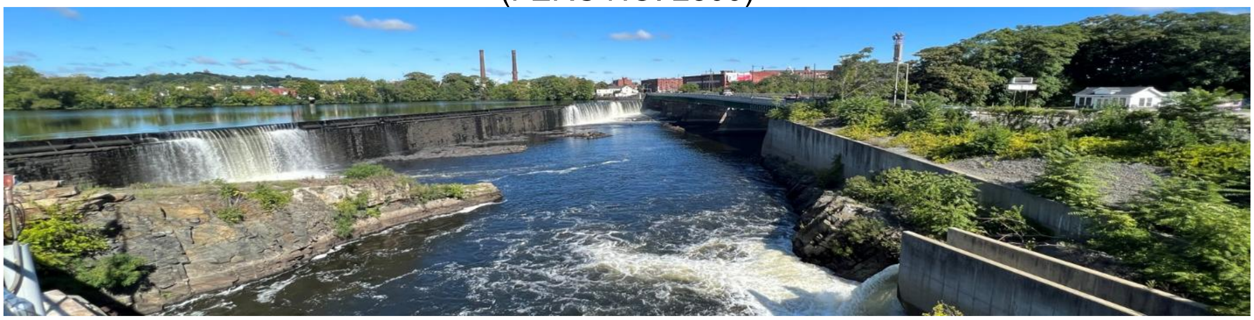
STURGEON DISTRIBUTION AND PROJECT INTERACTION STUDY

LAWRENCE HYDROELECTRIC PROJECT

(FERC NO. 2800)



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1. INTRODUCTION

Essex Company, LLC (Essex), a subsidiary of Patriot Hydro, LLC, is the Licensee, owner, and operator of the 16.8-megawatt (MW) Lawrence Hydroelectric Project (FERC No. 2800) (Project or Lawrence Project). The 50-year operating license issued by the Federal Energy Regulatory Commission (FERC or Commission) will expire in 2028. Essex is pursuing a new license for the Project using the Commission's Integrated Licensing Process (ILP) as defined in 18 Code of Federal Regulations (C.F.R.) Part 5. Essex filed a Pre-Application Document (PAD) with the Commission on June 16, 2023, the Proposed Study Plan (PSP) on November 28, 2023, and the Revised Study Plan (RSP) on April 10, 2024.

The Commission's August 15, 2023 Scoping Document 1 (SD1) and November 28, 2023 Scoping Document 2 (SD2) identified a variety of aquatic resource issues to be analyzed in the Environmental Assessment (EA) for the Project's relicensing. The United States Fish and Wildlife Service (USFWS), Massachusetts Division of Marine Fisheries (MA DMF), Massachusetts Division of Fisheries and Wildlife (MassWildlife), National Marine Fisheries Service (NMFS) and New Hampshire Fish and Game Department (NHFGD) subsequently submitted formal requests to determine the presence and movement of sturgeon downstream of and within the Lawrence Project boundary. The Lawrence Project is located within the historical range of both Atlantic (*Acipenser oxyrinchus oxyrinchus*) and Shortnose Sturgeon (*A. brevirostrum*) and currently defines the boundary of the NMFS-designated critical habitat for Atlantic Sturgeon.

In accordance with 18 C.F.R. § 5.15, Essex has conducted this study in response to study requests and study recommendations made by FERC in the Study Plan Determination (SPD), issued on May 10, 2024 and described in the study plan. This report describes the methods and results of the approved Sturgeon Distribution and Project Interaction Study.

1.1 FACILITY DESCRIPTION

The Project is located in Lawrence, Massachusetts, on the Merrimack River, approximately 29 river miles (RM) from the Atlantic Ocean and 11 RM downstream from another hydroelectric project in Lowell, Massachusetts. The Project consists of: a 35-foot-high by 900-foot-long dam known as Essex Dam (or the Great Stone Dam); a 9.8-mile long impoundment; a powerhouse with two 8.4-MW generating units with two horizontal, double-regulated Kaplan bulb turbines; a 130-foot long by 100-foot wide tailrace channel, bordered by bedrock and concrete remnants of an old fish ladder to convey the Project's powerhouse discharge; an underwater 23-kiloVolt transmission line; fish passage facilities; and the North and South canals.

1.2 BACKGROUND AND EXISTING INFORMATION

The Merrimack River downstream from the Lawrence Project has an amphidromous population of Shortnose Sturgeon (Kieffer and Kynard 1993). A study of the overwintering population of sturgeon in the Merrimack River counted 3,786 individuals in the 2020-2021 season and 3,424 individuals in the 2022-2023 season (Stantec 2023). Shortnose Sturgeon movement in the lower Merrimack has been documented up to the I-495 Lawrence Bridge (Stantec 2023) with documented spawning occurring near Haverhill between river kilometer 30 and 32 (Kieffer and Kynard 1996). The detections at the I-495 Lawrence Bridge occurred during the spawning season, suggesting that habitat between the I-495 Lawrence Bridge and the Essex Dam may be used for spawning or pre-spawning habitat. Post-spawn and juvenile Shortnose Sturgeon are present in the river throughout the year (Kieffer and Kynard 1993).

The Merrimack River downstream from the Lawrence Project is utilized by Atlantic Sturgeon from late May to early October for foraging (Kieffer and Kynard 1993; Wippelhauser et al. 2017). Kieffer and Kynard (1993) found that sub-adult Atlantic Sturgeon used only one discrete section of the Merrimack River each year. Sub-adult Atlantic Sturgeon during study were determined to frequent the "lower islands" section of the Merrimack River, located between river kilometers 5-10 and approximately 25 km downstream from Essex Dam. Overwintering in the Merrimack River has been documented for one individual (Wippelhauser et al. 2017).

1.3 SURVEY AREA

The study area includes the section of the Merrimack River located immediately downstream of Essex Dam, extending downstream to the I-495 Lawrence Bridge (an estimated reach length of 1.5 miles).

2. GOALS AND OBJECTIVES

The goal of this study is to determine if Atlantic or Shortnose Sturgeon are interacting with the Lawrence Project. Data collected as a part of this study will provide a baseline to inform on the presence of these species immediately downstream of the dam and to determine if measures are necessary to minimize potential effects for any new license issued for the Project.

Specifically, based on the SPD, the objectives of this study are:

1. Determine if Atlantic and Shortnose Sturgeon are present between the Project dam and the I-495 Lawrence Bridge;
2. If present, quantify the duration and seasonality of Atlantic and Shortnose Sturgeon presence in the study reach;
3. Identify any Project-related effects; and
4. Evaluate the need for upstream Atlantic and Shortnose Sturgeon passage at the project.

3. METHODS

The Sturgeon Distribution and Project Interaction Study consisted of three methodologies:

1. Mobile side-scan sonar (SSS) surveys, which were conducted within the 1.5-mile reach of the Merrimack River between Essex Dam and the Lawrence I-495 Bridge from late March through early May;
2. A pilot study to determine the feasibility of using fixed-location sonar to detect and identify artificial targets of similar size and shape as sturgeon in the Project tailrace and, if feasible, to monitor for the presence of sturgeon in the tailrace from mid-March through early November 2026; and
3. Tagging sturgeon with acoustic transmitters and installing acoustic receivers in the tailrace and downstream reach to monitor from mid-March to early-November (as river conditions allow).

3.1 MOBILE SIDE-SCAN SONAR SURVEYS OF STURGEON

Methods for the mobile SSS surveys were based on the updated study plan described in Appendix D of the Initial Study Report filed with FERC on April 28, 2025.

3.1.1 Survey Design

Repeated mobile SSS surveys were conducted to investigate the presence or absence of sturgeon along a 1.5-mile river reach between the Project and the I-495 Lawrence Bridge. If present, the detected sturgeon were georeferenced and counted.

The survey used similar equipment, software, and techniques used in previous SSS mobile surveys of Atlantic and Shortnose Sturgeon in the Merrimack River (Stantec 2023) and other rivers (Flowers and Hightower 2013, 2015; Kazyak et al. 2020). An aluminum flat-bottom vessel (approximately 6 m in length) was outfitted with a pole-mounted 600 and 1600-kHz dual-frequency EdgeTech 4125i SSS system (Figure 3-1).

Data were georeferenced using the real-time kinematic Global Navigation Satellite System (GNSS) provided by a Trimble BX992 GNSS system (including a dual-antenna setup for heading) and Trimble CenterPoint RTX subscription-based GNSS corrections (Figure 3-1). The projected coordinate system used for the surveys was WGS84 Universal Transverse Mercator (UTM) Zone 19N in meters (also known as EPSG:32619). For the georeferencing origin, the horizontal offsets for the towfish were X= -0.27 m and Y = -1.00 m. The center of the port and starboard transducer array for the towfish was approximately 0.53 m below the water line.

Six surveys were conducted between the Project and the Lawrence I-495 Bridge for approximately 1.5 river miles (2.4 km) from April 4 through May 20, 2025. The survey timing and spatial extent was constrained by safe river flows, navigable waters (avoiding shallow, rocky areas), and weather conditions. The vicinity of the tailrace upriver of the O'Leary Bridge and downstream to approximately the boat ramp at Pemberton State Park was not surveyed due to safety concerns and navigation hazards (Figure 3-2).

The vessel surveyed in navigable waters along parallel transects running longitudinally up and down the river, typically at approximately 3–4 knots over ground (1.5–2.1 meter per second [m/s] or 3.5–4.6 miles per hour [mph]). Depending on the current direction and speed, the vessel speed ranged from 2 to 5 knots (1.0 to 2.6 m/s, or 2.3 to 5.8 mph). A set of five longitudinal transects provided full overlapping coverage of the Merrimack River throughout the survey area (Figure 3-3). The planned transects, and an aerial background photo of the survey area, were displayed on a monitor onboard the vessel for real-time navigation aid and data acquisition using SonarWiz software, version 8.2.3 (Chesapeake Technology Inc., Los Altos, CA). A new file was recorded for each individual survey line.

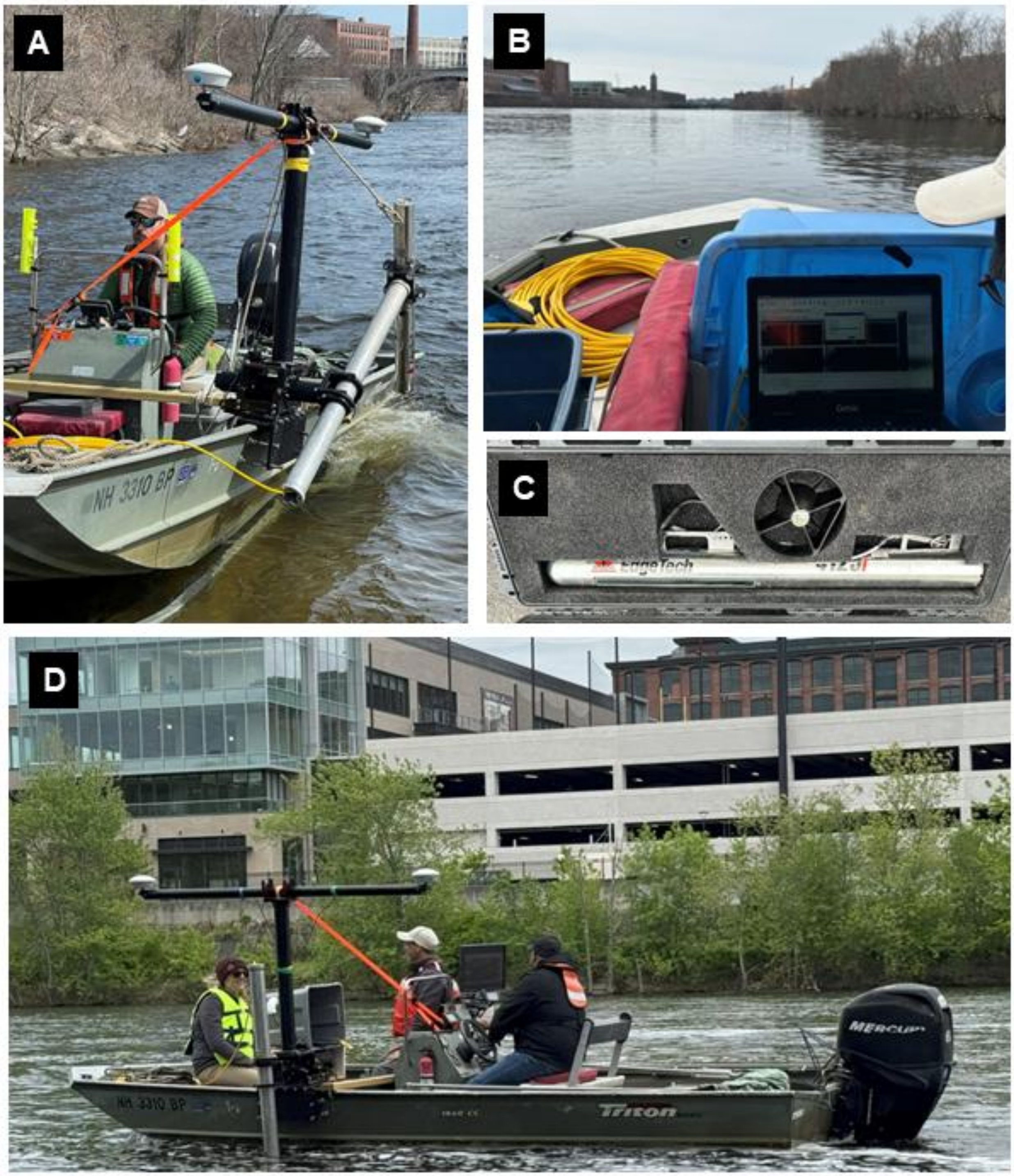


Figure 3-1 (A) outboard vessel shown being launched with towfish raised; (B) laptop computer sheltered and shaded during data acquisition; (C) Edgetech 4125 towfish; and (D) underway surveying a transect with side-scan sonar downstream of Lawrence Hydroelectric Project during spring of 2025.

Figure 3-2 The mobile side-scan surveys on the Merrimack River were constrained immediately downstream of Lawrence Hydroelectric Project by rough water, strong flow, and shallow, rocky riverbed, as exemplified on (A) April 2, (B) April 23, and (C) May 20, 2025.

Figure 3-3 The survey area of the Merrimack River for mobile side-scan sonar surveys included nearly bank to bank coverage by five planned lines (green) extending from the I-495 Lawrence Bridge to the boat ramp immediately downriver of the O'Leary Bridge (Route 28) and an old railroad bridge.

3.1.2 Side-Scan Sonar Data Processing and Analysis

The SSS data were imported into SonarWiz software for processing, visualization, and exporting data and images. After setting up the basemap in the matching projected coordinate system, the Edgetech SSS files in extended Triton format (*.xtf) were imported as samples per frequency channel using the actual sampling rate, and these data were saved in Chesapeake sonar format (*.csf files). Channels 1 and 2 were grouped as low-frequency SSS lines and channels 3 and 4 were grouped as high-frequency lines.

After inspecting the navigation time series and imagery, sufficient positional jitter — partly due to erratic, uncontrolled vessel motion from river conditions — was observed to necessitate applying a 50-s time-constant course smoothing. The time-series plots of the heading data identified dropouts, associated with bridge crossings, that required manual interpolation and applying a 30-point filter. Sound speed was adjusted for processing acoustic data from each survey, based on water temperature using a sonar calculator based on the equation by Del Grosso and Mader (1972; Table 3-1).

Bottom tracking, i.e., identifying the line separating the riverbed imagery from the water column, was first performed automatically and then manually edited. An automatic time varying gain was applied to the amplitude of the sonar echoes.

Each survey was manually inspected for sturgeon-like targets in the SSS imagery using the plan view and the waterfall display. Potential target detections were selected, in addition to multiple other types of target detections (boulders, tires, tree debris, and others), and exported, providing reviewers with a range of targets for classification for training and a measure of verification. Criteria for classifying targets as sturgeon included: (1) shadow silhouette with heterocercal tail and characteristic snout; (2) slender target with shadow isolated on the riverbed; (3) target length of approximately 80 to 120 centimeters; and (4) oblong slender (in contrast to the deep body characteristic of a Common Carp or Striped Bass) target in the water column. Three independent reviewers inspected the image and attributes of the target detections and classified them by a preset list of categories and a relative confidence score of low (=3) considered as a less than 50-percent certainty, medium (=2) considered as a 50- to 80-percent certainty, and high (=1) considered as a greater than 80-percent certainty in identification.

Table 3-1 Sound speed estimates used during sonar processing based on water temperature.

Survey	Date	Water Temperature (°C)	Sound Speed (m/s)
1	Apr 4	6	1431
2	Apr 10	5.5	1428
3	Apr 17	6	1431
4	Apr 23	10	1447
5	Apr 30	14.7	1465
6	May 20	16.9	1472

3.2 FIXED-LOCATION SONAR MONITORING IN THE TAILRACE

3.2.1 A Two-Phase Approach

Key objectives for fixed sonar monitoring include: (1) determining if sturgeon are present in the tailrace from mid-March through early November and, if present, (2) determining how they are distributed in the tailrace for purposes of informing the potential design and location of a fishway. Essex proceeded with a different methodology than the fixed-location SSS that FERC recommended in the SPD for Study 5, because fixed-location SSS is an untested stationary application with unknown performance, as described in the Study Plan. Given that using a fixed-SSS array to monitor sturgeon distribution and behavior in a tailrace is inconsistent with generally accepted scientific practice (Haxton et al. 2024; Munnelly et al 2024), a two-phase approach was taken that included a pilot study in 2025 to assess site conditions and test the performance of two sonar technologies more suitable for this task. If deemed feasible from the pilot study, monitoring for the presence of sturgeon in the tailrace would be considered from mid-March through early November 2026.

