

# **Study Report for the Upstream Anadromous Fish Passage Assessment**

**Lawrence Project (FERC No. 2800)**

**Prepared For**  
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## 1 Introduction

Essex Company, LLC (Essex), a subsidiary of Patriot Hydro, LLC, is the Licensee, owner, and operator of the Lawrence Hydroelectric Project (Project or Lawrence Project), which is Federal Energy Regulatory Commission (FERC or Commission) Project No. 2800. The Project was licensed by the Commission on December 4, 1978 (with an effective date of December 1, 1978), and the license expires on November 30, 2028. The Lawrence Project is located on the Merrimack River in the City of Lawrence in Essex County, Massachusetts.

In accordance with 18 C.F.R. § 5.15, Essex has initiated studies and information gathering activities as provided in the study plan and schedule approved by the Commission. Among the studies completed during 2025 was the Upstream Anadromous Fish Passage Assessment (Upstream Passage Study), the methodologies of which were outlined in the Revised Study Plan (RSP) filed by Essex with the Commission on April 10, 2024, and approved with modifications by FERC in their May 10, 2024, Study Plan Determination (SPD). This report describes the Licensee's implementation of the study plan and schedule, the data collected, and any variances from the study plan and schedule.

## 2 Goals and Objectives

The goal of the Upstream Anadromous Fish Passage Assessment was to determine the impact of the Lawrence Project on the upstream migration of anadromous fish species. Following receipt of comments on the PSP and additional consultation with the resource agencies, this evaluation was focused on the American shad (*Alosa sapidissima*) and, based on recommendations received from FERC in their SPD, also included sea lamprey (*Petromyzon marinus*). The specific objectives of this study were to:

- Determine approach of upstream migrating tagged fish from the downstream release location towards the Project fishway under a range of operational/river conditions.
- Determine tailrace residence duration of upstream migrating tagged fish following arrival downstream of the Project.
- Estimate the nearfield attraction efficiency, entrance efficiency, internal efficiency, and overall efficiency of the existing upstream fish lift under a range of operational/river conditions and with both entrances in the open position.
- Inform on fish lift entry (i.e., frequency, timing, and location of entry events).
- Inform on the departure of tagged fish from the upstream exit flume of the existing upstream fishway and subsequent movement into (1) the Project intake canal or (2) upstream and into the Project impoundment.

### 3 Project Description and Study Area

The Lawrence Project works consist of: (1) the 35-foot-high by 900-foot-long gravity Essex Dam of stone masonry construction (also known as the Great Stone Dam), with a five-foot-high pneumatic crest gate system mounted on the spillway crest; (2) a 9.8-mile-long impoundment having a surface area of 655 acres at a normal water elevation of 44.17 feet National Geodetic Vertical Datum of 1929 at the top of the crest gates, and gross storage capacity of approximately 19,900 acre-feet; (3) a powerhouse located at the end of a small forebay adjacent to the south abutment of the Essex Dam containing two 8.4 megawatt generating units and a tailrace channel extending into the Merrimack River channel; (4) fish passage facilities integral with the powerhouse, including a fish lift, downstream fish bypass, an eel lift at the left abutment of the dam, and an eel ladder at the right abutment of the dam; (5) the North Canal, approximately 5,300 feet long by 95 feet wide by 15 feet deep, originating at the north abutment of the dam and paralleling the Merrimack River downstream of the Essex Dam; (6) the South Canal, approximately 2,750 feet long by 35 feet wide by 10 feet deep, originating at the south abutment of the Essex Dam and generally paralleling the Merrimack River downstream of the Essex Dam; (7) a single-circuit, underground/underwater 23.0-kilovolt transmission line to the Massachusetts Electric Company's Lawrence No. 1 substation; and (8) appurtenant facilities.

The study area for the Upstream Anadromous Fish Passage Assessment included the mainstem Merrimack River from the upstream extent of the Project impoundment to the Haverhill Riverside Park (approximately 6.6 miles downstream of Essex Dam).

### 4 Study Methods

Essex employed radio telemetry for the evaluation of upstream passage of American shad and sea lamprey at the Lawrence Project. Following the release of radio tagged individuals into the Merrimack River at points downstream of Lawrence, passage was evaluated using a series of stationary radio telemetry receivers in place at the Project. Additional stationary monitoring receivers were installed at bank-side locations at points upstream and downstream of Essex Dam to inform on fish movements and project passage success. More specific details on monitoring equipment and detection locations are provided in the following sections.

#### 4.1 Radio Telemetry Equipment

Approach, residence, and passage of radio tagged American shad and sea lamprey were evaluated using a set of stationary radio telemetry receivers installed at specific locations at and in the vicinity of the Essex Dam and Project powerhouse. Installed radio telemetry equipment included a combination of Sigma-Eight Orion receivers and Lotek SRX receivers. These receivers were installed following consideration of the detection requirements for the specific area of coverage, as well as the attributes of the receiver model (i.e., broadband vs. single frequency capability). Several types of antennas were used for this study, including aerial Yagi antennas and custom-

made underwater antennas (dropper antennas). The specific antenna type for each stationary receiver location was determined in the field.

Transmitters were selected based on relative size and previous performance. Adult shad were tagged using transmitters manufactured by Sigma-Eight (model TX-PSC-I-80) with each transmitter measuring 10 x 10 x 27 mm, weighing 4.2 grams, and having an estimated battery life of 64 days when set at a 2.0 second burst rate. Sea lamprey were tagged using Sigma-Eight transmitters (model TX-PSC-I-450). These transmitters measured 45 x 12 x 12 mm, weighed 8.5 g and lasted for 357 days when set at a 2.0 second burst rate.

## 4.2 Monitoring Stations

Radio telemetry antennas and receivers were installed at a series of predetermined locations. Each monitoring station consisted of a data-logging receiver, one or more antennas, and a power source. Receivers were configured to receive transmitter signals from a designated area continuously throughout the study period. During installation of each station, range testing was conducted to configure the antennas and receivers in a manner that maximized detection efficiency at each location. The operation of the system was confirmed during installation and throughout the study period by using beacon tags. These beacon tags were stationed at strategic locations within the detection range of either multiple or single antennas and were programmed to emit a signal at a fixed time interval. These signals were detected and logged by the receivers and used to record the functionality of the system throughout the study period. Although each monitoring station was installed in a manner that limited the ability to detect transmitters from unwanted areas, the possibility of such detections did still exist. As a result, behavioral data collected during this study (i.e., duration at a specific location or passage route) was inferred based on the signal strength and the duration and pattern of contacts documented across the entire detection array.

The final installation locations for each monitoring station deployed to aid in the determination of the effectiveness of the existing upstream fish lift at Lawrence are outlined below and presented visually in Figures 4-1 and 4-2.

