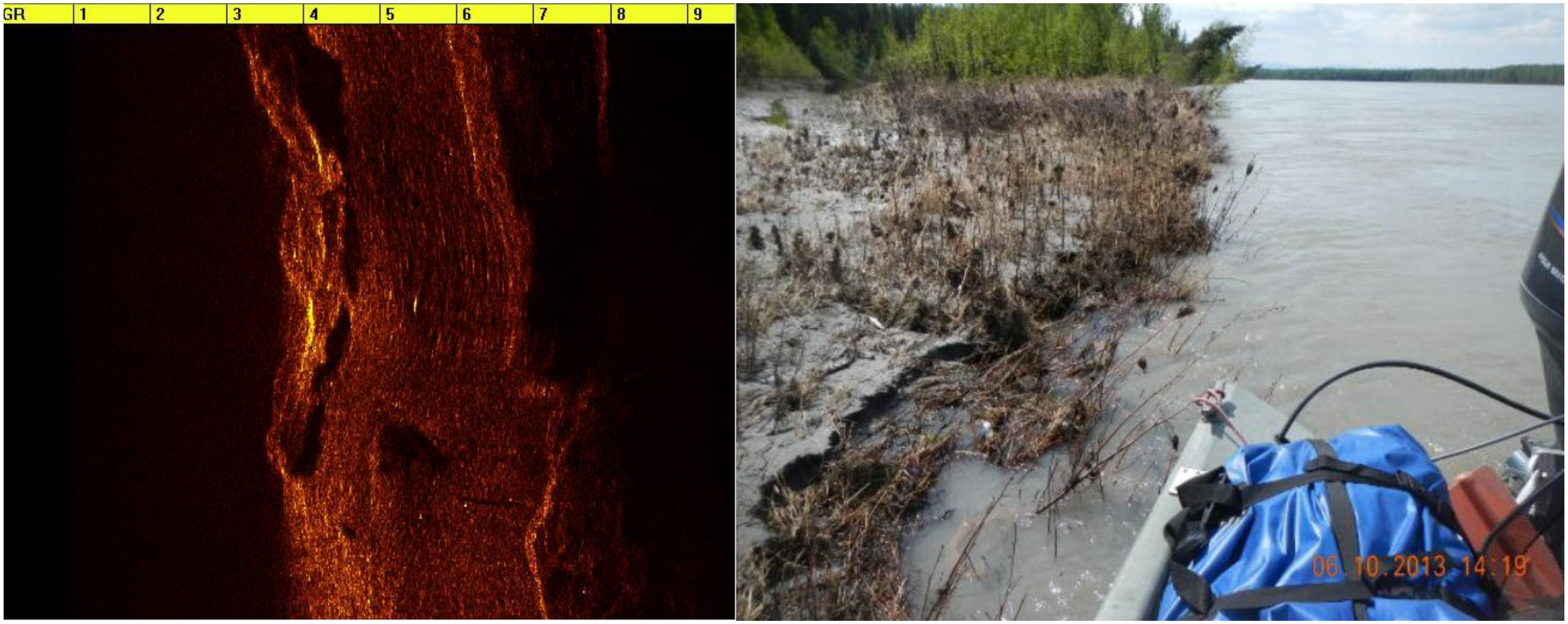
Appendix Figure C-15. Side scan image and photograph of steep bluff and peat over compacted clay base with possibly harder substrate below at Site 21 on June 7.



Appendix Figure C-16. Side scan image and photograph of gravel bar at Site 22 on June 8.



Appendix Figure C-17. Side scan image and photograph of gravel at base of high bluff at Site 27 on June 10.



Appendix Figure C-18. Side scan image and photograph of sand cut bank at Site 28 on June 10.