3.2.2 Sampling Design

3.2.2.1 Phase 1: Pilot Study to Assess Feasibility (Year 1)

During 2025, the pilot study evaluated deployment options and suitable locations in the tailrace for a fixed-location sonar installation and tested target detection and identification performance of two sonars at multiple sampling configurations (Langkau et al. 2012; Gurshin et al. 2017). If the sonar couldn't be securely mounted in an area with minimal turbulence, upwelling, entrained air bubbles or debris, then an eight-month deployment was considered not feasible because of the high likelihood of severe equipment damage from hydraulic stresses and collision of large objects, and limited detectability of sturgeon echoes from turbulence and acoustic interference (e.g., bubbles, debris field). One potential result was that some areas within the tailrace would not be feasible to sample due to turbulence and noise (e.g., bubbles, debris) throughout the water column, but monitoring could be possible for some portion of the tailrace.

The likelihood of detecting sturgeon and correctly differentiating between sturgeon and other objects of similar size (e.g., a submerged branch) is important and can depend on the sonar location, sampling volume (i.e., range, field of view, direction), and the sonar specifications (e.g., resolution, sampling rate, transmit power, etc.). Data were collected by deploying artificial targets within the field of view of the sonar(s) at known times and depths. Artificial targets consisted of a 97 cm rubber sturgeon, a 155 cm rubber sturgeon, a 71 cm rubber Striped Bass, and a 61 cm long and 3.8 cm diameter steel pipe (Figure 3-4; Figure 3-5). Targets were deployed from an outboard vessel and set to desired depth by attaching the target with thick monofilament line to a weight approximately two meters below and to measured rope several meters above which was tied off to plastic surface buoy. Targets were allowed to drift by the tailrace currents through the sonar field of view.

One of the sonars tested was the Adaptive Resolution Imaging Sonar (ARIS) with 1100 and 1800 kHz modes (Sound Metrics, Inc.; Belcher et al. 2001; Figure 3-6). The ARIS is the manufacturer's successor to the dual-frequency identification sonar (DIDSON), which, together with the DIDSON, have become accepted remote sensing technologies for successfully detecting and identifying sturgeon (Izzo et al. 2022; Haxton 2024; Munnelly et al. 2024). The effective sampling range may vary based on conditions but should be between 10 and 15 m for detection and identification. The ARIS has two beam modes: 48 beams with a 0.6° beam width and 96 beams with a 0.3° beam width. The field of view of the ARIS in the tests was 14° vertically and 28° horizontally.

The second imaging sonar tested was the Teledyne BlueView M900-2250-130-Mk2 high-resolution, dual-frequency imaging sonar. This BlueView sonar model can operate at 2,250 kHz for ultra-high resolution at close range (0.2–7 m) and 900 kHz for detection at 2–60 m. Up to 768 narrow beams (1° wide) provide a field of view of 130°. The vertical beam width is 12° at 900 kHz and 20° at 2,250 kHz.

Each sonar was equipped with a remote-controlled pan-and-tilt device that was mounted to aluminum brackets and attached to an aluminum I-beam affixed to the river-right fish lift entrance weir (Figure 3-7). As part of the two-phase approach to monitoring for presence of sturgeon in the tailrace using fixed-location sonar technologies, a pilot study to test the feasibility of the equipment, deployment, and the environment was completed between October 28, and November 10, 2025 (Table 3-2).

3.2.2.2 Phase 2: Long Term Monitoring in Year 2

Data collection from mid-March through early November would be considered if the pilot study demonstrates feasibility as described in the Study Plan. Sonar monitoring of sturgeon in the tailrace, if feasible, must consider infrastructure, deployment methods, sonar choice, and sampling configuration to effectively detect and identify sturgeon, and withstand the harsh river conditions known to occur in the tailrace (Figure 3-8). Criteria that must be demonstrated from the pilot study include: (1) reliable detection of a target with shape and size comparable to a sturgeon; (2) sufficient image resolution and observation duration in the sonar's field of view to distinguish a sturgeon from other oblong objects carried by currents; (3) the ability to detect and identify targets at relevant depths (from the riverbed to midwater) and ranges (15-20 m or greater); (4) adequate spatial and temporal sampling coverage (i.e., a sufficiently large sampled area or volume and sufficient target residence time in the beams) to enable successful sturgeon encounters; and (5) the instrument robustness such that performance is not compromised, nor equipment damaged, under conditions of fast flows, bubbles, eddies, turbulence, and floating or submerged debris, including large tree logs and branches.

3.2.3 Imaging Sonar Data Analysis

The dynamic nature of bubbles and debris in the water column precluded the use of background noise removal algorithms and other automated processing routines. The feasibility of sturgeon monitoring by each of the two sonar technologies was assessed qualitatively with known targets towed or drifted across the sonar's field of view at prescribed target depth and sonar pan and tilt angles.

Figure 3-4 Artificial targets for testing detection and identification capabilities of different imaging sonar technologies for fixed-location monitoring of sturgeon in the tailrace at Lawrence Hydroelectric Project: (A) 61-cm long x 3.8-cm diameter steel pipe; (B) 71-cm rubber Striped Bass; and (C) 97-cm rubber sturgeon.

Figure 3-5 For comparison, a large 155-cm rubber sturgeon target and a smaller 97-cm rubber sturgeon target.

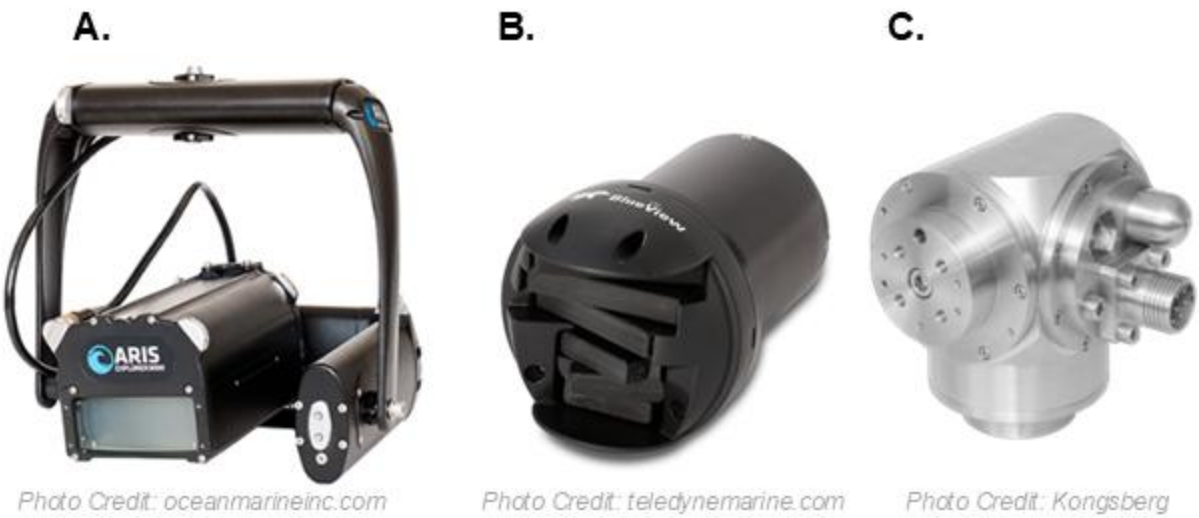


Figure 3-6 Imaging sonars used in the pilot study: (A) Sound Metrics ARIS 1800 Explorer with AR2 rotator (pan and tilt) and (B) Teledyne Blue View M900-130-Mk2 with (C) Kongsberg OE10-102 pan and tilt device.

Figure 3-7 Photos from sonar installation: (A) on the river-right weir(or fish lift entrance) gate of the Project powerhouse which, similar to the testing phase, was complicated due to (B) eddies, upwelling, large debris fields and logs in the tailrace. Sonars (C,D) were attached to aluminum brackets on the cabled door, to be lowered and raised for testing days in November 2025.

Table 3-2 Field activities completed for the 2025 pilot study to investigate the feasibility of three fixed-location sonar technologies to monitor for the presence of sturgeon in the Lawrence Project tailrace.

Date		Activity Description
Oct 28	T	Mobilization
Oct 29	W	Site mobilization
Oct 30	R	Completed attaching the sonar I-beam mount frame to the gate
Oct 31	F	Mobilization of gear
Nov 3	M	Rigged equipment and installed ARIS
Nov 4	T	Rigged equipment and installed Blueview sonar; tested ARIS
Nov 5	W	Testing with ARIS and Blueview sonars with targets
Nov 6	R	Testing with targets
Nov 10	M	Demobilization

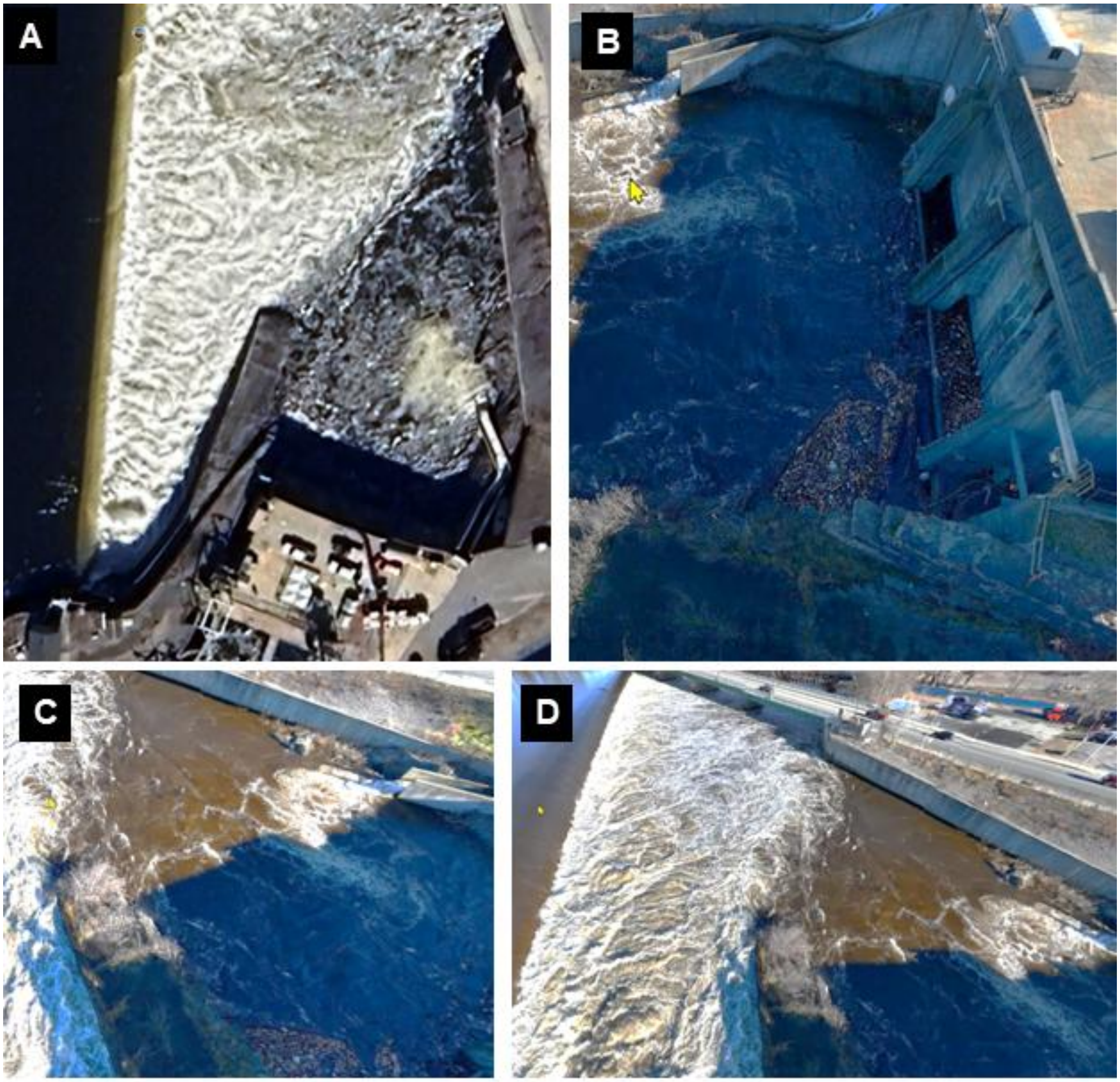


Figure 3-8 **Long-term deployments of fixed-location sonar to monitor for presence in the tailrace must contend with extreme river conditions known to occur at Lawrence Hydroelectric Project.**

3.3 ACOUSTIC TELEMETRY

3.3.1 Acoustic Telemetry Equipment

Seasonal use and movement of tagged sturgeon was evaluated in the downstream project reach using a series of acoustic receivers operating on one of two frequencies. High frequency 416.7kHz coded Juvenile Salmon Acoustic Telemetry System (JSATS) transmitters were detected using Advanced Telemetry Systems (ATS) autonomous SR3001 and shore-based SR3017 Trident acoustic receivers. The SR3001 model receiver is a single, completely submersible package that includes a hydrophone, receiver/datalogger, and battery inside of a PVC housing (Figure 3-9). The SR3017 model consists of a cabled hydrophone that is independent of and connected to a shore-based receiver/datalogger. InnovaSea VR2Tx acoustic receivers were used to detect sturgeon carrying a 69kHz acoustic transmitter. Similar to the ATS SR3001 autonomous receiver, the InnovaSea VR2Tx is a single, completely submersible unit consisting of a hydrophone, receiver/datalogger, battery, and a built-in beacon transmitter (Figure 3-10).

Transmitter models used for tagging sturgeon included the ATS model SS300 and InnovaSea models V13 and V16. The SS300 transmitter weighed 1,050 mg, measured 17.2 x 8.3 x 5.4 mm, and were set to produce a signal once every 10 seconds. The anticipated tag life for the SS300 transmitters was 127 days. Transmitters manufactured by InnovaSea measured approximately 30 and 70 mm and weighed (in air) approximately 9 and 24 g, respectively. The V13 transmitters were programmed to emit a signal once every 30-90 seconds during the 344 days of expected operation. The V16 transmitters were programmed to emit a signal once every 30-90 seconds during the first 730 days of operation then once every 150-210 seconds for the following 1,447 days of operation.

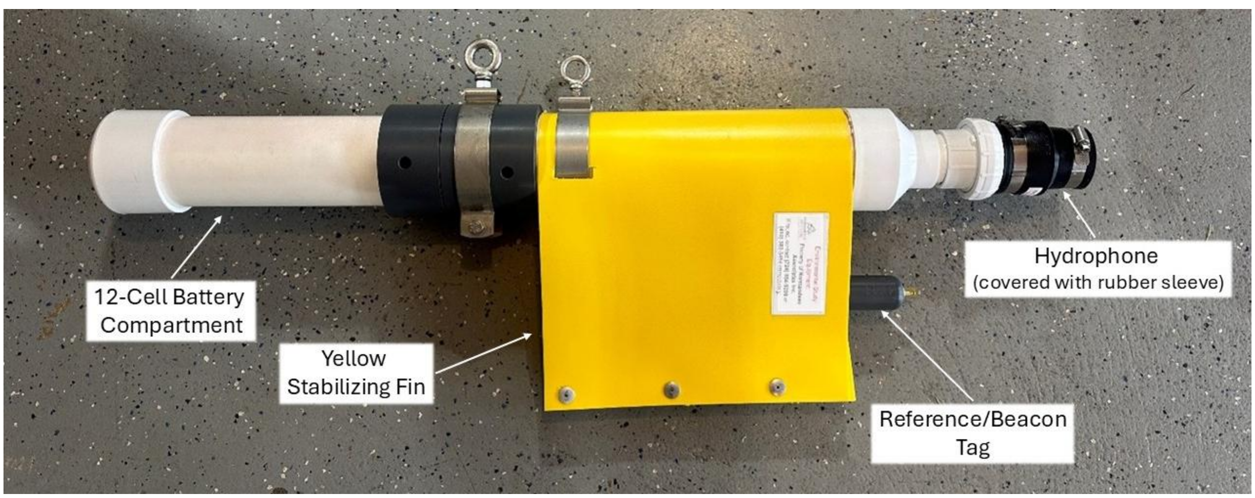


Figure 3-9 ATS SR3001 submersible autonomous acoustic receiver showing: hydrophone, stabilizing fin, reference transmitter and 12-cell battery compartment.

Figure 3-10 InnovaSea VR2Tx submersible autonomous acoustic receiver prior to deployment downstream of Essex Dam.

3.3.2 Telemetry Monitoring Stations

A large array of JSATS ATS acoustic receivers were installed in the section of the Merrimack River extending from the Essex Dam downstream to the I-495 Lawrence Bridge as part of the Diadromous Fish Behavior, Movement, and Project Interaction Study. In addition to the collection of detection information for the river herring, American Shad, and Striped Bass tagged as part of that separate evaluation, each JSATS receiver was also available to collect detection information on any sturgeon carrying a 416.7kHz JSATS transmitter which entered the detection zone. As described in the RSP for the Diadromous Fish Behavior, Movement, and Project Interaction Study this array operated from late-April through mid-July. Deployment of a subset of the JSATS acoustic receivers was extended into late September to provide an extended period of monitoring for tagged sturgeon.

In their May 10, 2024 Study Plan Determination, FERC identified four locations downstream of Essex Dam at which an InnovaSea acoustic receiver should be deployed (I-495 Lawrence Bridge, Duck Bridge, 28 Bridge, tailrace). InnovaSea receivers were deployed at each of those locations to provide coverage from mid-March through late November 2025. A total of three 69 kHz VR2Tx acoustic receivers were installed in the vicinity of the tailrace due to the anticipated poor detection efficiency expected for these receivers and the acoustical background noise associated with discharge from the powerhouse.

The final locations of acoustic receivers used for evaluating the presence of Atlantic and Shortnose Sturgeon downstream of the Essex Dam during 2025 are outlined here and presented in Figure 3-11 and Figure 3-12.