**Station 1:** Station 1 was installed at the Haverhill Riverside Park and consisted of a single receiver and aerial antenna oriented perpendicular to the Merrimack River channel. Station 1 was the lowermost receiver station and detections at this location were used to confirm departure of outmigrating tagged fish from the study area. Station 1 was installed approximately 6.6 miles downstream of Essex Dam and 4.5 miles downstream of Station 2.

**Station 2:** This station consisted of a single receiver and aerial antenna oriented perpendicular to the river channel and installed on the grounds of the Essex County Correctional Facility. Detections at Station 2 were used to confirm departure from the study area by outmigrating tagged fish. Station 2 was located approximately 2.1 miles downstream of Essex Dam and 4.5 miles upstream of Station 1.

**Station 3:** Station 3 consisted of a single radio receiver intended to provide aerial coverage of the “approach” (i.e., the section of the Merrimack River just downstream of Essex Dam and leading up into the fish lift area). Field evaluations prior to the initiation of the fish releases associated with the Upstream Anadromous Fish Passage Assessment determined that shoreline access for installation of a bank-side receiver station looking crosswise across the Merrimack River downstream of Essex Dam was not feasible due to both logistical and safety concerns. As a result, Station 3 was installed in a manner which consisted of a single aerial antenna mounted at the downstream extent of the old fishway adjacent to the powerhouse tailrace. The antenna associated with Station 3 was oriented to scan in a downstream direction and provide coverage of the region extending approximately 150-200m downstream of Essex Dam.

**Station 4:** Station 4 consisted of a single radio receiver and aerial antenna to provide coverage of the lower portion of the downstream tailrace area immediately below the Lawrence powerhouse. The Station 4 antenna was installed on the old fishway adjacent to the powerhouse tailrace and set at an angle by which it provided cross-channel coverage.

**Station 5:** Station 5 consisted of two radio receivers; each connected to an aerial antenna to provide coverage of the upper portion of the downstream tailrace area immediately below the Lawrence powerhouse. The antennas were attached to the downstream side of the powerhouse and were positioned in a manner by which they provided coverage of the area immediately outside of the primary (river side) and secondary (street side) entrances to the fish lift. Detections from Station 5 were considered as representative of arrival within the nearfield attraction area immediately downstream of the two entrances to the Lawrence fish lift. The fish detected by Station 5 were considered as candidates to enter the fishway.

**Station 6:** This station consisted of a single receiver and underwater drop antenna to provide detection information for radio tagged fish in the area immediately inside of the primary (river side) fish lift entrance (i.e., located on the eastern or left [when viewed looking downstream] side of the fishway).

**Station 7:** Station 7 consisted of a single receiver and underwater drop antenna to provide detection information for radio tagged fish in the area immediately inside of the secondary (street side) fish lift entrance (i.e., located on the western or right [when viewed looking downstream] side of the fishway).

**Station 8:** Station 8 provided detections of radio tagged fish located within the lower fishway entrance flume and towards the hopper. This station consisted of a single receiver and underwater drop antenna. The intent of Station 8 was to provide detection information for fish which had successfully passed through an entrance (i.e., Station 6 or 7) and reached the vicinity of the hopper.

**Station 9:** This station consisted of a single receiver and underwater drop antenna to provide detection information for radio tagged fish in the upstream exit flume of the Lawrence fish lift indicating successful upstream passage via the hopper. Fish detected at this location were successfully transported upstream via the lift hopper.

**Station 10:** Station 10 consisted of a single receiver and drop antenna providing redundant detection information for radio tagged fish in the upstream exit flume of the Lawrence fish lift. This station was positioned at the upstream end of the exit flume at the point where flows converge with the power canal and provided additional detection information on successful upstream passage via the lift hopper.

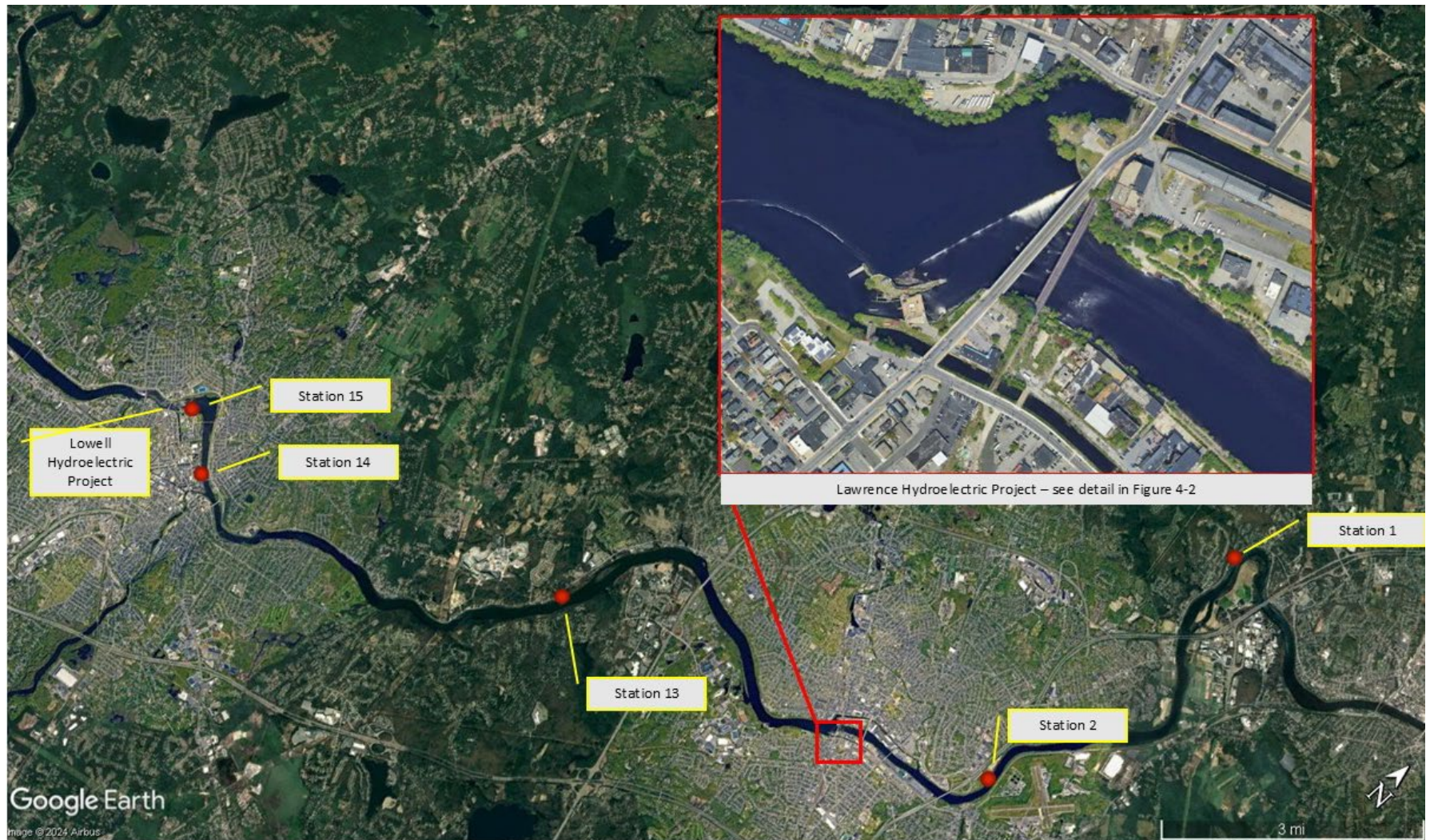
**Station 11:** Station 11 consisted of one radio receiver and aerial antenna to provide detection information for radio tagged fish having exited the upstream exit flume of the Lawrence fish lift and moved into the Project forebay.

**Station 12:** This station was installed to provide detection information for radio tagged individuals which had exited the upstream exit flume of the Lawrence fish lift and moved upstream to the point where they were exiting from the powerhouse forebay. Station 12 consisted of one radio receiver and aerial antenna to provide cross-channel coverage.

**Station 13:** Station 13 was installed along the mainstem of the Merrimack River near the midpoint between the upstream non-Project Lowell Hydroelectric Project (P-2790) and the Lawrence Project and consisted of a single receiver and aerial antenna oriented perpendicular to the river channel. This station was installed to collect detection information for the confirmation of continued upstream movement of radio tagged fish as they moved away from the Lawrence Project. Station 13 was installed at a point sitting approximately 4.5 miles upstream of Essex Dam.

**Station 14:** This station was installed along the mainstem of the Merrimack River at a point approximately 9.0 miles upstream of the Essex Dam and was considered representative of the upstream extent of the Project impoundment. Station 14 consisted of a single receiver and aerial antenna oriented perpendicular to the river channel and was installed, with permission, at the Lowell Wastewater Treatment Plant.

**Station 15:** Station 15 was the furthest upstream receiver location installed to detect radio tagged test fish and was located along the mainstem of the Merrimack River at a point just downstream of the convergence of flow from the Lowell Project bypassed reach and E.L. Field powerhouse tailrace channel. Station 15 consisted of a single receiver and aerial antenna oriented perpendicular to the river channel.



**Figure 4-1. Stationary radio telemetry receiver locations associated with the Upstream Anadromous Fish Passage Assessment relative to the Lawrence Project, spring 2025.**



**Figure 4-2. Stationary radio telemetry receiver locations associated with the Upstream Anadromous Fish Passage Assessment relative to Essex Dam and the Lawrence powerhouse, spring 2025.**

### 4.3 Tagging and Release Procedures

Adult American shad intended to assess the effectiveness of the upstream fish lift at Lawrence were collected from the section of the Merrimack River downstream of the Project and between the Union Street Duck Bridge and the first crossing of Route 495. All shad collected for radio tagging were obtained via boat electrofish collections. Following capture, shad were immediately placed in a large, onboard, flow-through live well and the crew navigated the boat to a safe shoreline location for tagging. Each fish was visually assessed to ascertain their suitability for tagging. Any individuals exhibiting excessive scale loss or other signs of significant stress were not considered and were released back into the river untagged. Individuals deemed acceptable for tagging were quickly measured (total length, nearest mm), and sex was determined (when possible) by gently expressing eggs or milt from running-ripe fish. Radio transmitters were inserted gastrically. To facilitate gastric implantation, transmitters were affixed to a flexible tube with their trailing antenna running through the hollow center. The transmitter and leading edge of the flexible tube were pushed through the mouth and down to the stomach. Once in place, the tube was removed leaving the transmitter antenna trailing from the mouth. Following tagging, shad were immediately released back into the Merrimack River and the coordinates and date/time of release were recorded. A total of 430 American shad were targeted for radio-tagging to evaluate the effectiveness of the upstream fish lift at Lawrence.

Sea lamprey were collected at the Lawrence fish lift facility. Sea lamprey determined to be in good condition (i.e., do not have any visible wounds) were placed in MS-222 solution (buffered 20 MM Na<sub>2</sub>CO<sub>3</sub>, pH = 7.0) until they lost their ability to orient and became unresponsive to touch stimuli. Following anesthesia, lamprey were measured for total length and transferred to a wet towel. For tagging, an incision was made off-center on the ventral surface of the individual during which time sex was determined through visual observation of gonads. A hollow needle was inserted into the incision and pushed through the body wall just off the ventral mid-line and at a point posterior to the incision. The antenna was fed through the needle and gently pulled so that the transmitter entered the body cavity. The needle was then pulled through the body wall and removed from the antenna. The transmitter was positioned by pulling the antenna so that it sat directly under the incision. The incision was then closed with two or three interrupted sutures. A small amount of antibacterial ointment was applied to the incision site to prevent infection. Following tagging, each individual was transferred directly to a truck transport tank filled with aerated river water and allowed to recover within the tank prior to release. Recovery was deemed complete when a tagged lamprey could orient to an upright position and swim about the transport tank. A total of 50 lamprey were collected and all downstream releases of lamprey took place at a point along the mainstem of the Merrimack River in the vicinity of the first crossing of Route 495 (approximately 1.5 miles downstream of the dam).

## 4.4 Data Collection

Data was off-loaded from receivers using a laptop computer and was stored on removable memory sticks. Data downloads occurred at least once weekly during the period from the initial tag and release date until completion of the monitoring period (July 15). Backup copies of all telemetry data were made prior to receiver initialization. Field tests to ensure data integrity and receiver performance included confirmation of file integrity, confirmation that the last record was consistent with the downloaded data (beacon tags were critical to this step), and lastly, confirmation that the receiver was operational upon restart and actively collecting data post download. Within a data file, transmitter detections were stored as a single event (i.e., single data line). Each event included the date and time of detection, frequency, ID code, and signal strength.

In addition to stationary radio telemetry data, river and Project operations data representative of the full duration of the evaluation period were obtained. Mainstem river temperature was recorded via a continuous logger installed at the Project. Hourly records of inflow, discharge (canal, fish lift, downstream bypass, turbine, and spill), and tailwater and impoundment elevations were obtained from Essex at the completion of the study period. During the upstream passage season, Essex completed a daily fishway inspection log which included information related to river conditions, flow allocation, unit status, and fishway conditions. Information specific to attraction flows and fishway operations (i.e., daily Auxiliary Water Supply (AWS) gate setting, AWS discharge in cubic feet per second [cfs], entrance gate setting [feet], entrance drop [feet], and v-trap opening [inches] are summarized in this study report.

## 4.5 Data Management

During fish tagging, a systematic approach was used for recording tag codes and other physical and biological data. Data collected during tagging was recorded manually on field data sheets and later key-punched into electronic format. Simple data verification processes were performed following data entry to ensure that information contained within the tag database was accurate. During downloads of receiver equipment, detailed records were maintained to log the condition of each receiver station and antenna and document download start and end times. Downloaded files were named following a standardized convention of SSMDDYY.txt where SS = the two-digit station ID, MM = month, DD = day and YY = year. Field personnel saved a backup of any telemetry download prior to receiver initialization.