Station 1: This station consisted of two ATS SR3001 416.7 kHz acoustic receivers (one river right and one river left) deployed to provide cross-channel coverage of the Merrimack River at a point directly downstream of the I-495 Lawrence Bridge. In addition to the ATS hydrophones, a single InnovaSea VR2Tx 69 kHz acoustic receiver was deployed at the center of the river channel. Station 1 was located approximately 1.7 miles downstream of Essex Dam.

Station 2: This station consisted of two ATS SR3001 416.7 kHz acoustic receivers (one river right and one river left) deployed to provide cross-channel coverage of the Merrimack River at a point directly downstream of the confluence with the Spicket River. Station 2 was located approximately 1.2 miles downstream of Essex Dam.

Station 3: This station consisted of two ATS SR3001 416.7 kHz acoustic receivers (one river right and one river left) deployed to provide cross-channel coverage of the Merrimack River at a point downstream of the Duck Bridge. In addition to the ATS hydrophones, a single InnovaSea VR2Tx 69 kHz acoustic receiver was deployed at the center of the river channel. Station 3 was located approximately 0.8 miles downstream of Essex Dam.

Station 4: This station consisted of two ATS SR3001 416.7 kHz acoustic receivers (one river right and one river left) deployed to provide cross-channel coverage of the Merrimack River at a point immediately upstream of the Duck Bridge. Station 4 was located approximately 0.6 miles downstream of Essex Dam.

Station 5: This station consisted of a single ATS SR3001 416.7 kHz acoustic receiver deployed to provide coverage of the Merrimack River at a point downstream of the City of Lowell boat ramp. Water depths in this reach restricted deployment of JSATS hydrophones to a single unit. In addition to the ATS hydrophone, a single InnovaSea VR2Tx 69 kHz acoustic receiver was deployed at the center of the river channel. Station 5 was located approximately 0.3 miles downstream of Essex Dam.

Station 6: This station consisted of a single ATS SR3001 416.7 kHz acoustic receiver oriented to provide cross-channel coverage at a point just downstream of the Route 28 Bridge, adjacent to the City of Lowell boat ramp. Water depths in this reach restricted deployment of JSATS hydrophones to a single unit. Station 5 was located approximately 0.2 miles downstream of Essex Dam.

Station 7: Station 7 consisted of eleven ATS SR3001 416.7 kHz acoustic receivers installed to inform on 2-dimensional positions of tagged fish within the tailrace channel immediately downstream of the powerhouse. In addition to the ATS hydrophone array, a single InnovaSea VR2Tx 69 kHz acoustic receiver was deployed towards the downstream end of the tailrace channel.

Station 8: This station consisted of two cabled, shore-based SR3017 416.7kHz receivers installed along the downstream face of the powerhouse and positioned adjacent to the fish lift entrances. In addition to the shore-based ATS receivers, two InnovaSea VR2Tx 69 kHz acoustic receivers were suspended via a davit mounted on the downstream face of the powerhouse and centered on the discharge of each unit.

Station 12: Station 12 consisted of a single ATS SR3001 416.7 kHz acoustic receiver positioned to provide coverage along the powerhouse side of the river and immediately downstream of Station 7.

Station 13: This station consisted of a single ATS SR3001 416.7 kHz acoustic receiver and was positioned to provide coverage of the river downstream of the Essex Dam spillway and towards the non-powerhouse side of the river.

3.3.3 Sturgeon Tagging

Capture and tagging of Shortnose and Atlantic Sturgeon in the lower Merrimack River downstream from Lawrence was conducted by U.S. Geological Survey (USGS) staff from the S.O. Conte Research Laboratory located in Amherst, Massachusetts. Sturgeon sampling consisted of gill nets set during daylight hours and occurred in areas identified by USGS staff as being reliable for sturgeon capture based on previous experience in the Merrimack River. USGS staff were responsible for all capture, handling, and tagging of the fish and followed methods allowed under their federal permitting for handling these species in the Merrimack. Sampling efforts were intended to capture and tag adult Shortnose Sturgeon and sub-adult and juvenile Atlantic Sturgeon. Essex purchased and provided acoustic transmitters for this effort as outlined in Table 3-3. Adult Shortnose Sturgeon were dual-tagged, carrying both a JSATS 416.7 kHz and an InnovaSea 69 kHz transmitter. A number of additional transmitters were provided by both Mass Heritage and USGS to tag additional Shortnose Sturgeon for potential detection during this study.

Table 3-3 Acoustic transmitters (ATS and InnovaSea) purchased by Essex and provided to USGS for tagging Shortnose and Atlantic Sturgeon in the lower Merrimack River, spring 2025.

Sturgeon Species	Life Stage	Transmitter Model		
		SS300	V13	V16
Shortnose	Adult	15[1]		15
Atlantic	Sub-Adult			15
Atlantic	Juvenile		15	

[1] Note: an additional 25 Shortnose Sturgeon were tagged using ATS JSATS transmitters. These transmitters were provided by the resource agencies resulting in a total of 40 SS300 transmitters for use during 2025

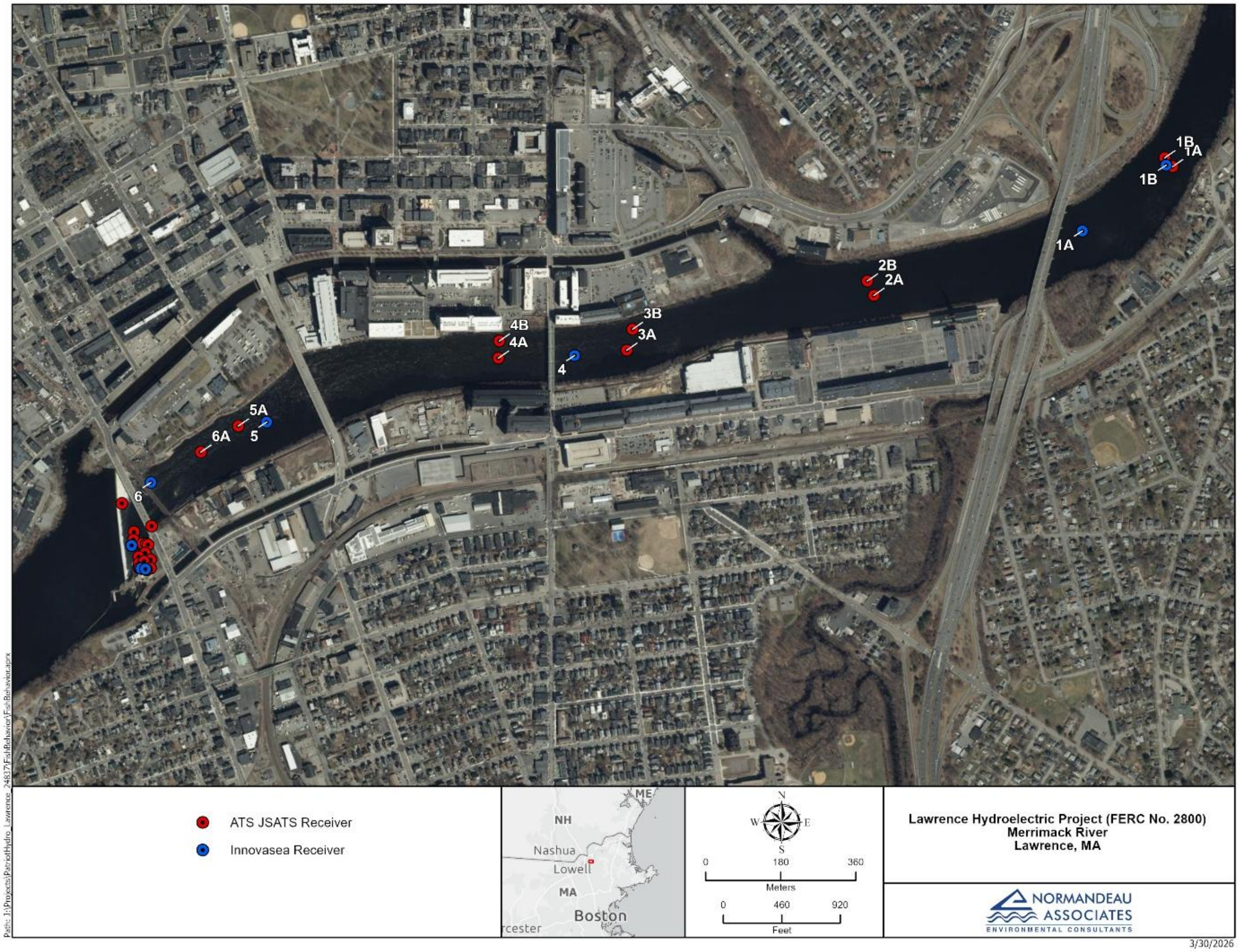


Figure 3-11 Deployment locations of the ATS JSATS and InnovaSea acoustic receivers installed in the section of the Merrimack River extending from Essex Dam downstream to the I-495 Lawrence Bridge.

Figure 3-12 Deployment locations for the ATS JSATS and InnovaSea acoustic receivers installed in the immediate vicinity of the Lawrence Project tailrace.

4. RESULTS

4.1 MOBILE SIDE-SCAN SONAR SURVEY

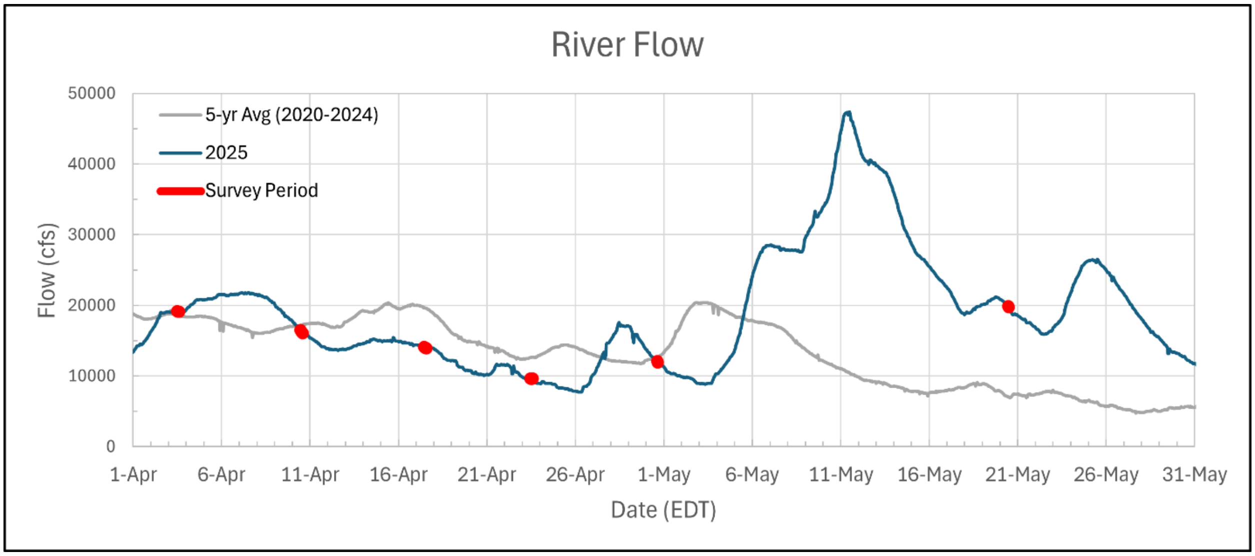
4.1.1 Surveys Completed

Overlapping SSS imagery covering nearly bank-to-bank of the river was collected from six mobile surveys completed between April 4 and May 20, 2025 (Table 4-1). The upriver portions of the five planned transects were inconsistently sampled or not sampled due to navigational hazards. The river discharge and stage (at Duck Bridge) during the surveys at times posed some challenges to survey implementation, such as non-navigable rocky shallows and effects on vessel speed and steering (Figure 4-1). The sampled SSS coverage and the actual vessel tracks are shown in Figure 4-3 through Figure 4-8.

River flows during April were between 10,000 and 20,000 cubic feet per second (cfs), which were similar to or below the 2020–2024 average. However, safety and data quality concerns related to high flows (up to approximately 47,000 cfs during the first half of May) delayed the last survey until May 20, 2025, when flows receded to 20,000 cfs and water levels increased by a couple of feet.

Table 4-1 Start and end times for collecting side-scan sonar imagery for detecting sturgeon downstream of Lawrence Hydroelectric Project during spring of 2025.

Survey	Date	Data Collection Time (Local)	
		Start	End
1	Apr 4	12:28	14:02
2	Apr 10	11:50	13:40
3	Apr 17	11:23	13:04
4	Apr 23	11:33	13:31
5	Apr 30	14:59	16:40
6	May 20	11:43	12:42



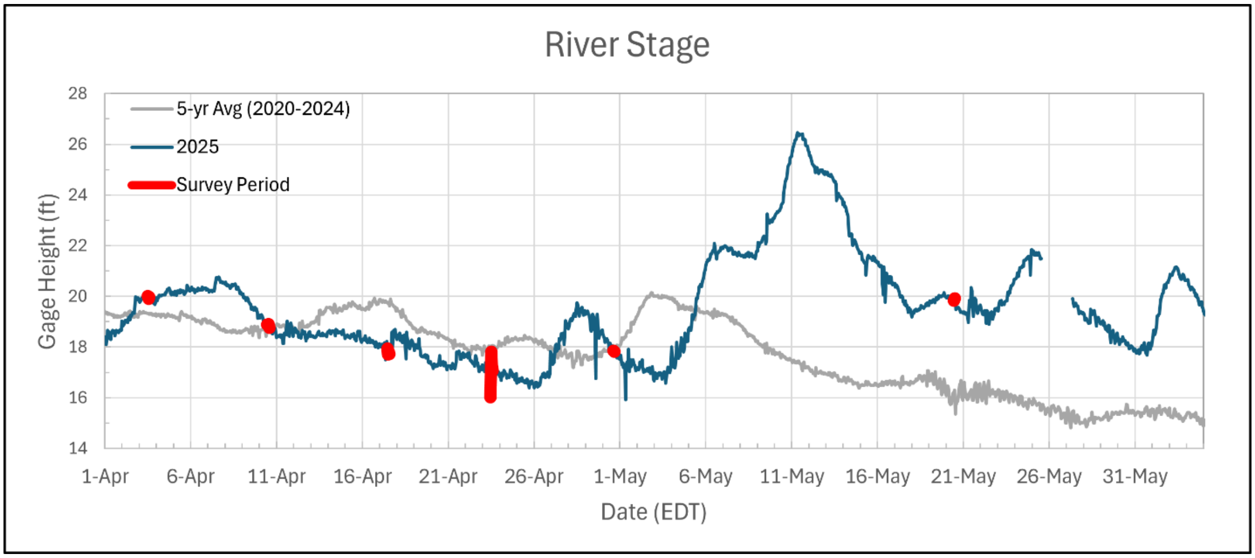


Figure 4-1 **River discharge and stage during each of the six mobile side-scan surveys, based on discharge rates from USGS gage 01100000 at Lowell, MA, (adjusted for additional water sources between the gage and Essex Dam) and stage from USGS gage 01100500 at Duck Bridge.**

4.1.2 Target Classification

The initial reviewer selected 169 target detections and visually classified the SSS imagery among the six surveys. These target detections were then independently classified by two additional reviewers (Table 4-2). Overall, about 19 percent of the target classifications were in full agreement, while 53 percent were agreed upon by two of three reviewers (Table 4-3). Boulders, including large rocks, followed by tires were most frequently classified in full agreement by the three independent reviewers (Table 4-3). Four targets were classified as sturgeon by two out of three reviewers and six targets were classified as sturgeon by all three reviewers (Table 4-5). Figure 4-2 shows four examples of sturgeon classifications assigned by the three independent reviewers with low to mostly medium relative confidence. No sturgeons were classified with high relative confidence, in part, due to the image resolution perhaps resulting from the erratic boat movement under the survey conditions and lack of well-defined “textbook” shadow geometry indicative of sturgeons. There was no strong evidence of sturgeon targets detected during the first survey on April 4 and the last survey on May 20; however, at least one sturgeon was classified by two or more independent reviewers from the other four surveys (April 10, 17, 23 and 30; Figure 4-3 through Figure 4-8).

Table 4-2 Side-scan target classifications and associated confidence levels[1] (high, medium, low) assigned by three independent reviewers for targets selected from six mobile surveys conducted downstream of the Lawrence Hydroelectric Project.

Classification	Reviewer 1				Reviewer 2				Reviewer 3			
	Relative Confidence			Total	Relative Confidence			Total	Relative Confidence			Total
	High	Medium	Low		High	Medium	Low		High	Medium	Low	
Boulders	7	30	3	40	1	21	9	31	6	30	10	46
Branch		3		3		7	7	14		2	2	4
Cable	2	4		6	4	2	2	8	3	3		6
Debris	3			3		1	5	6		3	1	4
Fish		24	1	25		17	9	26		27	12	39
Grass	1	2		3		2	5	7	2		1	3
Parabola object[2]	3	4		7		4	2	6		8	2	10
Piling					1	2	1	4		6		6
Pipeline	1	2		3	5	1		6	2			2
Rock outcrop	1	2		3	1	3	1	5			1	1
Sturgeon		24	3	27		3	7	10		12	2	14
Tires	9	2		11	3	2	1	6	7	4	2	13
Tree log		3		3		9	8	17		4	4	8
Tree trunk						4	5	9			1	1
Unknown				36				16				12

[1] Relative confidence level: High (>80% relative probability), Medium (50-80% relative probability), Low (<50% relative probability)

[2] Parabola object appeared as a large rock-boulder object with a sharp U-shaped bright echo intensity

Table 4-3 Agreement among three reviewers in classification of all selected target detections from six mobile side-scan sonar surveys conducted downstream of the Lawrence Hydroelectric Project.

Agreement	N	%
No Agreement	48	28.4
Agreement in 2 of 3 Reviewers	89	52.7
100% Agreement	32	18.9
Total Detections	169	100.0

Table 4-4 Side-scan target classification with 100% agreement among three independent reviewers of the targets detections selected from six mobile side-scan sonar surveys conducted downstream of the Lawrence Hydroelectric Project during 2025.