Raw data collected as part of this study included transmitter and biological information on each fish tagged as well as fixed-station telemetry detections. Additional parameters requiring definition included a list of each antenna along with the unique signal strength threshold (i.e., the power level below which detections are likely noise and should be discounted). Similarly, a listing of receivers was required along with a noise filtering threshold (i.e., the minimum number of expected detections in a specified time period, below which detections are likely to be noise).

Upon defining the project structure and noise filtering, the data for multiple receiver stations was merged and processed into a single set. Detection zones for many stations associated with this study were spatially independent from one another. In a limited number of cases, the detection zones of two stations slightly overlapped. In those instances, the relative signal strength for a sequential series of detections was utilized to determine the “break points” where highest signal strength shifts from receiver 1 to receiver 2.

## 4.6 Data Processing

Tag detections in each downloaded stationary telemetry data file were validated through a series of site-specific and logical criteria: These criteria included:

1. Signal strength threshold level of the detection,
2. Frequency of the radio tag signals per unit of time, and
3. Spatial and temporal characteristics of each individual detection with respect to the full series of detections at monitoring stations within the entire detection array.

To determine the signal strength threshold for a valid tag signal, power levels associated with background noise were recorded at each monitoring station prior to the release of radio tagged fish. These “false” signals are typically received at relatively low power levels, and they were removed from the analysis using a series of data filters. The frequency of the signal detections for an individual radio tag was examined at each monitoring station, such that over a set period of time, there were an adequate number of detections to rule out an isolated false detection (e.g. at least 3 detections within 1 minute). Finally, the spatial and temporal distribution of detections across multiple monitoring stations was examined to verify that the pattern of detections did not occur in a manner that was unreasonable (i.e., time for a fish to have relocated within the time between the detections).

## 4.7 Upstream Passage Analysis

### 4.7.1 Approach and Passage Metrics

Detection information from Stations 1 through 3 was used to inform on (1) the proportion of radio tagged individuals which aborted upstream movements following tagging (as evidenced by detection at Stations 1 or 2) or (2) moved upstream from the release location to approach the Essex Dam (as evidenced by detection at Station 3). The subset of individuals which approached Essex Dam (as evidenced by detection at Station 3) were further considered in the evaluation of upstream passage at the dam.

For radio tagged fish detected in the vicinity of the Lawrence fish lift entrances, each unique passage attempt was defined. These passage attempts were defined as a unique movement from the nearfield attraction water area (i.e., Station 5) upstream to either the primary or secondary fish lift entrances (Station 6 or 7). Attempts which ended in successful upstream passage were identified by detection at the exit of the forebay region (i.e., Station 12). Unsuccessful attempts

were defined by a series of detections at the internal fish way receivers (Stations 6, 7, and/or 8) followed by a return to the coverage zone of the nearfield receiver (Station 5). For each unsuccessful attempt it was noted if the individual reached the detection zone nearest to the hopper (i.e., Station 8). The duration of each passage attempt was calculated as the time from initial detection at the nearfield receiver (Station 5) until detection in the at the exit of the forebay region (Station 12) for test fish successfully passing upstream, or until a subsequent detection was made in the nearfield receiver detection zone (Station 5) for test fish failing to pass upstream.

In addition to evaluation of fish way entries, the stationary telemetry data set was also examined to inform on the (1) the seasonal and temporal distribution for the arrival of radio tagged individuals at the Lawrence fishway and (2) the duration of time from initial detection in the downstream Project area to successful upstream passage or outmigration.

#### 4.7.2 Parameter Estimates

Detection information obtained from the installed receiver array was used to construct an encounter history for each individual radio tagged test fish. These encounter histories were assembled as the series of sequential detection (“1”)/no detection (“0”) records for each individual fish between the release location and Essex Dam:

- Known release location (=1 for all fish);
- Station 3 – Lawrence approach (0 or 1);
- Station 4 – Lawrence tailrace (0 or 1);
- Station 5 – Lawrence fish lift nearfield (0 or 1);
- Station 6/7 – Lawrence fish lift entrance (0 or 1);
- Station 8 – Lawrence fish hopper area (0 or 1);
- Station 9 – Lawrence fish lift exit flume (downstream end) (0 or 1);
- Station 10 – Lawrence fish lift exit flume (upstream end) (0 or 1);
- Station 12 – Lawrence forebay exit (0 or 1);
- Station 13 – Lawrence impoundment (mid-point) (0 or 1);
- Station 14 – Top of Lawrence impoundment (last station) (0 or 1); and
- Station 15 – Uppermost receiver station (Lowell) (0 or 1).

These encounter histories formed the basis of a Cormack Jolly Seber (CJS) model constructed in Program MARK (White and Burnham 1999) which provided estimates for passage success (*Phi*) and detection (*p*) probabilities of radio tagged test fish downstream of Lawrence. The estimates of *Phi* generated by the CJS model represent the probability of passage success between a selected monitoring station and the adjacent upstream monitoring station. The detection probabilities estimate the likelihood that a tagged fish was

detected at a particular monitoring station given that it had successfully ascended upstream and reached that point.

The resulting model allowed for estimation of (1) nearfield attraction, (2) fish lift entrance efficiency, and (3) overall lift efficiency.

- *Nearfield attraction*: estimated as the probability for a radio tagged fish to move upstream into the fish lift nearfield attraction field (i.e., Station 5) following presence at the downstream end of the tailrace channel (i.e., Station 4).
- *Entrance efficiency*: estimated as the probability for a radio tagged test fish to move from the fish lift nearfield attraction field (i.e., Station 5) to detection at one of the two fish lift entrances (i.e., Station 6 or 7).
- *Overall fish lift efficiency*: representing successful passage from entry into the Lawrence Project area until entrance into the upper exit flume of the fish lift. The overall effectiveness was calculated as the joint probability of reach-specific estimates for Stations 3 to 4, 4 to 5, 5 to 6/7, 6/7 to 8, 8 to 9, 9 to 10, 10 to 11, and 11 to 12.

In addition to assessing rates of passage associated with the upstream fish lift structure, the CJS model developed as part of this Upstream Anadromous Fish Passage Assessment also informed on the rate of egress for radio tagged shad departing the powerhouse forebay and passage through the Project impoundment.

To evaluate passage success, a suite of candidate models were developed based on whether passage success, recapture (i.e., detection), or both varied or were constant among stations. Models included:

- $\Phi(t)p(t)$ : survival and recapture allowed to vary between receiver stations;
- $\Phi(t)p(.)$ : survival allowed to vary between stations; recapture constant between stations;
- $\Phi(.)p(t)$ : survival constant between stations; recapture allowed to vary between stations;
- $\Phi(.)p(.)$ : survival and recapture constant between stations;

Where;

- $\Phi$  = probability of survival
- $p$  = probability of detection
- $(t)$  = parameter varies
- $(.)$  = parameter is constant

## 5 Results

### 5.1 Merrimack River Conditions

Hourly flow data was obtained from the USGS streamflow gaging station on the Merrimack River in Lowell, MA (USGS No. 01100000) for the period from May 1 to July 15, 2025, and was prorated by a factor of 1.02 to approximate inflows at the Lawrence Project. Figure 5-1 presents the prorated Lawrence inflow and associated water temperature (as measured using an Onset HOBO Tid-Bit located just upstream of the Essex Dam). Merrimack River inflow at Lawrence peaked at over 47,000 cfs on May 11 and inflow was consistently higher than the 25% exceedance value (i.e., 15,208 cfs; May flow duration curve; Figure 5-2) for the remainder of the month. Inflow at Lawrence remained high into the month of June, remaining at levels higher than the monthly 25% exceedance value until the latter part of the month (i.e., 8,151 cfs; June flow duration curve; Figure 5-3).

Water temperature at the Project increased over the course of the monitoring period. The mean daily temperature ranged between 12.8°C and 19.4°C among dates where American shad were tagged and released and were around 19°C on dates when sea lamprey were tagged and released.

### 5.2 Project Operations

Total river flow, as distributed among available conveyance routes at Lawrence for the period from May 1 to July 15, is presented in Figure 5-4. Spill flow was present at Lawrence from early May through late June, encompassing all tagging dates for both American shad and sea lamprey. The downstream bypass was open for the duration of the period and was set to pass 160 cfs. Turbine generation occurred near continuously during the 2025 upstream passage evaluation. Unit 1 was online for the duration of the season and Unit 2 was online through June.

The Lawrence fish lift was operated from April 15 through July 15. Table 5-1 summarizes daily lift events during the portion of the upstream passage season during which radio tagged shad and lamprey were active in the reach downstream of Lawrence (i.e., May 20 to July 15). In general, the lift was operated approximately 10 times daily with the initial lift occurring around 0800 and last lift around 1600. The fish lift was offline on June 21 and the morning of June 22 while operations crews dewatered the lower flume for debris removal.

The two entrance gates (i.e., “primary” or river side and “secondary” street side) were operationally available for the duration of the upstream passage season. In agreement with the Merrimack River Technical Committee (MRTC), Essex followed standard operating criteria for the gate(s) in use during the 2025 study. Operation of each entrance gate was discussed prior to the study season, with prioritization and configuration authority delegated to Essex by the resource agencies for the 2025 study season to facilitate favorable passage conditions (Appendix B). Prior assessment of both gates consistently operating at the Lawrence fish lift demonstrated workable but not optimal gate setting conditions which include a reduction in each gate’s crest depth and

diminished AWS plume signature when in pursuit of suitable differentials. Past evidence also suggests a possible net loss of fish entering the lower fishway (more fish exited than entered through the secondary gate) leading to it being closed off following an internal lift study in 1994 and 1995 (Normandeau 1996). As a result, the primary (river side) gate was prioritized and the secondary (street side gate) only leveraged if Striped Bass pressure on river herring was observed in the area of each gate (to provide alternate entry) or until a submergence depth of 3.0 feet or less could no longer be sustained at the primary gate, as driven by tailwater elevation. The shift from the primary to the secondary gate occurred on June 27, 2025 and remained in effect through the conclusion of the 2025 effectiveness study, as improved gate depth was achieved with seasonal reductions in river flow and tailwater elevations.

During operation of the river side gate (May 20 through June 27), approximately 200 cfs of attraction water was supplied, representing an approximate mean of 3.2% of the hydraulic discharge of the station. The average entrance gate drop during operation of the river side gate was 0.78 feet. Similar to the period of operation for the river side entrance, the period of operation for the street side entrance (June 27 to July 15) also passed approximately 200 cfs of attraction water. Due to the decreased inflow at the Project, the attraction water flow during this later time period represented an approximate mean of 8.4% of the hydraulic discharge of the station. The average entrance gate drop during operation of the street side gate was 1.6 feet. The average value likely overestimates the true differential due to transducer placement when only the secondary (street-side) gate is operating. Flow buildup in front of the closed riverside gate elevates the internal fishway water level before entering the gallery flume. As a result, second gate conditions are visually confirmed at the second entrance rather than transducer readings. The v-gate width was set at 18 inches for the duration of the 2025 study season.