Classification	N	%
Boulders	17	37.0
Branch	1	2.2
Cable	1	2.2
Fish	4	8.7
Grass	1	2.2
Parabola object	4	8.7
Pipeline	2	4.3
Sturgeon	6	13.0
Tires	6	13.0
Unknown	4	8.7
Agreed detections	46	100

Table 4-5 Side-scan target detections classified as sturgeon by at least two out of three independent reviewers from six mobile side-scan sonar surveys conducted downstream of the Lawrence Hydroelectric Project during 2025.

Survey	Date	Target	Measured Length (cm)	Reviewer 1		Reviewer 2		Reviewer 3	
				Classification	Confidence Score	Classification	Confidence Score	Classification	Confidence Score
2	Apr 10	0102	102	Sturgeon	Medium	Fish	Low	Sturgeon	Medium
2	Apr 10	0103	108	Sturgeon	Medium	Unknown	Unknown	Sturgeon	Medium
2	Apr 10	0110	76	Sturgeon	Medium	Fish	Low	Sturgeon	Medium
3	Apr 17	0235	91	Unknown	Unknown	Sturgeon	Low	Sturgeon	Medium
2	Apr 10	0100[a]	119	Sturgeon	Medium	Sturgeon	Medium	Sturgeon	Medium
2	Apr 10	0108	135	Sturgeon	Medium	Sturgeon	Low	Sturgeon	Medium
3	Apr 17	0218[a]	105	Sturgeon	Medium	Sturgeon	Low	Sturgeon	Low
3	Apr 17	0220	86	Sturgeon	Low	Sturgeon	Low	Sturgeon	Medium
4	Apr 23	0427[a]	100	Sturgeon	Medium	Sturgeon	Medium	Sturgeon	Low
5	Apr 30	0028[a]	89	Sturgeon	Medium	Sturgeon	Medium	Sturgeon	Medium
N = 10									

[a] See Figure 4-2

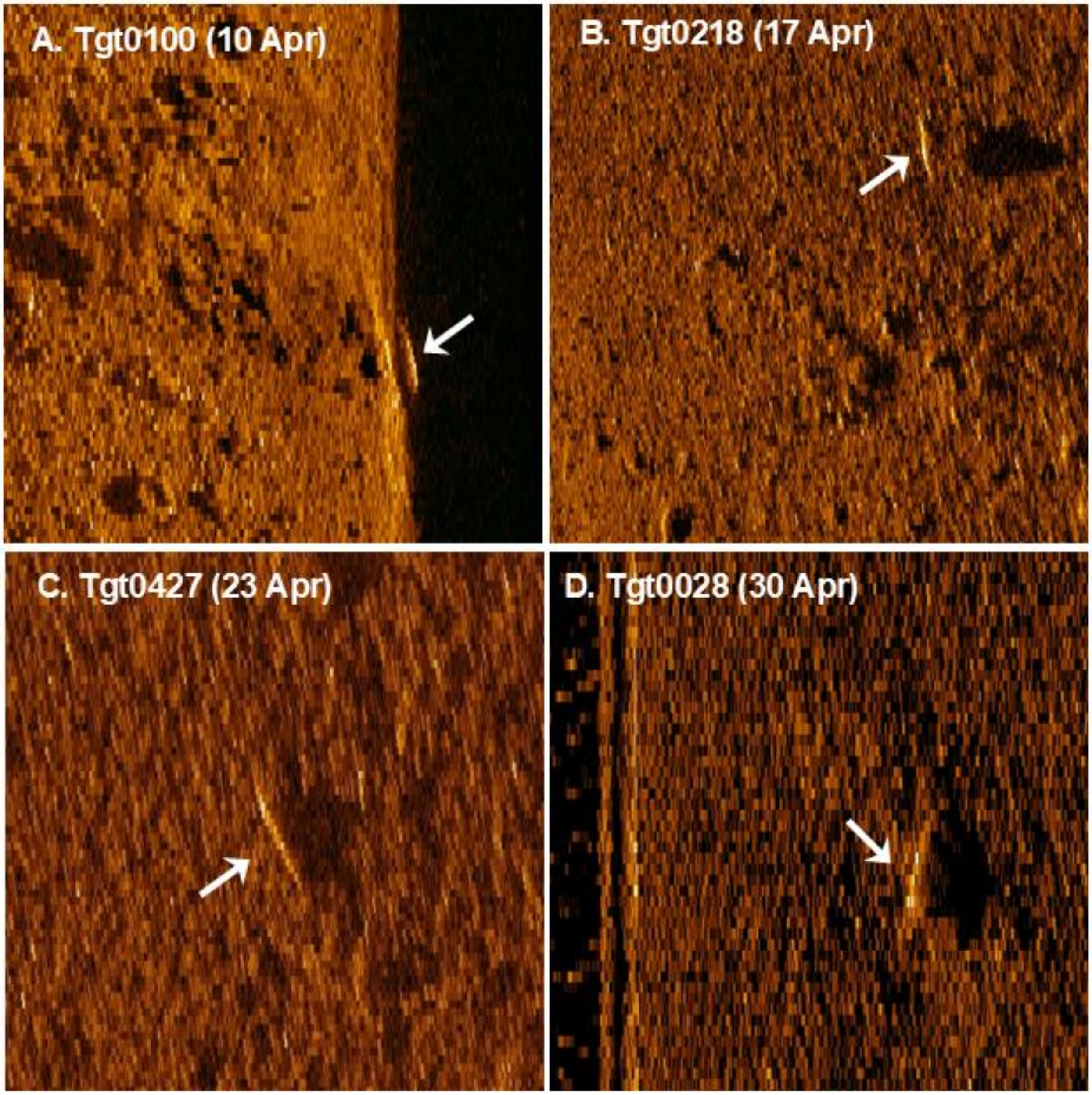


Figure 4-2 (A–D) Examples of target detections classified as sturgeon by three independent reviewers from side-scan sonar surveys conducted downstream of the Lawrence Hydroelectric Project during 2025.

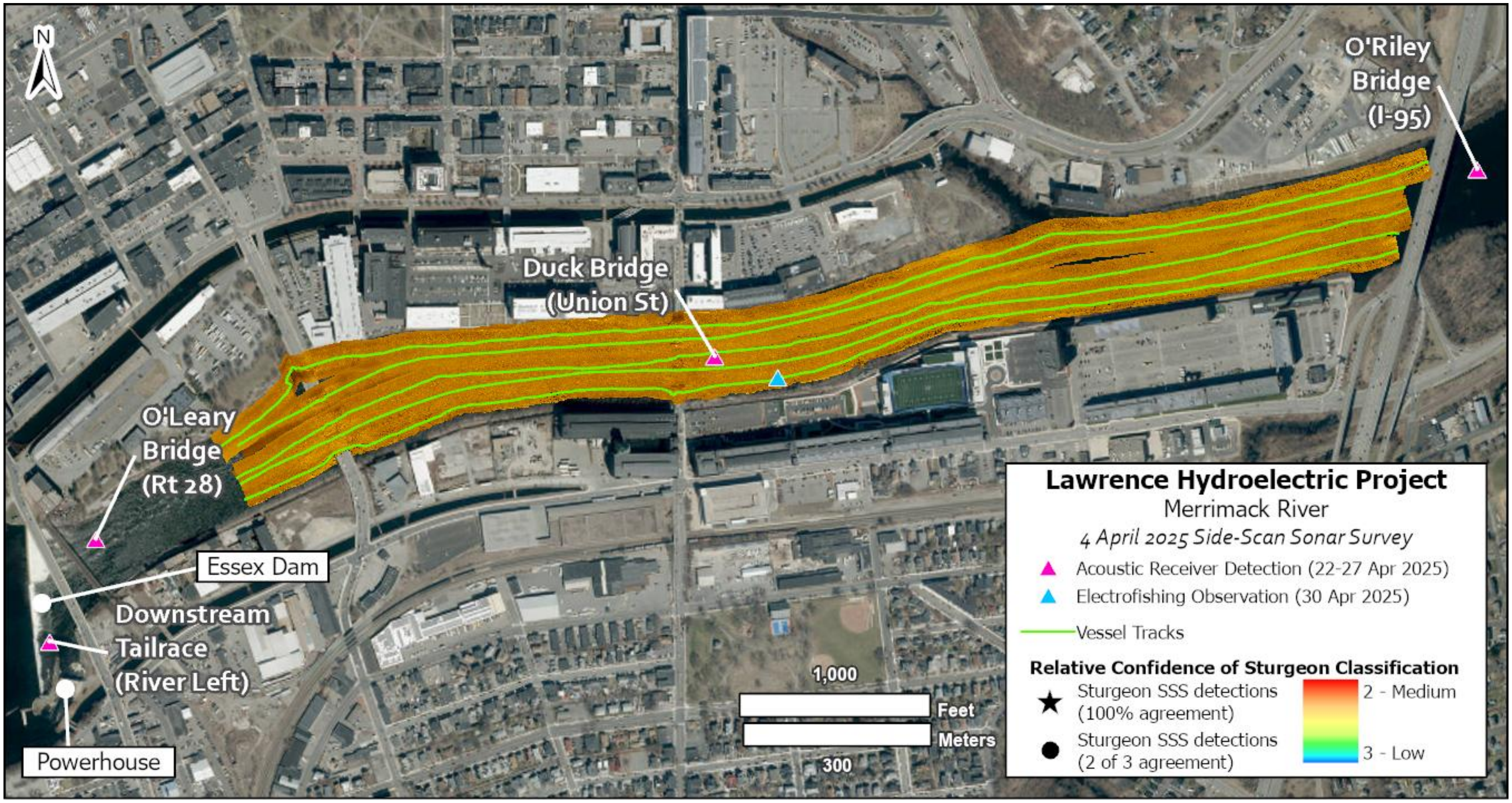


Figure 4-3 High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on April 4, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.

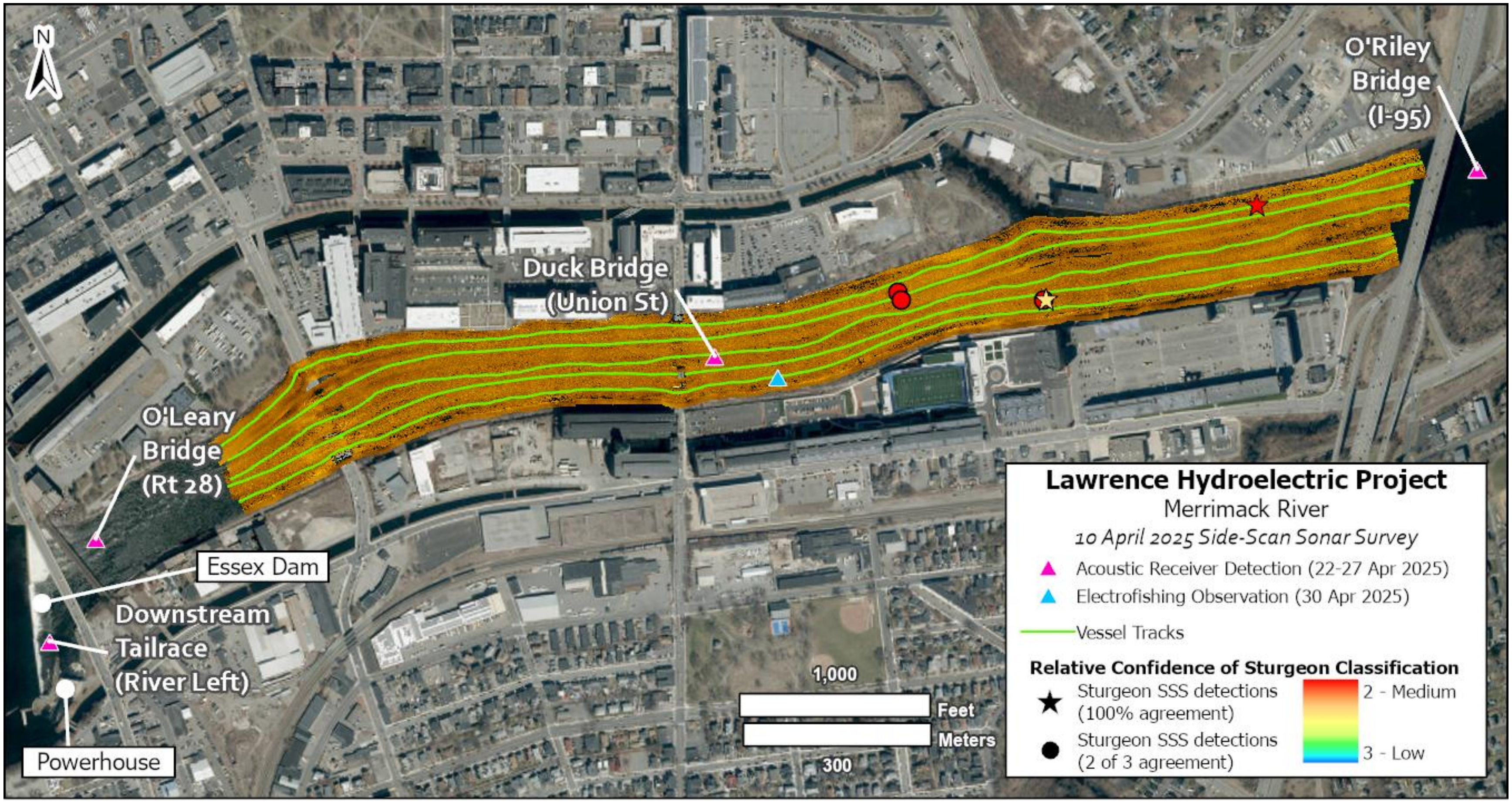


Figure 4-4 High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on April 10, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.

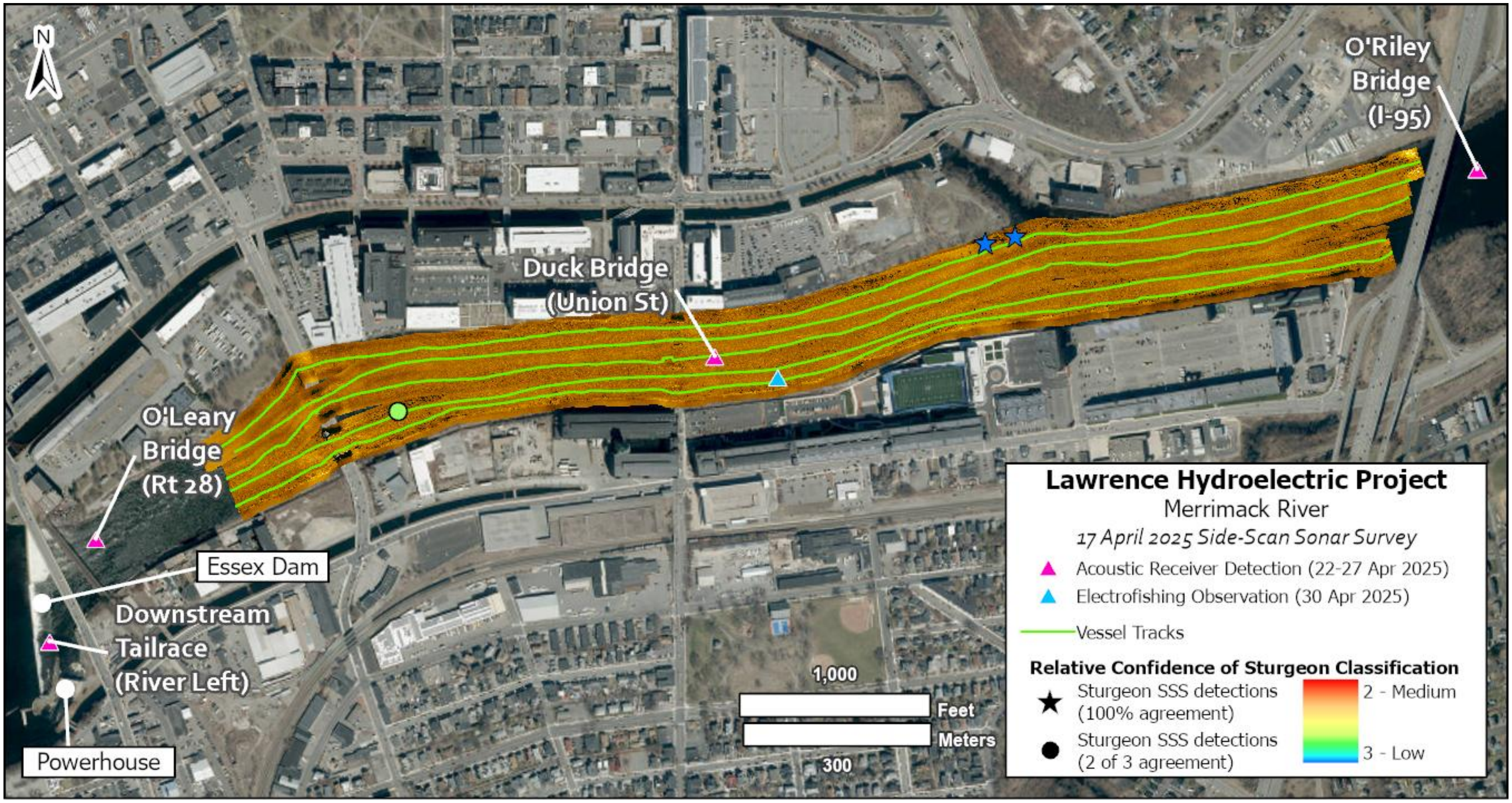


Figure 4-5 High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on April 17, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.