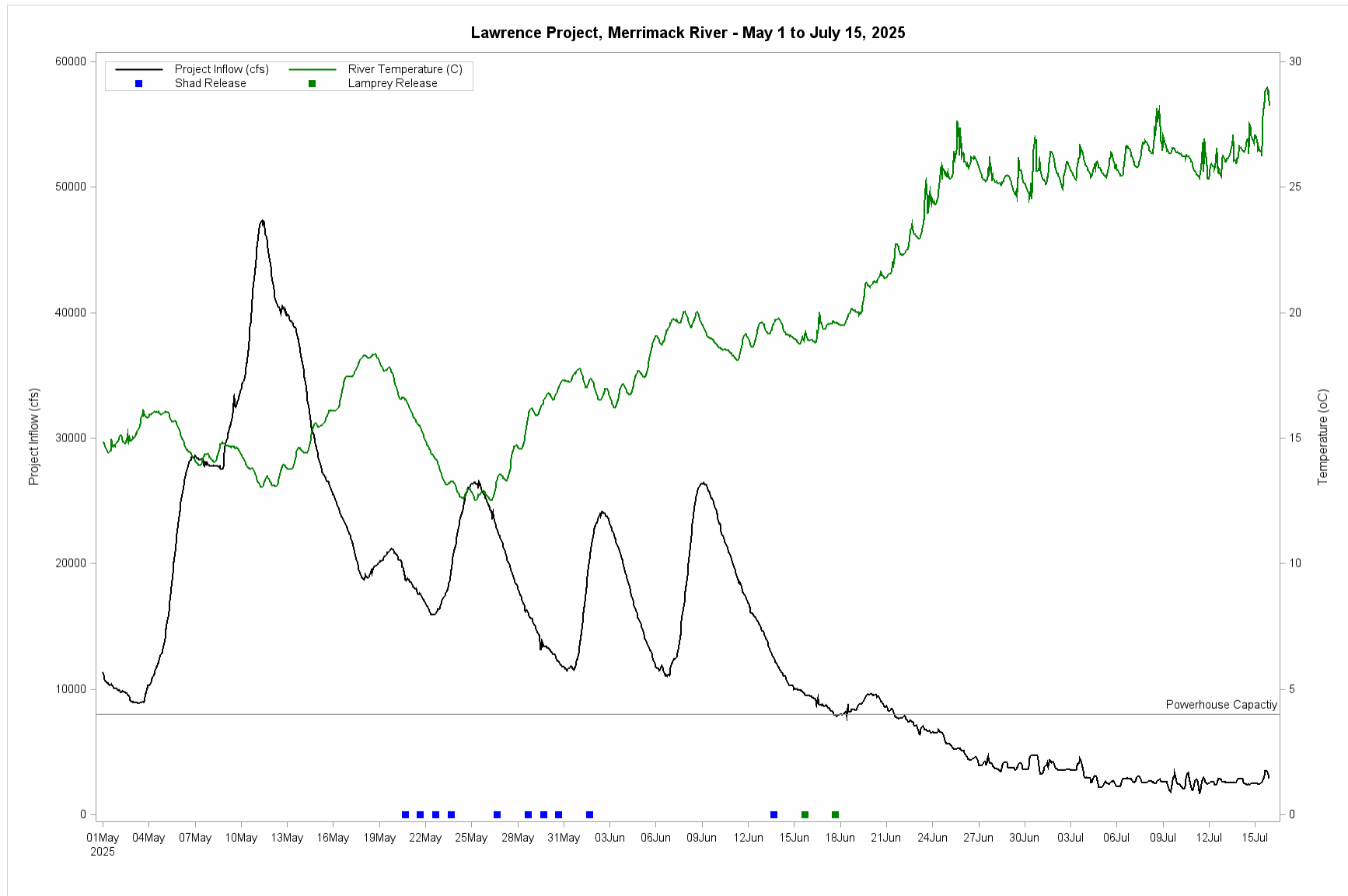
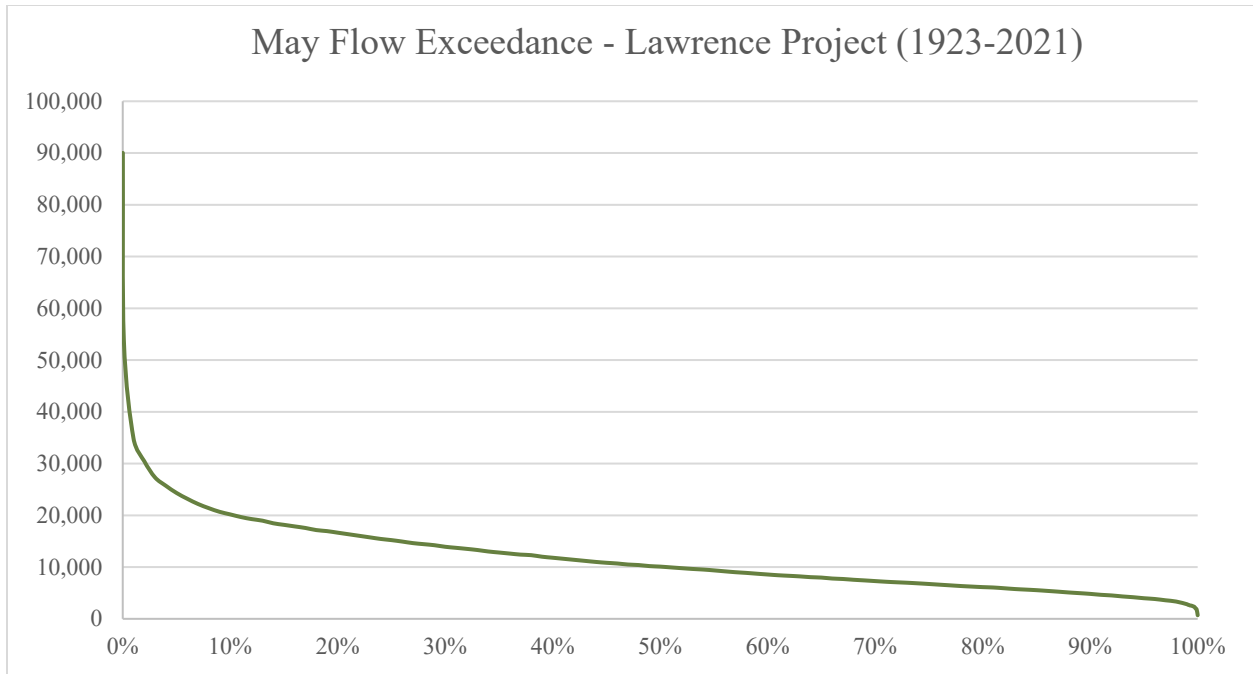
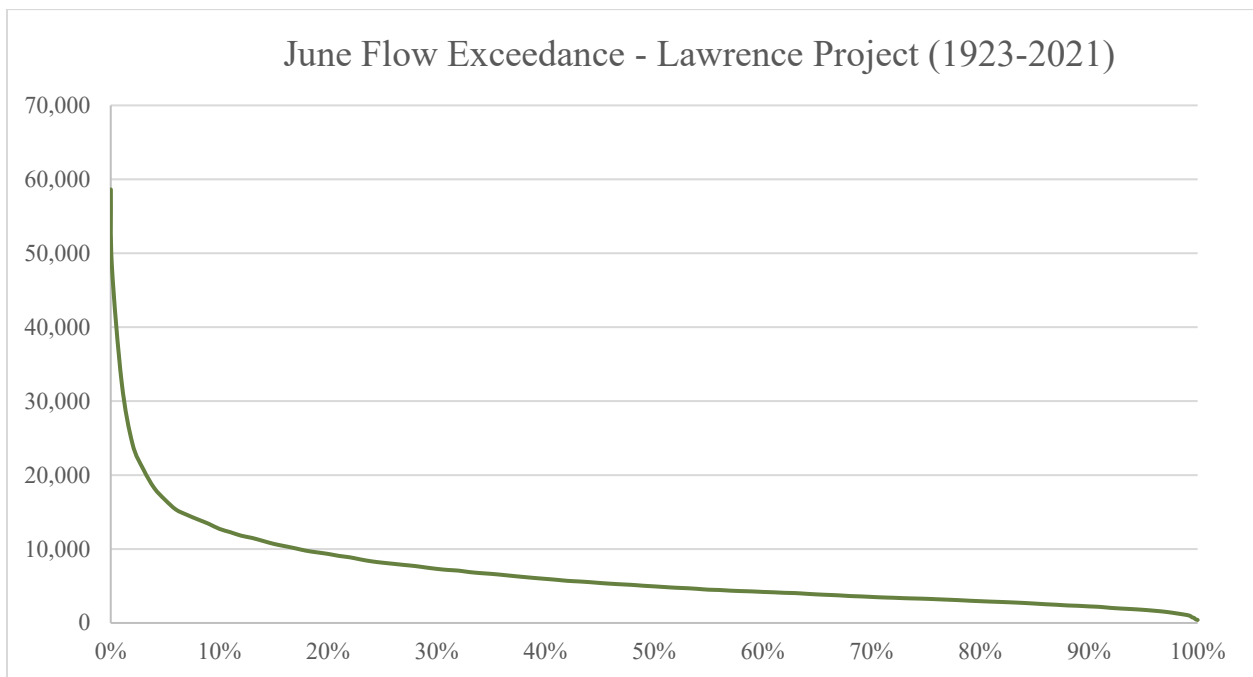