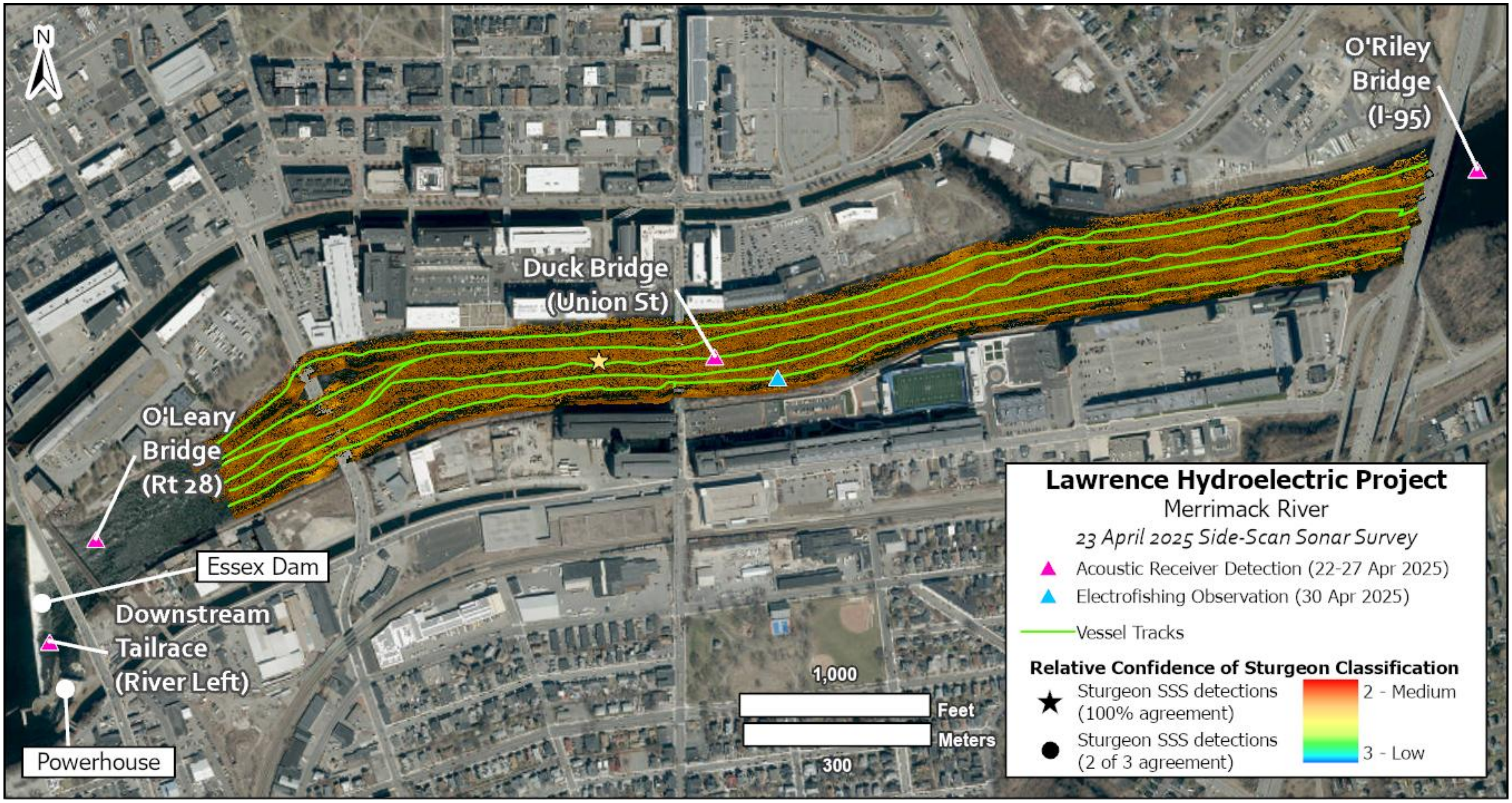


Figure 4-6 **High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on April 23, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.**

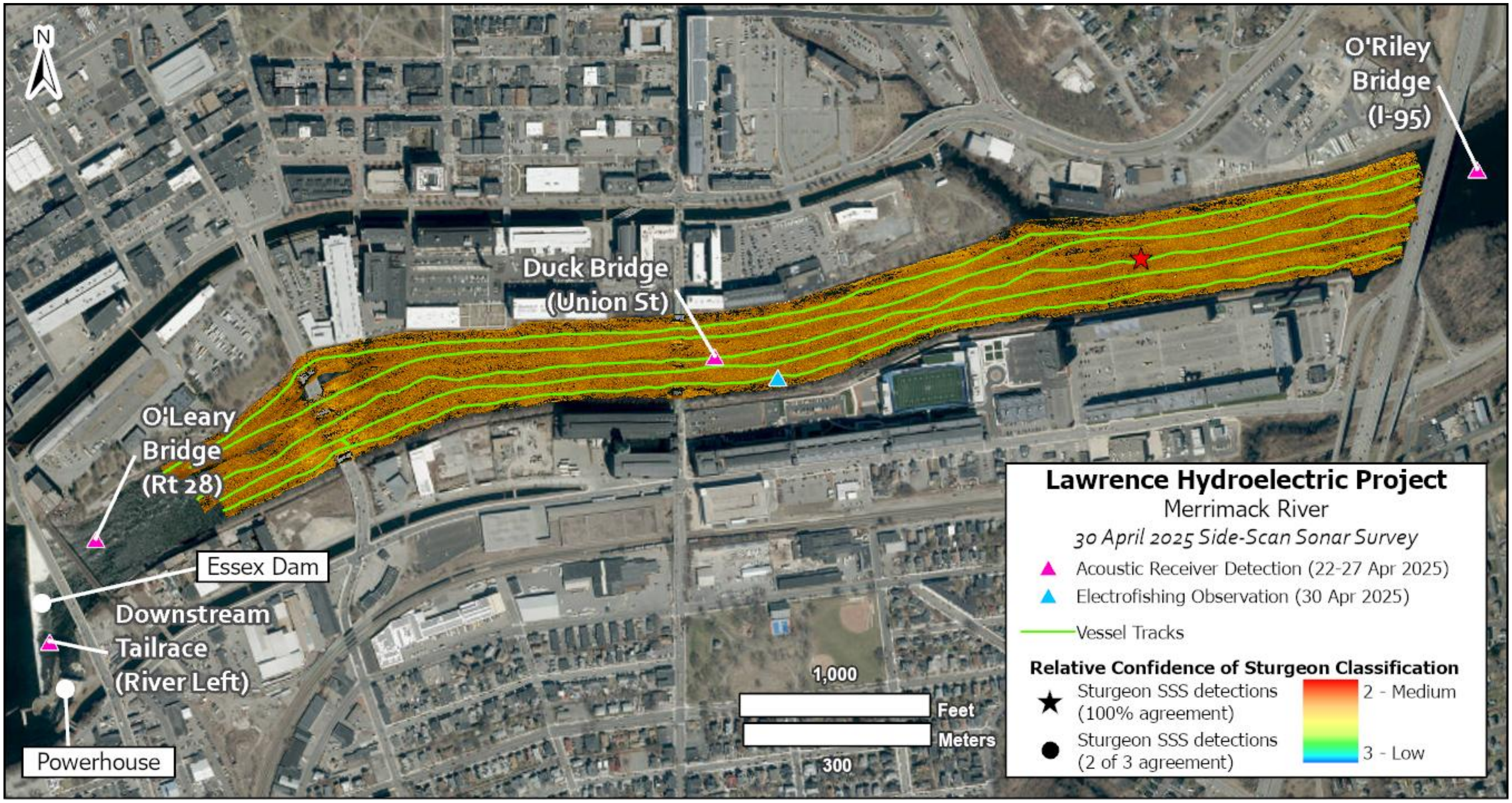


Figure 4-7 High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on April 30, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.

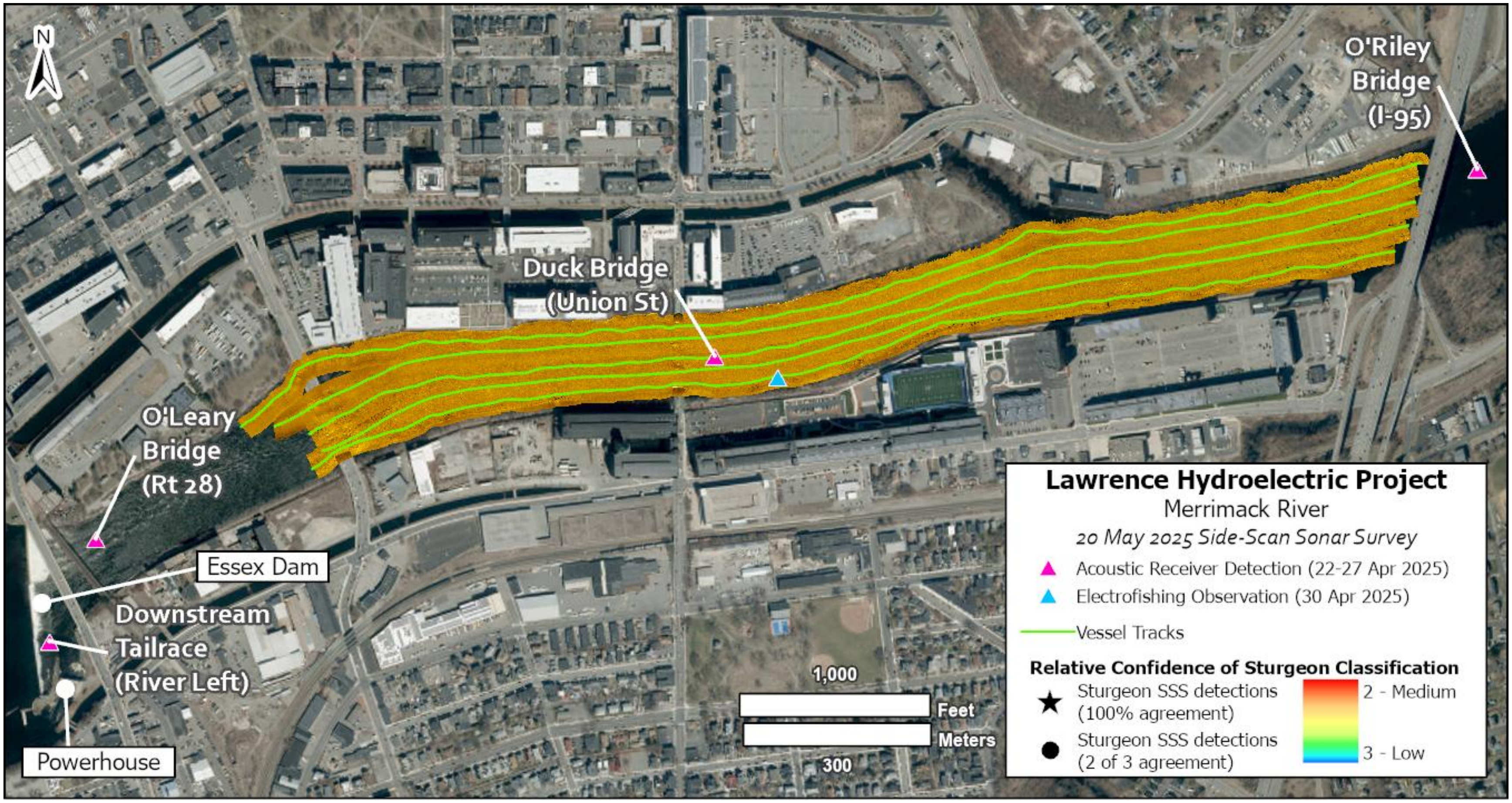


Figure 4-8 **High-frequency (1600 kHz) side-scan sonar imagery collected in the Merrimack River up to 1.5 miles downstream of Lawrence Hydroelectric Project on May 20, 2025, showing target detections classified as potential sturgeon and locations of Shortnose Sturgeon identified by electrofishing and acoustic telemetry during spring 2025.**

4.2 PILOT STUDY RESULTS FOR FIXED-LOCATION SONAR MONITORING IN THE TAILRACE

4.2.1 Environmental Factors Affecting Sonar Monitoring Performance

The pilot study demonstrated that experimental comparison of the two sonar technologies for detecting and distinguishing artificial sturgeon from other known targets was not feasible due to direct and indirect effects of environmental conditions encountered in the Project tailrace. Towing or drifting an artificial sturgeon by rope-monofilament line was difficult due to fast moving currents, which often formed eddies that spun the vessel, and entanglement with floating large wood debris (Figure 4-9). It was impractical to keep a target within the sonar field of view for an adequate amount of time for both detection and more so for identification as a result of current speeds moving the targets through sonar beams with one or few echo returns. Observations suggest any future attempt at monitoring midwater to the surface will need to contend with a dynamically changing background of bubble clouds created, in part, by the spill of bypass water into the tailrace as shown in Figure 4-10 and Figure 4-11. The tailrace lack of sheltered areas in the tailrace makes it difficult to mount sonars under harsh hydraulic conditions and not be subject to vibration impacts. Woody debris and trash in the tailrace floating or churning underwater renders long-term sonar monitoring deployment impractical due to potentially causing excessive false sturgeon detections and high risk of physical damage to fixed-location sonar systems over time.

4.2.2 Sampling Area

With the sonars submerged approximately two meters below the water surface, both sonars were capable of being adjusted to display the surface of the riverbed or shoreline ledge. However, both sonars had limitations. The ARIS, due to a 28° field of view, requires to be panned left or right to cover the entire width of the tailrace channel (Figure 4-12) and aimed down to see sturgeon near the riverbed at a distance of approximately 10 m (13-14 m range) from the Project Dam (Figure 4-13). The BlueView sonar's field of view is 130° which essentially can cover the width of the tailrace channel without requiring to be panned and can cover approximately 20-30 m in range (Figure 4-14 and Figure 4-15).

4.2.3 Detection and Identification

Four artificial targets (155 cm rubber sturgeon, 97 cm rubber sturgeon, 71 cm rubber Striped Bass, and 61 cm long and 3.8 cm diameter steel pipe) were towed or drifted in each sonar's field of view. However, the flow environment made detection at range difficult to conduct the experiment as planned and described in the Study Plan. Instead, the capability of each sonar was further evaluated through semi-stationary, slow drift testing within the field of view during a two-hour low-flow period, during which both turbines were intentionally taken offline and generation was suspended on November 6, 2025.

Detection of artificial targets was tested for each sonar while the vessel was within 2 m of the transducers and the Project Dam and targets were lowered to depth. Due to time constraints of the generation shutdown, the artificial Striped Bass was omitted from further testing to allow focus on a pipe (non-sturgeon object) and two sturgeon (one small and one large) targets. The pipe and both artificial sturgeons were detected at close range by the ARIS, but the shape features were inadequate for clear target identification (Figure 4-16). At close range sufficient for the BlueView's high-frequency mode, the large sturgeon, including fins, could be detected and identified (Figure 4-17). Moreover, the acoustic shadow that was cast showed the fins and head of a sturgeon shape. In contrast, 900-kHz low-frequency mode of the BlueView that would be used for long-term monitoring detected the 97-cm sturgeon target at 1-2 m range but showed no diagnostic target or shadow features to distinguish from another oblong object in the currents.

Figure 4-9 Woody debris (sometimes comparable to the sturgeon targets) and complex water circulation patterns were encountered in the Project tailrace during deployment of tethered artificial targets.

Figure 4-10 Fixed-location monitoring using ARIS and BlueView high-resolution imaging sonars to detect and identify sturgeon within the Project tailrace is not feasible as indicated by the pilot study under controlled conditions due to (A) the high abundance of floating and submerged drift debris; (B-D) entrained bubbles, strong eddies and currents, and upwelling.

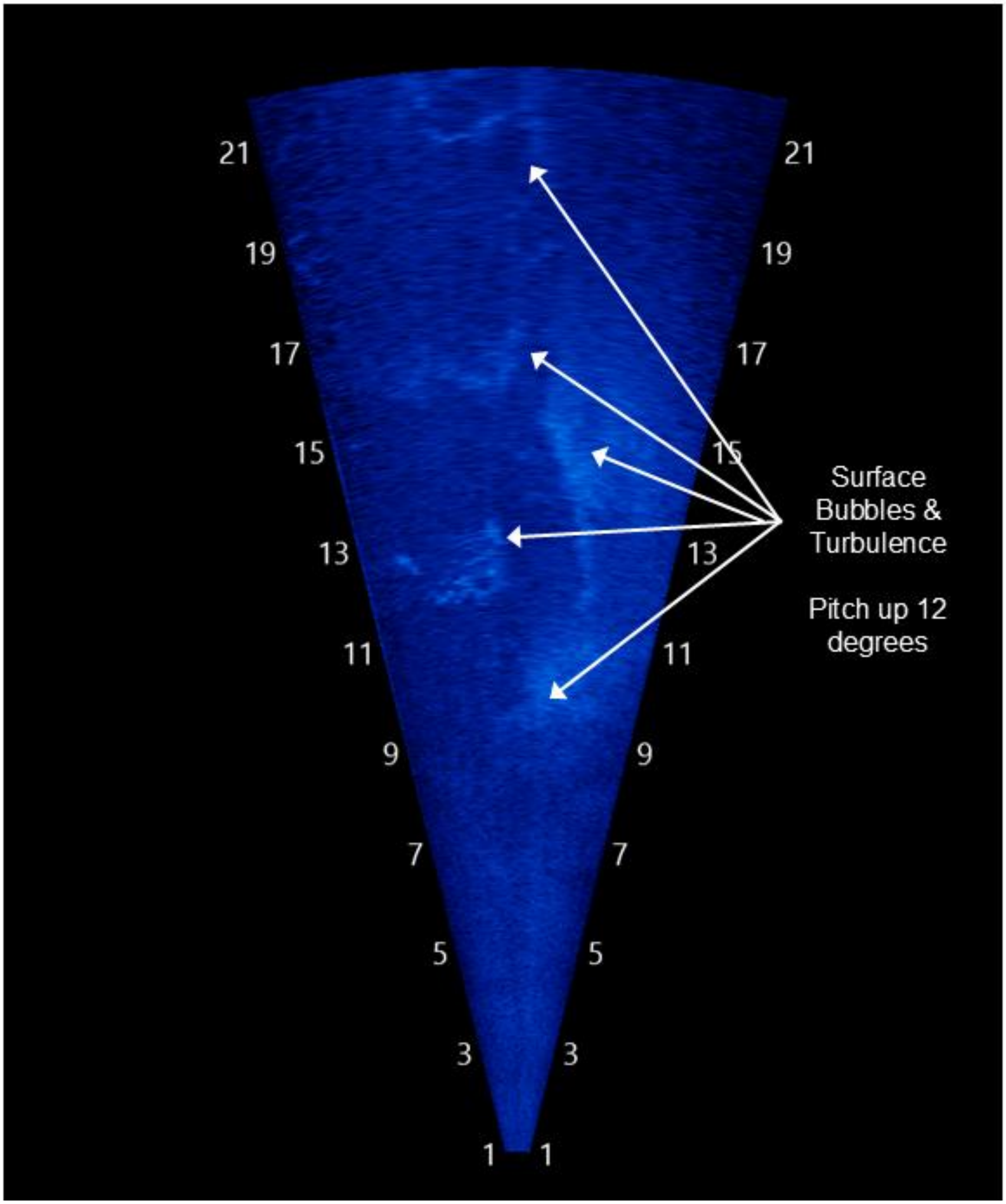


Figure 4-11 ARIS sonar image of surface bubble clouds entrained from the fish bypass water and turbulence caused by complex water circulation patterns created by the fish bypass and flow from the turbine unit(s) at the Lawrence Hydroelectric Project.