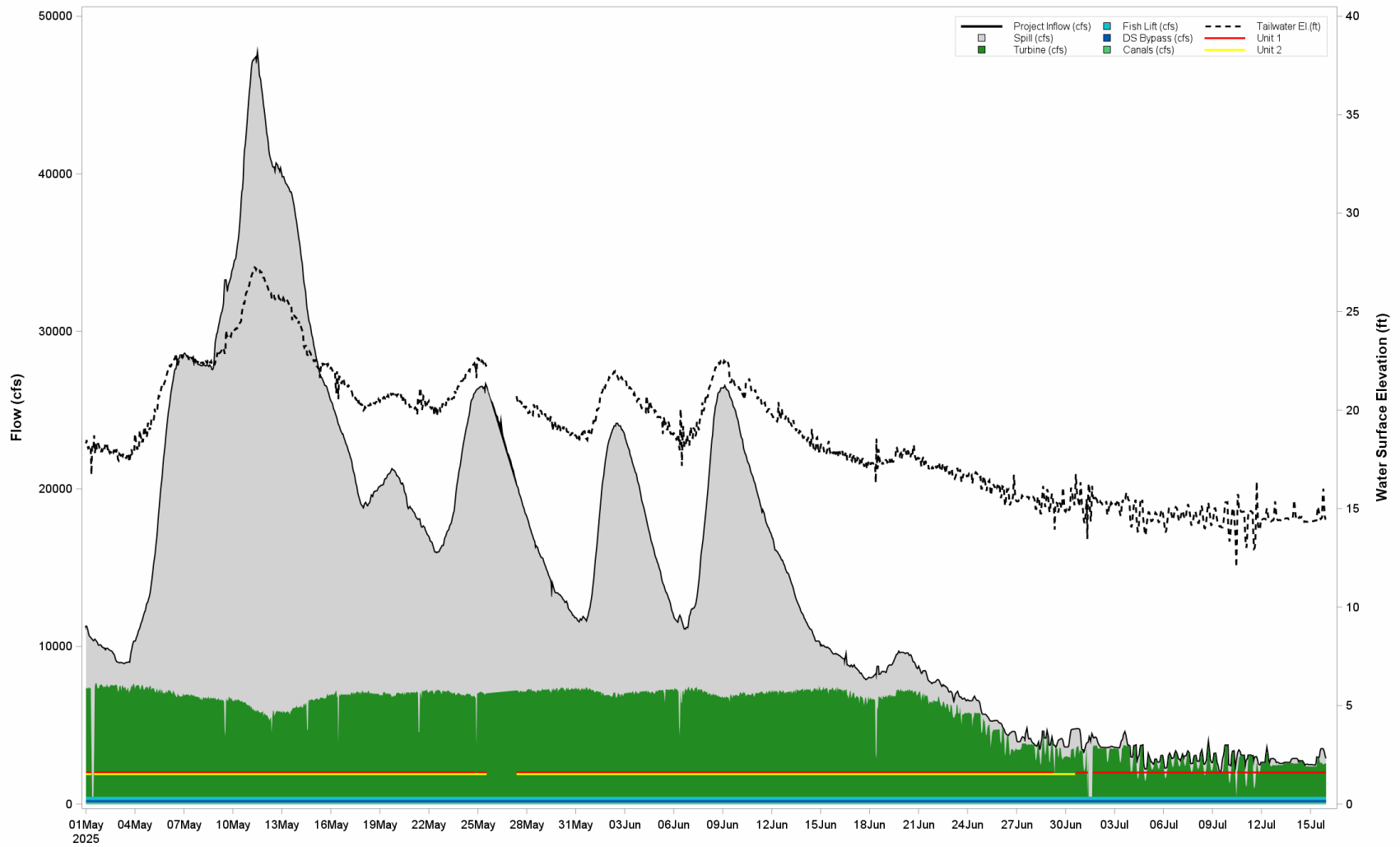
Figure 5-1. Merrimack River discharge and water temperature at Lawrence for the period May 1 to July 15, 2025.



**Figure 5-2. Flow duration curve for the Lawrence Hydroelectric Project during the month of May (1923-2021 flow set).**



**Figure 5-3. Flow duration curve for the Lawrence Hydroelectric Project during the month of June (1923-2021 flow set).**



Canal System = 100 cfs; Downstream Bypass = 160 cfs; Upstream Fishway = 200 cfs (online April 15)

**Figure 5-4. Lawrence inflow distribution, turbine operation, and tailwater elevation for the period May 1 to July 15, 2025.**

**Table 5-1. Summary of Lawrence fish lift operations for the period of tagged fish movements (May 20 to July 15, 2025).**