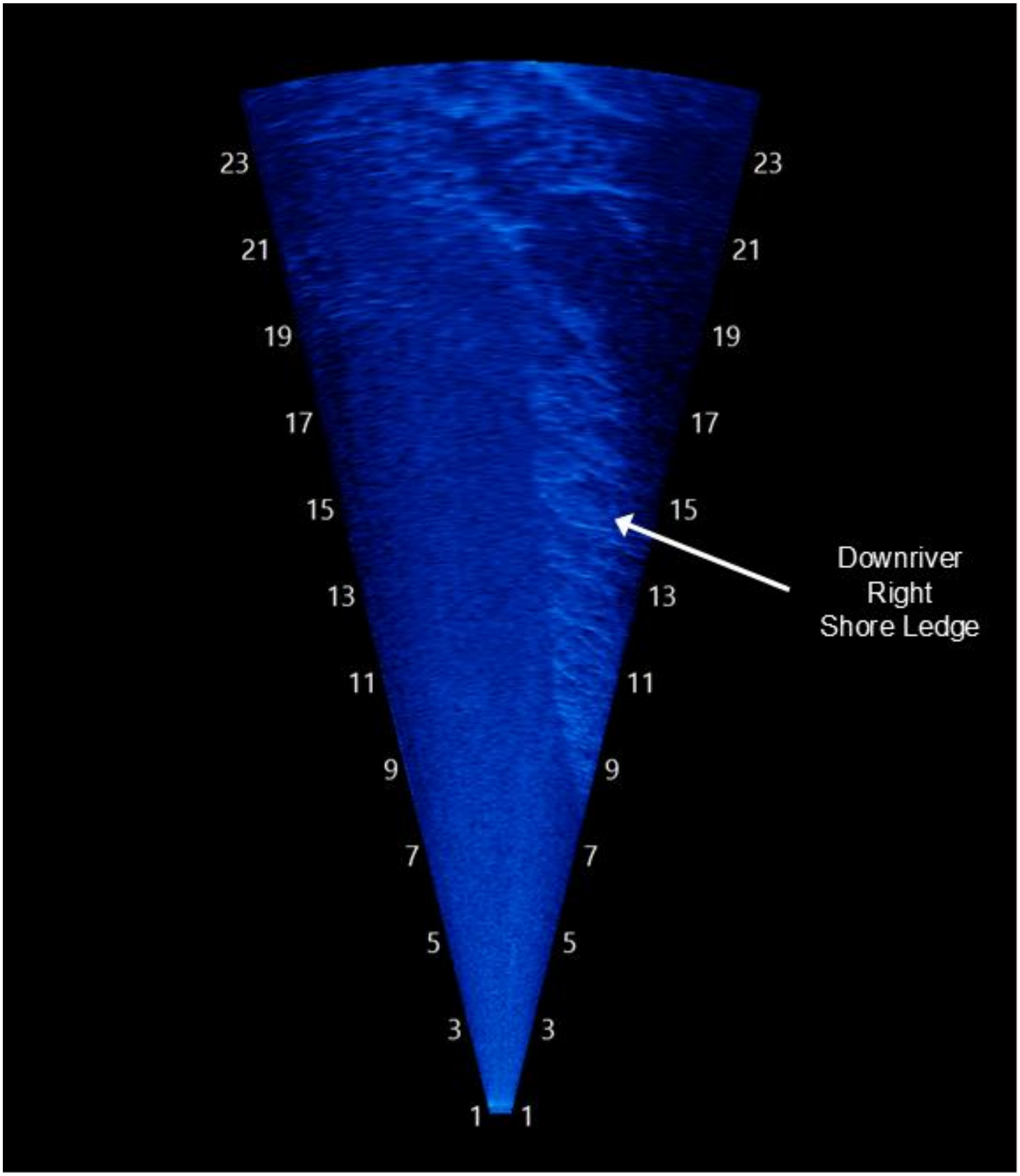


Figure 4-12 Sonar image from the ARIS at 1,100 kHz of the Project tailrace with the sonar tilted 35° down and panned about 50° toward the shore downriver right, which shows the bedrock ledge coming into view on the right at 8 m range and the riverbed at 17–19 m range on November 6, 2025. Range measured in meters.

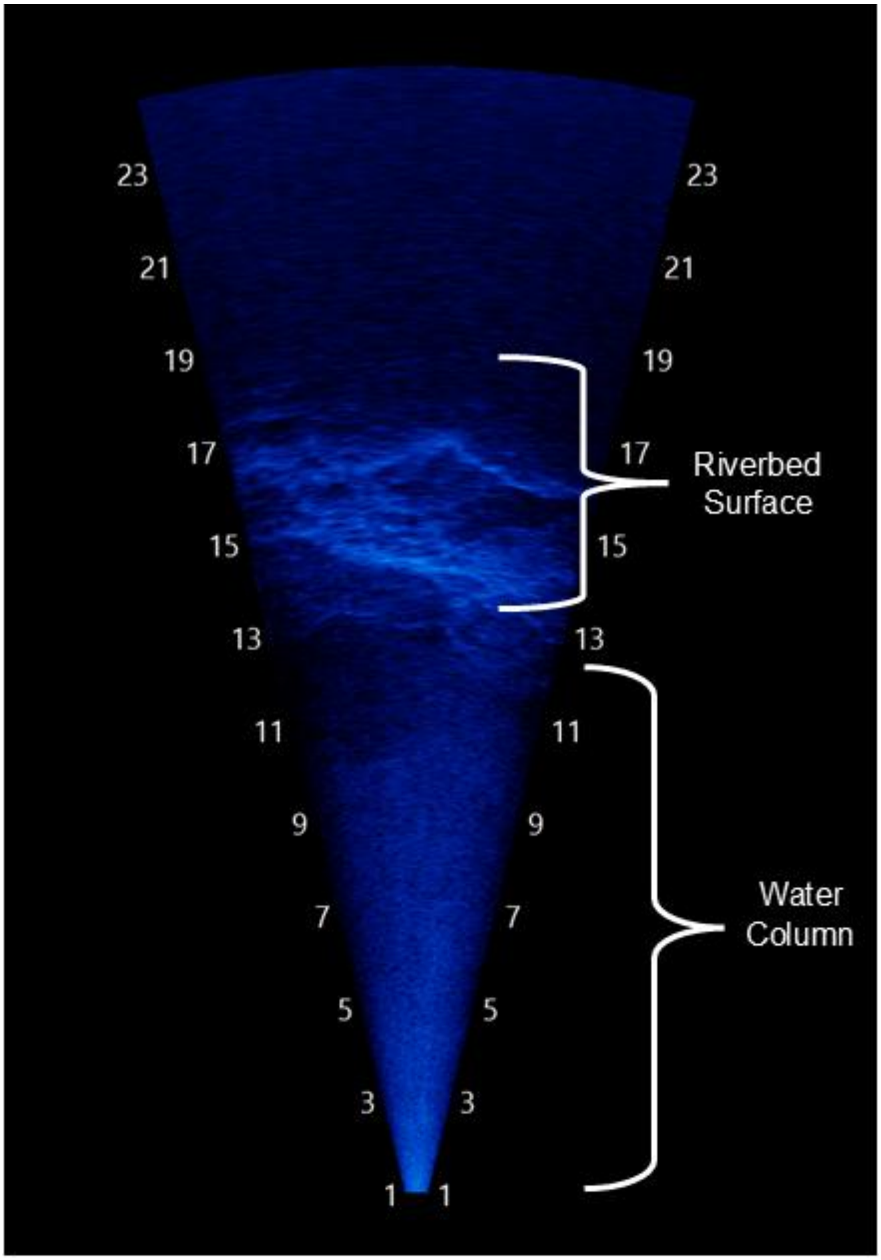


Figure 4-13 Sonar image from the ARIS at 1,100 kHz of the Project tailrace with the sonar tilted 35° down and panned about 50° toward the shore downriver right, which shows the water column background out to 13 m where the riverbed begins to appear on November 6, 2025. Range measured in meters.

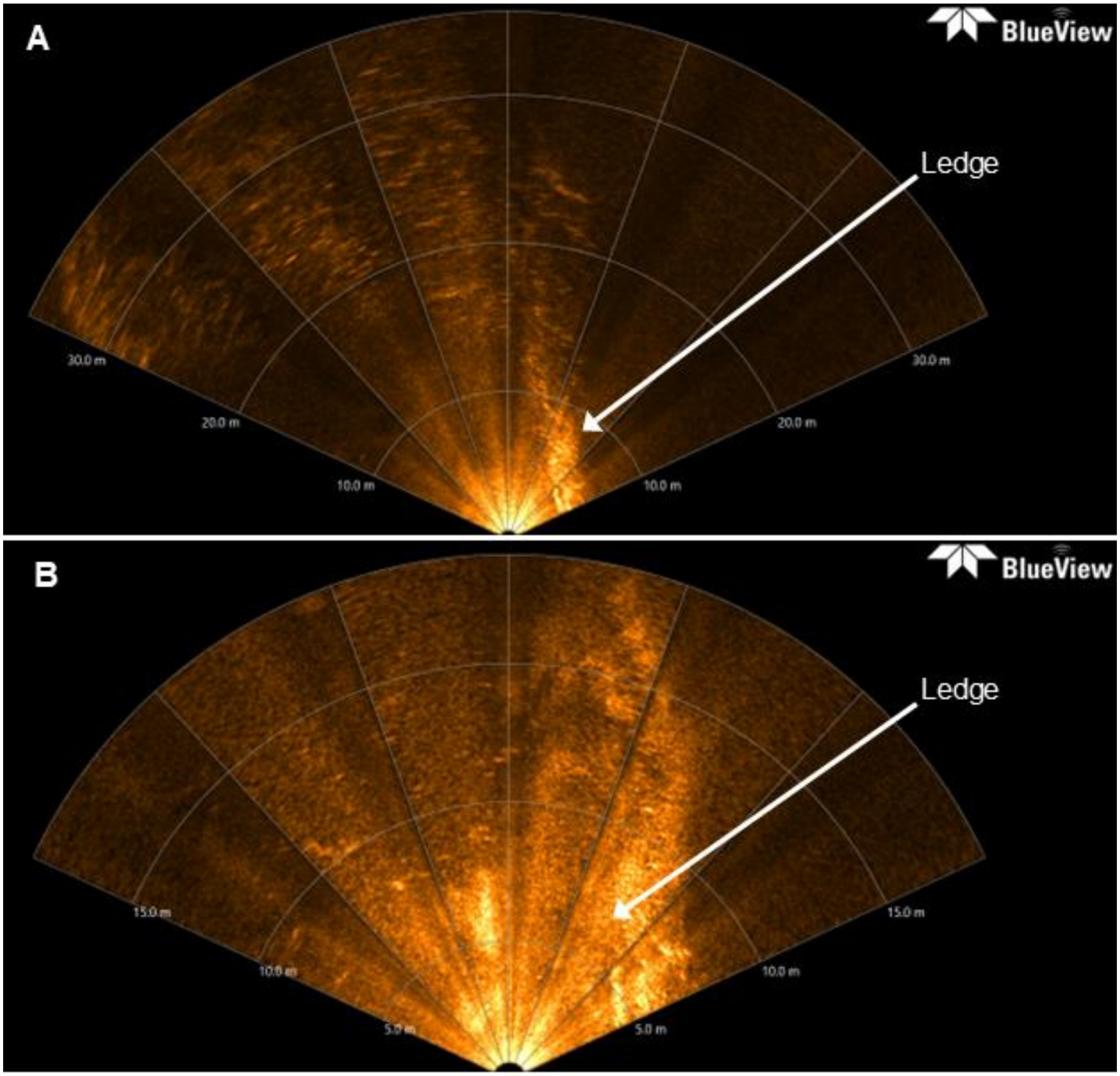


Figure 4-14 Sonar image from the BlueView at 900 kHz of the Project tailrace with the sonar tilted 35° down and panned about 50° toward the shore downriver right, which shows the bedrock ledge coming into view on the right at 5 m range on November 6, 2025.

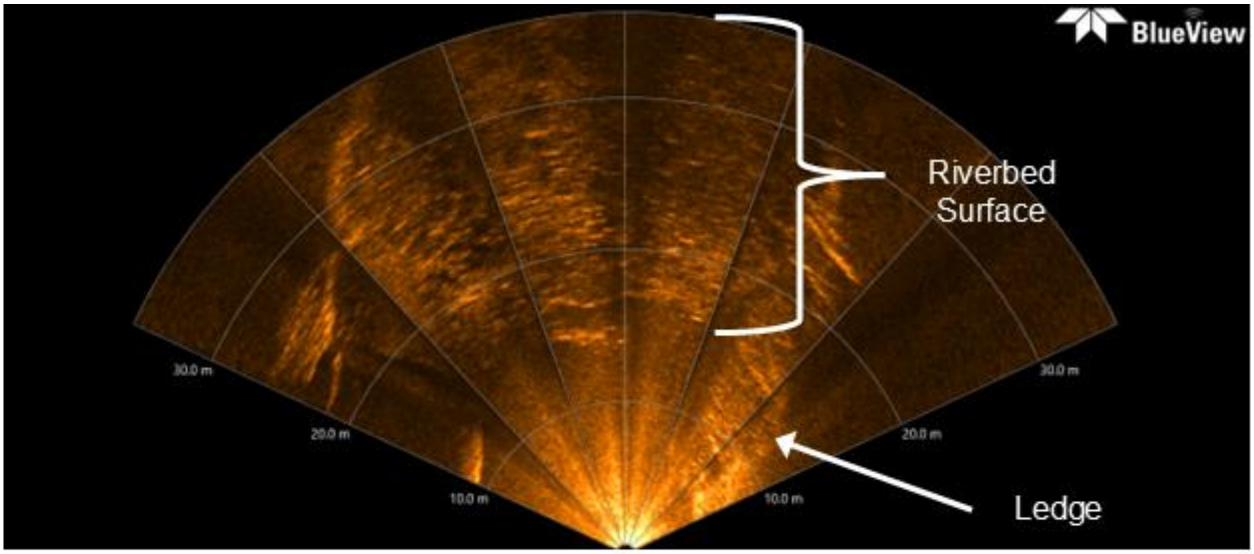


Figure 4-15 BlueView sonar image of the riverbed at 20 m range and nearly the entire width of the tailrace channel at the Lawrence Hydroelectric Project. The shoreline ledge is to the right, and concrete structures are to the left.

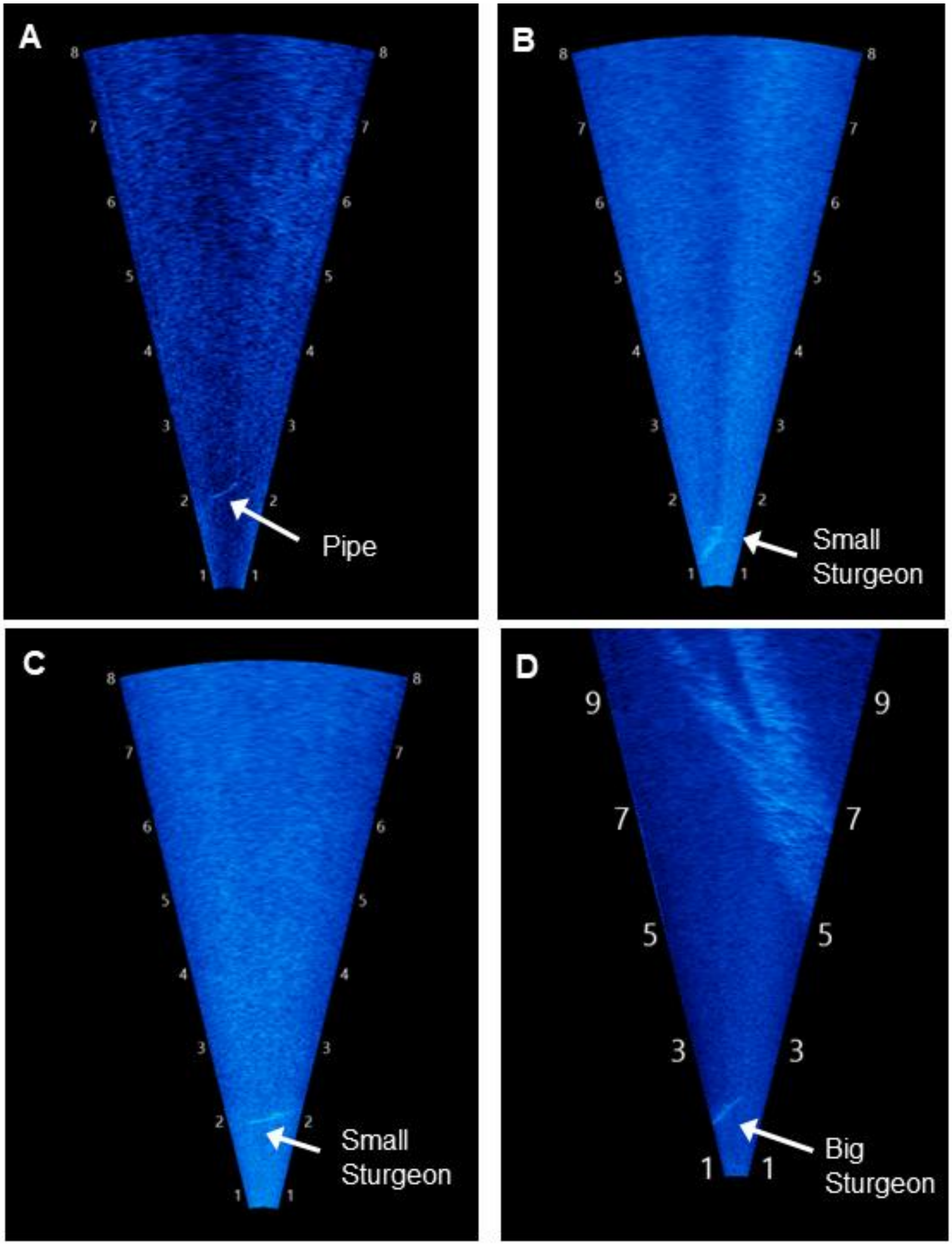


Figure 4-16 Detection of known artificial targets using the 1100-kHz ARIS at close range (~2 m) and shallow field-of-view depth (2–3 m) on November 6, 2025. Observations were made while both turbine units were offline, resulting in atypical low-flow conditions in the Project tailrace. A) steel pipe; (B and C) small sturgeon; and D) big sturgeon.

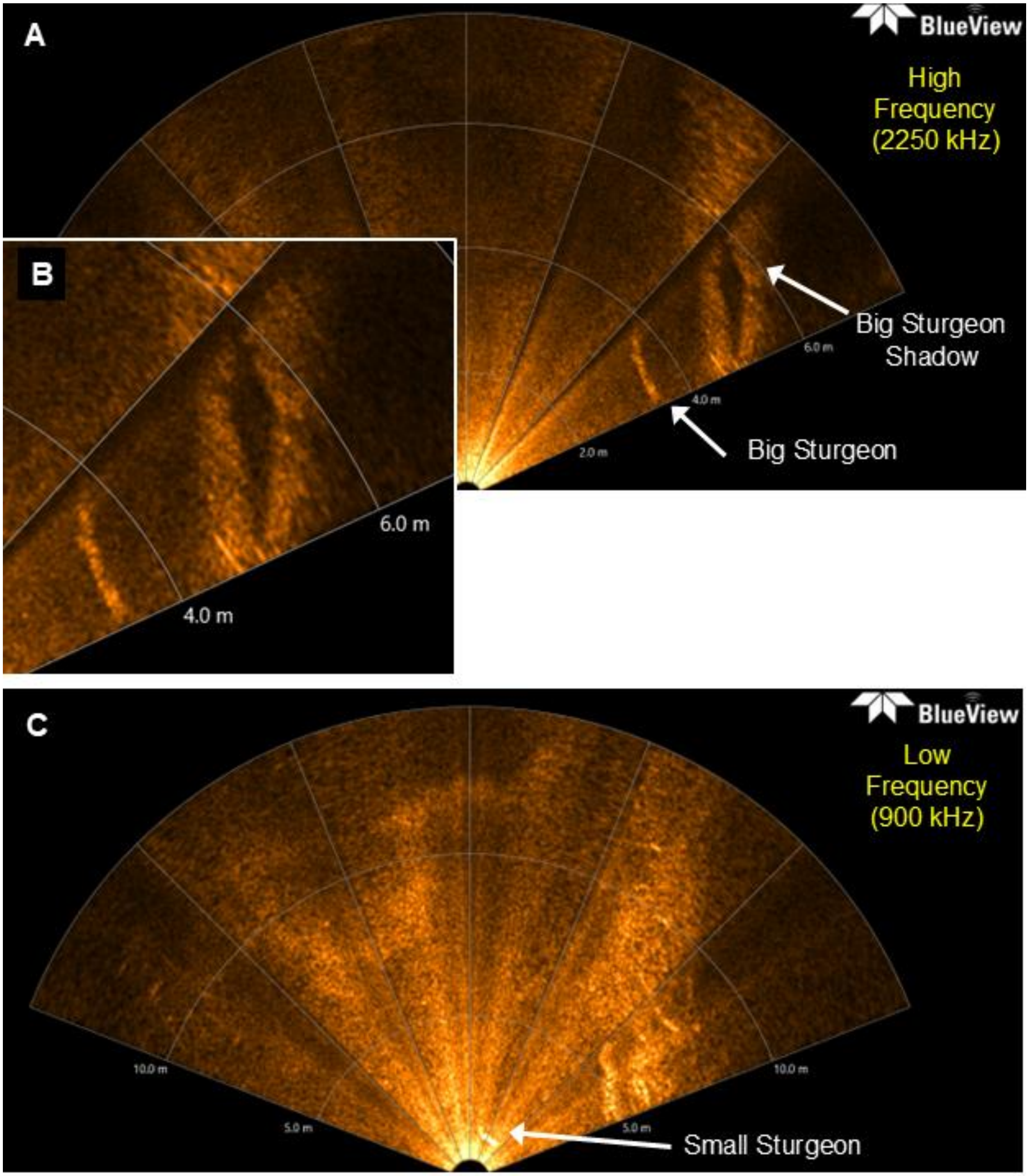


Figure 4-17 BlueView imaging sonar detection of (A and B) the 155 cm artificial sturgeon at close range and high frequency (2250 kHz) and (C) the 97-cm artificial sturgeon at close range and low frequency (900 kHz) on November 6, 2025, while both turbine units were offline, resulting in atypical low-flow conditions in the Project tailrace.

4.3 ACOUSTIC TELEMETRY

4.3.1 Acoustic Receiver Operation

4.3.1.1 ATS JSATS Receiver Array

As part of the concurrent Diadromous Fish Behavior, Movement, and Project Interaction Study, a total of 25 JSATS acoustic receivers were installed at locations downstream of the Essex Dam over two dates during late April and one date during early May. Table 4-6 summarizes the deployment date, receiver type (autonomous SR3001 or cabled SR3017) and the intended data collection type (2D vs. 1D) for each location.

The full 2D receiver array was installed and operational on April 28, 2025. Shortly thereafter, Merrimack River flows increased and spill was present at Lawrence well into June, which eliminated any access to autonomous receivers installed as part of the 2D array in the powerhouse tailrace and reduced visibility of and access to autonomous receivers installed at mainstem locations. Recovery of deployed autonomous receivers was conducted during the latter part of July. The high discharge and non-laminar flow conditions in the Lawrence powerhouse tailrace during the 2025 upstream passage season were unsuitable for the deployment and operation of autonomous JSATS receivers. These conditions resulted in catastrophic damage to and/or loss of 10 of the 13 autonomous receivers installed as part of the array intended to collect 2D information from the Project tailrace (i.e., Stations 7 and 8). With the exception of Station 6, located slightly downstream of the Route 28 Bridge, all autonomous receivers installed at mainstem locations were successfully recovered in working condition. It is assumed that despite the heavy river discharge through the mainstem of the Merrimack both upstream and downstream of Essex Dam for most of the study period, the flows at the non-tailrace deployment locations were more laminar in nature which resulted in a lower incidence of significant damage.

Following recovery of ATS receivers during late July, all data files were downloaded, receivers were inspected for damage, and new internal batteries were installed. Normandeau redeployed a total of 11 JSATS acoustic receivers on July 24 and July 31(s) (Table 4-7). These units were allowed to operate through most of September 2025 to provide detection information on any JSATS tagged sturgeon utilizing the reach immediately downstream of Essex Dam during the fall season. All 11 ATS receivers deployed during the latter part of 2025 were successfully recovered at the completion of the monitoring period.

4.3.1.2 InnovaSea Receiver Array

A total of six InnovaSea acoustic receivers were installed at locations downstream of the Essex Dam over two dates during late March and two dates during early April. Table 4-8 summarizes the deployment date, and receiver type (VR2TX or VR2W). All InnovaSea hydrophones were deployed for the collection of 1D data. As was the case with the JSATS hydrophones, the InnovaSea gear experienced significant flow conditions causing two of the original six hydrophones to be unrecoverable following a download which occurred on April 21, 2025. Once this issue was confirmed, those two hydrophones were replaced on August 8, 2025. The two replacement units along with the remaining four original units were successfully recovered at the completion of the monitoring season on November 24, 2025.

Table 4-6. Deployment and retrieval information for JSATS acoustic receivers deployed downstream of Essex Dam for the period from late-April to late-July, 2025.

Deployment Date	Data Type	Rx Type	Station Name	Latitude	Longitude	Recovery Date	Final Status
4/24/2025	1D	SR3001	1A	42.70827	-71.13517	7/23/2025	Recovered
4/24/2025	1D	SR3001	1B	42.70846	-71.1354	7/23/2025	Recovered
4/24/2025	1D	SR3001	2A	42.70552	-71.14393	7/23/2025	Recovered
4/24/2025	1D	SR3001	2B	42.70583	-71.14412	7/23/2025	Recovered
4/24/2025	1D	SR3001	3A	42.70436	-71.15117	7/23/2025	Recovered
4/24/2025	1D	SR3001	3B	42.70481	-71.151	7/23/2025	Recovered
4/24/2025	1D	SR3001	4A	42.7042	-71.15493	7/23/2025	Recovered
4/24/2025	1D	SR3001	4B	42.70457	-71.1549	7/23/2025	Recovered
4/24/2025	1D	SR3001	5A	42.70276	-71.16255	7/23/2025	Recovered
4/24/2025	1D	SR3001	6A	42.7022	-71.16365		Lost
4/25/2025	1D	SR3001	12A	42.700608	-71.1651		Lost
4/25/2025	2D	SR3001	7B	42.700484	-71.165617		Lost
4/25/2025	2D	SR3001	7C	42.700317	-71.165633	7/22/2025	Recovered
4/25/2025	2D	SR3001	7D	42.700233	-71.165368		Lost
4/25/2025	2D	SR3001	7E	42.700226	-71.165256		Lost
4/25/2025	2D	SR3001	7F	42.700207	-71.165207		Lost
4/25/2025	2D	SR3001	7G	42.700026	-71.165292		Lost
4/25/2025	2D	SR3001	7H	42.699945	-71.165483		Lost
4/25/2025	2D	SR3001	7I	42.699882	-71.165135		Lost
4/25/2025	2D	SR3001	7J	42.699804	-71.165477		Lost
4/25/2025	2D	SR3001	7K	42.699848	-71.165325		Lost
4/25/2025	2D	SR3001	7L	42.699701	-71.165138		Lost
4/25/2025	2D	SR3017	8A	42.699664	-71.165248	7/24/2025	Recovered
4/25/2025	2D	SR3017	8B	42.699705	-71.16546	7/24/2025	Recovered
5/2/2025	1D	SR3001	13A	42.701099	-71.165967		Lost

Table 4-7. Deployment and retrieval information for JSATS acoustic receivers deployed downstream of Essex Dam for the period from late-July to mid-September, 2025.

Deployment Date	Data Type	Rx Type	Station Name	Latitude	Longitude	Recovery Date	Final Status
7/31/2025	1D	SR3001	1A	42.70827	-71.13517	9/24/2025	Recovered
7/31/2025	1D	SR3001	1B	42.69968	-71.16529	9/24/2025	Recovered
7/31/2025	1D	SR3001	2A	42.69970	-71.16541	9/24/2025	Recovered
7/31/2025	1D	SR3001	2B	42.70019	-71.16569	9/24/2025	Recovered
7/31/2025	1D	SR3001	3A	42.70155	-71.16512	9/24/2025	Recovered
7/31/2025	1D	SR3001	3B	42.70284	-71.16172	9/24/2025	Recovered
7/31/2025	1D	SR3001	4A	42.70425	-71.15270	9/24/2025	Recovered
7/31/2025	1D	SR3001	4B	42.70830	-71.13536	9/24/2025	Recovered
7/31/2025	1D	SR3001	5A	42.70689	-71.13782	9/24/2025	Recovered
7/24/2025	1D	SR3017	8A	42.699664	-71.165248	9/11/2025	Recovered
7/24/2025	1D	SR3017	8B	42.699705	-71.16546	9/11/2025	Recovered

Table 4-8. Deployment and retrieval information for InnovaSea acoustic receivers deployed downstream of Essex Dam for the period from late-March to mid-November, 2025.

Deployment Date	Data Type	Rx Type	Station Name	Latitude	Longitude	Recovery Date	Final Status
3/27/2025	1D	VR2Tx	1A	42.70689	-71.13782	4/21/2025	Lost
8/8/2025	1D	VR2Tx	1B	42.70830	-71.13536	11/24/2025	Recovered
3/27/2025	1D	VR2Tx	4	42.70425	-71.15270	11/24/2025	Recovered
8/8/2025	1D	VR2Tx	5	42.70284	-71.16172	11/24/2025	Recovered
3/27/2025	1D	VR2Tx	6	42.70155	-71.16512	4/21/2025	Lost
4/23/2025	1D	VR2W	7	42.70019	-71.16569	11/24/2025	Recovered
4/7/2025	1D	VR2W	8A	42.69970	-71.16541	11/24/2025	Recovered
3/20/2025	1D	VR2W	8B	42.69968	-71.16529	11/24/2025	Recovered

4.3.2 Sturgeon Tagging

USGS gill net sampling occurred from mid-April though late May 2025. Sampling efforts during the early portion of the period occurred in the vicinity of known spawning habitats in the Haverhill, Massachusetts area and during the latter portion of the period occurred in the Joppa Flats region in the lowermost portion of the Merrimack River in Newburyport, Massachusetts. All told, USGS staff successfully captured and tagged a total of 54 individuals: 39 adult Shortnose Sturgeon, 8 sub-adult Atlantic Sturgeon, and 7 juvenile Atlantic Sturgeon. Adult Shortnose Sturgeon were tagged from both sampling locations (Haverhill and Joppa Flats) whereas captures of Atlantic Sturgeon for tagging were limited to Joppa Flats. A summary of all sturgeon tagged by USGS in the Merrimack River is provided in Table 4-9.

Table 4-9. Summary of Shortnose and Atlantic Sturgeon marked with acoustic transmitters by USGS staff in the lower Merrimack River during spring 2025.

Species	Life Stage	Tagging Date	Capture Location	JSAT Tag ID	InnovaSea Tag ID	W (kg)	TL (cm)	Sex
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42299	3.9	95	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42300	4.8	90	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42307	4.2	94	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42310	3.4	88	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42302	3.5	94	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42304	3.9	92	-
Atlantic	Juvenile	5/28/2025	Joppa Flats	-	42305	5.1	95	-
Atlantic	Sub-adult	5/20/2025	Joppa Flats	-	42309	4.2	92	-
Atlantic	Sub-adult	5/20/2025	Joppa Flats	-	42308	4.8	95	-
Atlantic	Sub-adult	5/20/2025	Joppa Flats	-	42306	5.3	102	-
Atlantic	Sub-adult	5/20/2025	Joppa Flats	-	42311	7.4	112	-
Atlantic	Sub-adult	5/20/2025	Joppa Flats	-	42303	7.4	106	-
Atlantic	Sub-adult	5/28/2025	Joppa Flats	-	42301	-	122	-
Atlantic	Sub-adult	5/28/2025	Joppa Flats	-	42298	5.5	108	-
Atlantic	Sub-adult	5/8/2025	Joppa Flats	26027	42287	-	145	-
Shortnose	Adult	4/18/2025	Haverhill	714	46043	3.8	97	F
Shortnose	Adult	4/18/2025	Haverhill	746	-	4.7	102	M
Shortnose	Adult	4/18/2025	Haverhill	680	-	4.0	94	M
Shortnose	Adult	4/18/2025	Haverhill	660	-	5.0	112	M
Shortnose	Adult	4/18/2025	Haverhill	612	-	4.9	103	M
Shortnose	Adult	4/18/2025	Haverhill	678	-	4.1	102	M
Shortnose	Adult	4/18/2025	Haverhill	694	-	5.1	108	M
Shortnose	Adult	4/18/2025	Haverhill	698	-	2.9	89	M
Shortnose	Adult	4/18/2025	Haverhill	662	-	5.1	104	M
Shortnose	Adult	4/18/2025	Haverhill	726	-	4.4	105	M
Shortnose	Adult	4/18/2025	Haverhill	602	-	4.9	104	M
Shortnose	Adult	4/18/2025	Haverhill	692	-	4.3	100	M
Shortnose	Adult	4/18/2025	Haverhill	684	-	4.8	103	M
Shortnose	Adult	4/18/2025	Haverhill	346	-	5.9	110	M
Shortnose	Adult	4/18/2025	Haverhill	724	-	2.5	88	M
Shortnose	Adult	4/18/2025	Haverhill	690	-	4.4	105	M
Shortnose	Adult	4/18/2025	Haverhill	658	-	5.7	107	M
Shortnose	Adult	4/18/2025	Haverhill	676	-	3.4	104	M
Shortnose	Adult	4/18/2025	Haverhill	686	-	3.8	92	M
Shortnose	Adult	4/18/2025	Haverhill	666	-	4.5	100	M
Shortnose	Adult	4/18/2025	Haverhill	598	-	3.5	94	M
Shortnose	Adult	4/22/2025	Haverhill	26293	42295	5.2	106	M
Shortnose	Adult	5/8/2025	Joppa Flats	26325	42292	3.1	84	-
Shortnose	Adult	5/8/2025	Joppa Flats	26027	42289	3.0	83	-
Shortnose	Adult	5/14/2025	Joppa Flats	26277	42294	-	109	F

Species	Life Stage	Tagging Date	Capture Location	JSAT Tag ID	InnovaSea Tag ID	W (kg)	TL (cm)	Sex
Shortnose	Adult	5/14/2025	Joppa Flats	26283	42293	-	98	-
Shortnose	Adult	5/14/2025	Joppa Flats	26197	42296	-	111	-
Shortnose	Adult	5/14/2025	Joppa Flats	26037	42312	-	102	-
Shortnose	Adult	5/14/2025	Joppa Flats	26069	42290	-	87	-
Shortnose	Adult	5/14/2025	Joppa Flats	26029	42297	-	80	-
Shortnose	Adult	5/14/2025	Joppa Flats	15701	42291	-	98	F
Shortnose	Adult	5/14/2025	Joppa Flats	26285	42285	-	96	-
Shortnose	Adult	5/14/2025	Joppa Flats	11435	42283	-	102	-
Shortnose	Adult	5/14/2025	Joppa Flats	11437	42286	-	101	-
Shortnose	Adult	5/14/2025	Joppa Flats	26261	42288	-	113	-
Shortnose	Adult	5/14/2025	Joppa Flats	26453	42284	-	104	-
Shortnose	Adult	5/20/2025	Joppa Flats	674	-	3.6	90	-
Shortnose	Adult	5/20/2025	Joppa Flats	342	-	6.5	104	-
Shortnose	Adult	5/28/2025	Joppa Flats	650	-	3.2	94	-

4.3.3 Sturgeon Movements and Project Interaction

During the period of active monitoring downstream of the Essex Dam (late April to late September for JSATS transmitters and late April to mid-November for InnovaSea transmitters), only one of the 54 tagged sturgeon was determined to have ascended upstream at least as far as the I-495 Lawrence Bridge (Station 1). A single Shortnose Sturgeon (JSATS ID 26069) was initially detected on June 21 in the vicinity of the I-495 Lawrence Bridge (Figure 4-18). Shortnose 26069 was an 87 cm fish of unknown sex that was tagged by USGS on May 14 in the Joppa Flats region. This individual was detected within the detection field of Station1 over the span of several hours on June 21. It was not detected again during the 2025 monitoring period.

A previously tagged Shortnose Sturgeon was also recorded on the acoustic receiver array downstream of Essex Dam during 2025 (InnovaSea ID 24350; Figure 4-19). This male Shortnose Sturgeon was originally tagged by USGS during 2016 at RM 6.8 of the Merrimack River and was detected in the reach downstream of Essex Dam during April. It was initially detected by the InnovaSea receiver installed just downstream of the Duck Bridge (Station 4) on April 22, 2025. Following this initial detection, Sturgeon 24350 was subsequently detected by an InnovaSea receiver installed in the downstream end of the tailrace channel (Station 7) with the majority of those detections occurring on April 25. The fish's last detection from the InnovaSea receivers operated by Essex during the 2025 season occurred on April 27 at the Duck Bridge (Station 4).

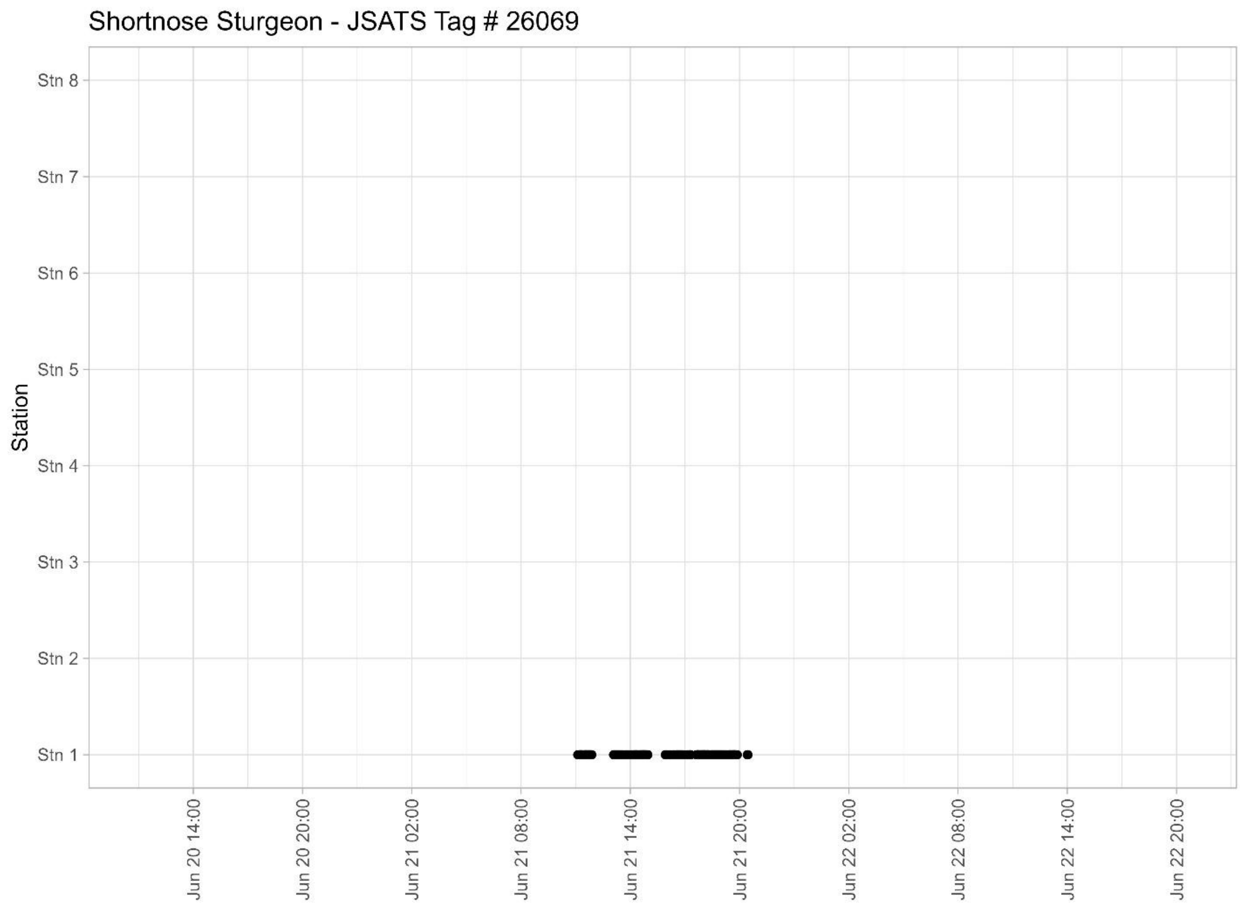


Figure 4-18 Detection history for tagged Shortnose Sturgeon ID 26069 in the section of the Merrimack River downstream of Essex Dam as determined by JSATS receiver detections from Station 1 (downstream of I-495 Lawrence Bridge) to Station 8 (downstream of powerhouse).

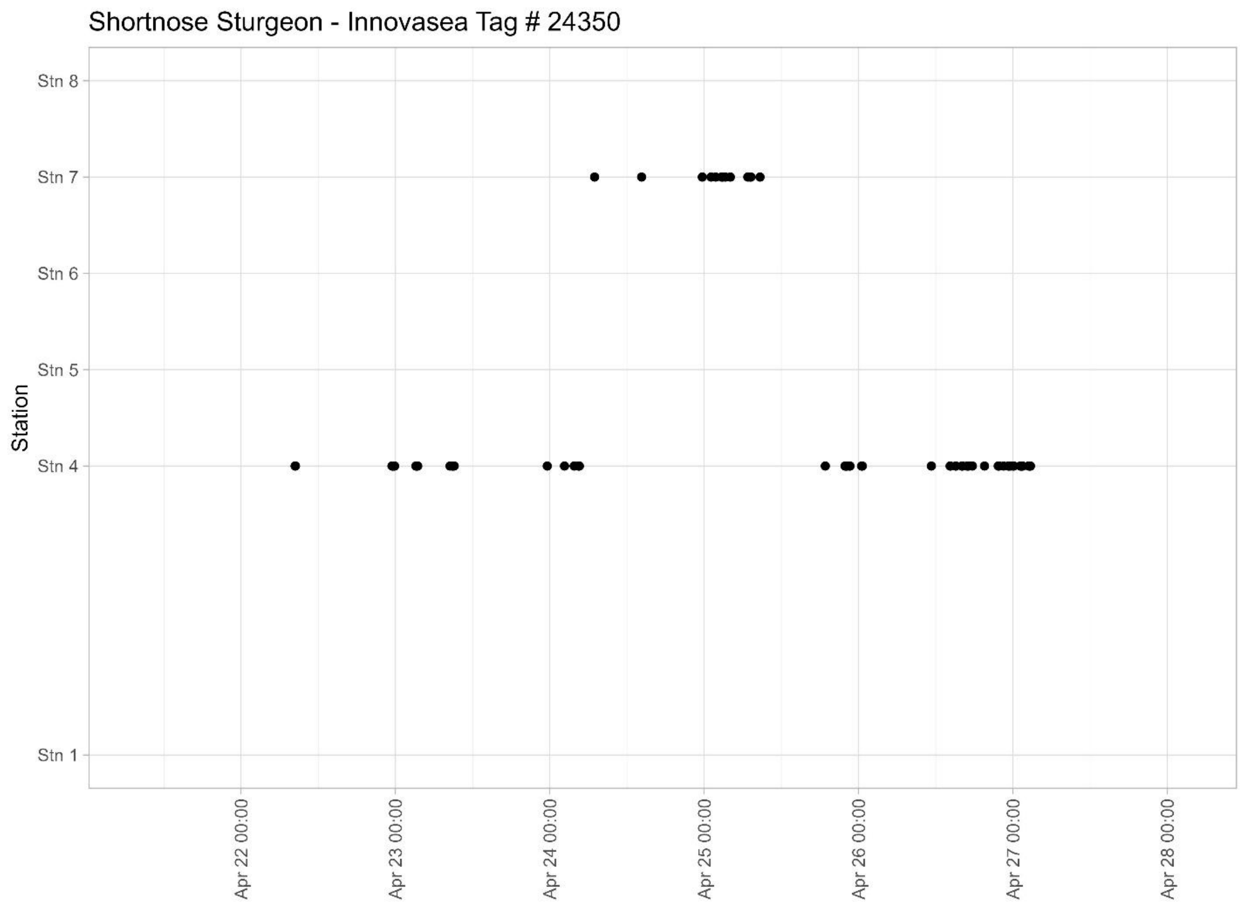


Figure 4-19 Detection history for tagged Shortnose Sturgeon 24350 in the section of the Merrimack River downstream of Essex Dam as determined by InnovaSea receiver detections from Station 1 (downstream of I-495 Lawrence Bridge) to Station 8 (downstream of powerhouse).

5. SUMMARY AND CONCLUSIONS

5.1 MOBILE SIDE-SCAN SONAR SURVEYS

The six mobile SSS surveys completed between April 4 and May 20, 2025 between the Project tailrace and the I-495 Lawrence Bridge resulted in the following:

1. Ten targets were classified as sturgeon with relative low (32%) to medium (68%) confidence between April 10 and 30, through a process involving assessment by three independent reviewers. None were identified upriver of Joseph W. Casey Bridge (Amesbury St.), which is located approximately 0.4 miles downriver of the Project Dam. The potential sturgeon targets were observed between 500 ft downriver of Joseph W. Casey Bridge and approximately 1,000 ft upriver of the I-495 Lawrence Bridge. The sturgeon targets observed by SSS were comparable in time and space as the acoustic receiver detections of a USGS sturgeon acoustically tagged in 2016 and the one individual observed during electrofishing in 2025.

2. The mobile SSS survey was not able to identify to species level of sturgeon and not able to quantify duration or seasonality of either species in the sampled river reach. However, repeated surveys were able to detect and classify sturgeon during mid to late April, but not on April 4th or May 20th.

3. No Project-related effects were identified in the SSS survey results. However, natural fluctuations in river flow, non-navigable rocky shallows, and turbulent conditions affected vessel access and controllability of the survey vessel underway in some areas.

4. Sturgeon were likely identified in the river reach between 1 and 1.5 miles downstream of the Project, but direct evidence of sturgeon observed in the mobile SSS surveys could not determine if the tailrace structure or flow conditions related to the Project dam created a barrier to upriver movement.

5.2 FIXED-LOCATION SONAR MONITORING PILOT STUDY

The fixed-location sonar monitoring pilot study used an ARIS (1100 and 1800 kHz) imaging sonar and a dual-frequency (900 and 2250 kHz) BlueView M900-2250-130-Mk2 imaging sonar to test the feasibility of detecting and identifying artificial life-size sturgeon in the Project tailrace channel during November 2025. Findings relating to the study objectives were the following:

1. No sturgeon were observed in the Project tailrace using either device. The study demonstrates that it is not feasible to detect or identify sturgeon-shaped targets using these two sonar technologies at suitable ranges for a long-term deployment of a fixed-location sonar monitoring in the Project tailrace, due to a variety of factors. These factors include mounting capability, geographical layout, high flows, entrained bubbles, submerged debris, turbulence in the tailrace, safety, site-specific limitations to sonar performance, and logistical challenges of prolonged operation.

2. Relative to Objective 2, no fixed-location sonar monitoring data were collected to describe duration or seasonality of sturgeon.

3. Project layout, flow conditions, and logistics within the tailrace limited the feasibility of deploying fixed-location sonar in specific locations and for long-term monitoring of

sturgeon. It was impractical to keep a target within the sonar field of view for an adequate amount of time for both detection and more so for identification. Woody debris and trash in the tailrace floats or churns underwater, which makes a long-term sonar monitoring deployment impractical due to potentially causing excessive false sturgeon detections as well as high risk of physical damage to fixed-location sonar systems over time. Fixed-location monitoring using ARIS and BlueView high-resolution imaging sonars to detect and identify sturgeon within the Project tailrace is not feasible as indicated by the pilot study under controlled conditions due to the high abundance of floating and submerged drift debris, entrained bubbles, strong eddies and currents, and upwelling.

4. The pilot study provided no insight into the potential need for upstream passage at the Project for either Atlantic or Shortnose Sturgeon. However, the pilot study did highlight challenges with future monitoring that environmental conditions create.

5.3 ACOUSTIC TELEMETRY

The installation of InnovaSea and ATS acoustic receivers took place from March through mid-November 2025 between the Project tailrace and region immediately downstream of the Lawrence I-495 Bridge. Findings related to the study objectives were the following:

1. Relative to Objective 1, a limited number of tagged adult Shortnose Sturgeon (n = 2) were confirmed as present during the monitored area. One individual ascended far enough upstream to be detected at the downstream entrance of the tailrace channel. The second individual was not detected at any stationary receivers located upstream of the Lawrence I-495 Bridge. There were no detections of tagged Atlantic Sturgeon (juvenile or sub adult) at any stationary receiver location during the 2025 monitoring period.

2. Relative to Objective 2, seasonal presence of adult Shortnose Sturgeon across the full array occurred from late-April through mid-June. Shortnose Sturgeon presence in the region closest to Essex Dam was limited to a two-day duration during late April. The remainder of detections were from the receiver immediately downstream of the Lawrence I-495 Bridge.

3. No Project related effects were identified in the acoustic telemetry study results. A limited number of individuals were detected in the monitored reach downstream of Essex Dam and the seasonal timing of these detections is in line with previously reported Shortnose Sturgeon movements within the Merrimack River.

4. Results of the 2025 acoustic tag monitoring do not provide conclusive evidence to support the current need for upstream passage at the Project. Observations in the immediate vicinity of Essex Dam were limited to a single adult Shortnose Sturgeon detected only by the receiver at the downstream end of the tailrace channel (i.e., undetected by the two acoustic receivers positioned at the downstream face of the powerhouse and in vicinity of the upstream fish lift entrances.

6. VARIANCES FROM THE APPROVED STUDY PLAN

6.1 MOBILE SIDE-SCAN SONAR SURVEYS

With the exception of initiating data collection on April 4 rather than late March, and the inability to safely access non-navigable waters in close proximity to the Project Dam, there have been no variances from the approved study plan or the SPD for this portion of the study.

6.2 FIXED-LOCATION SONAR MONITORING PILOT STUDY

The fixed-location sonar monitoring varied in both instrumentation and approach from the SPD, which resulted in a two-phase approach using imaging multibeam sonars instead of a SSS as described in the Initial Study Report (ISR) and the accompanying Study Plan (Appendix D of the ISR). The pilot study did vary from the Study Plan in two ways. After challenges related to overall logistics, safety considerations, equipment protection, site accessibility, and reliable performance of the monitoring devices were encountered, the Pilot Study focused on testing the performance of two sonar technologies and chose the best suited, most practical mounting solution. This created a variance from mounting the sonar out at the tip of the old fish ladder structure, to mounting the frame and devices leveraging the river-side fish lift entrance weir structure. The other variance resulted from the actual implementation revealing that it was not feasible to execute a controlled experiment of deploying known targets at distant ranges, known depths, and known times for an analyst to independently process targets to measure sonar performance. As described herein, environmental conditions (e.g., flows, bubbles, debris) and personnel safety prevented this from working adequately. Instead, atypical low-flow Project operations and unrealistic close ranges were used to focus on identifying artificial sturgeon targets.

6.3 ACOUSTIC TELEMETRY

The acoustic telemetry was conducted following the methodology outlined in consultation with the Merrimack River Technical Committee following issuance of the May 10, 2024 FERC Study Plan Determination.

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