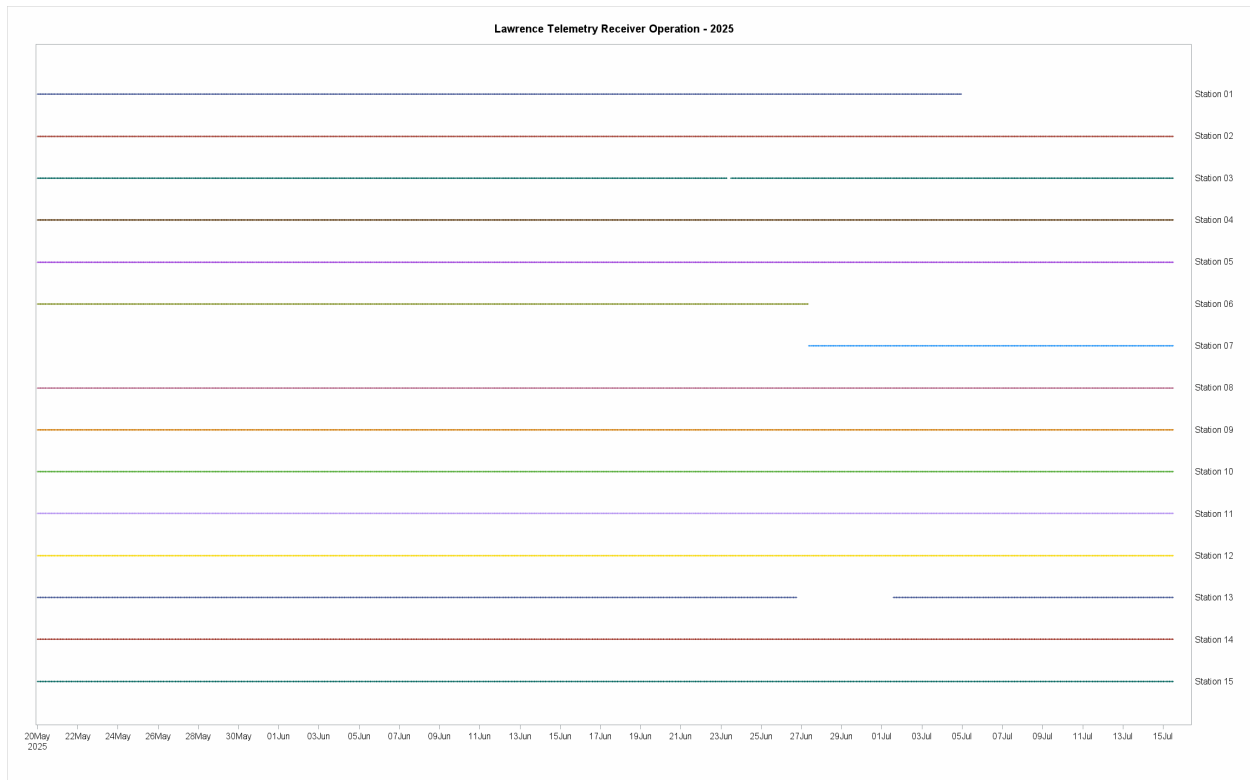
Date	No. Lifts	First Lift	Last Lift
5/20/2025	10	7:00	16:00
5/21/2025	10	7:00	16:00
5/22/2025	9	7:00	16:00
5/23/2025	11	7:00	16:00
5/24/2025	10	7:00	16:00
5/25/2025	10	7:00	16:00
5/26/2025	10	7:00	16:00
5/27/2025	10	7:00	16:00
5/28/2025	9	7:00	16:00
5/29/2025	10	7:00	16:00
5/30/2025	11	7:00	16:00
5/31/2025	9	8:00	16:00
6/1/2025	10	7:00	16:00
6/2/2025	9	7:00	16:00
6/3/2025	10	7:00	16:00
6/4/2025	10	7:00	16:00
6/5/2025	10	7:00	16:00
6/6/2025	10	7:00	16:00
6/7/2025	10	7:00	16:00
6/8/2025	10	7:00	16:00
6/9/2025	10	7:00	16:00
6/10/2025	10	7:00	16:00
6/11/2025	10	7:00	16:00
6/12/2025	8	7:00	16:00
6/13/2025	10	7:00	16:00
6/14/2025	10	7:00	16:00
6/15/2025	10	7:00	16:00
6/16/2025	10	7:00	16:00
6/17/2025	10	7:00	16:00
6/18/2025	9	7:00	15:00
6/19/2025	9	8:00	16:00
6/20/2025	4	7:00	10:00
6/21/2025	0		
6/22/2025	4	13:00	16:00
6/23/2025	10	7:00	16:00
6/24/2025	10	7:00	16:00
6/25/2025	10	7:00	16:00

Date	No. Lifts	First Lift	Last Lift
6/26/2025	10	7:00	16:00
6/27/2025	10	7:00	16:00
6/28/2025	10	7:00	16:00
6/29/2025	10	7:00	16:00
6/30/2025	10	7:00	16:00
7/1/2025	9	7:00	15:00
7/2/2025	9	7:00	15:00
7/3/2025	10	0:00	16:00
7/4/2025	10	7:00	16:00
7/5/2025	10	7:00	16:00
7/6/2025	10	7:00	16:00
7/7/2025	10	7:00	16:00
7/8/2025	10	7:00	16:00
7/9/2025	8	9:00	16:00
7/10/2025	9	7:00	16:00
7/11/2025	10	7:00	16:00
7/12/2025	10	7:00	16:00
7/13/2025	10	7:00	16:00
7/14/2025	9	7:00	16:00
7/15/2025	8	7:00	16:00

### 5.3 Monitoring Station Functionality

Figure 5–5 presents the coverage provided by each radio telemetry station installed as part of the detection array to evaluate American shad and sea lamprey at the Lawrence Project during 2025. Station coverage was determined by a combination of beacon transmitter detections and observations reported by field personnel conducting weekly receiver checks and data downloads. Most monitoring stations operated with no issues for the duration of the study (i.e., the date of first release [May 8] through the end of July). Inconsistencies included:

- Station 1 (Haverhill Riverside Park) – Offline from 0000 on July 5 through the end of the monitoring period. This receiver suffered a power supply failure. Due to its role as a redundant downstream station it was not replaced for the final two weeks of the study. Station 2 continued to function through the late portion of the study and detections from this location were not useful to inform passage effectiveness associated with the Lawrence fish lift.
- Station 3 (Lawrence Approach) – Offline from 0800 to 1100 on June 23 due to a severed coaxial cable occurring during landscape maintenance. Due to the short duration of this outage and continued operation of the remainder of the array at Lawrence, this period of non-operation is not assumed to have had any significant impact on assessing passage effectiveness of the fish lift.
- Station 5 (Lawrence Nearfield) – Offline from 0100 to 1100 on July 1. The power supply for this station required replacement. Due to the timing of this outage (early July) relative to observed fish movements associated with passage at the lift, this short outage is not assumed to have had any significant impact on assessing passage effectiveness of the fish lift.
- Station 6 (River Side Lift Entrance) – Offline from 0900 on June 27 through end of study as the river side entrance to the fish lift was closed based on tailwater elevation and the inability to maintain a three-foot submergence depth (i.e., gate prioritization protocols).
- Station 7 (Street Side Lift Entrance) – Offline from the initiation of monitoring on May 20 until 0900 on June 27 as the street side entrance to the fish lift was closed for the duration of time that the river side entrance was open and maintaining a three-foot submergence depth.
- Station 13 (Mid-Point Impoundment) – Offline from 1900 on June 26 to 1400 on July 1 due to a failed power supply. Based on the seasonal timing of this outage and operational status of the stationary receivers both upstream and downstream of this location, this period of non-operation is not assumed to have had any significant impact on assessing passage effectiveness of the fish lift.



**Figure 5-5. Coverage for stationary telemetry receivers installed for the evaluation of American shad and sea lamprey upstream passage at the Lawrence Project, 2025.**

## 5.4 Collection, Tagging, and Release

### 5.4.1 American Shad

A total of 404 American shad were radio tagged following collection via boat electrofishing in the section of the Merrimack River downstream of Essex Dam extending from just upstream of the confluence with the Spicket River to the Lawrence I-495 Bridge (approximately 1.0 to 1.4 miles downstream of Essex Dam; Table 5-2). American shad were collected and radio tagged on ten dates during the 24-day period from May 20 to June 13. The mean total length for tagged shad was 477 mm and the sex ratio of collected individuals was skewed towards male fish (69% of individuals).

American shad were initially observed in the Lawrence fish lift on May 1 with the mid-point of cumulative returns occurring on June 3 (Figure 5-6). Tagging and release of American shad downstream of Essex Dam took place on dates corresponding to the 10th–80th percentiles of the 2025 passage returns at the Lawrence lift.

### 5.4.2 Sea Lamprey

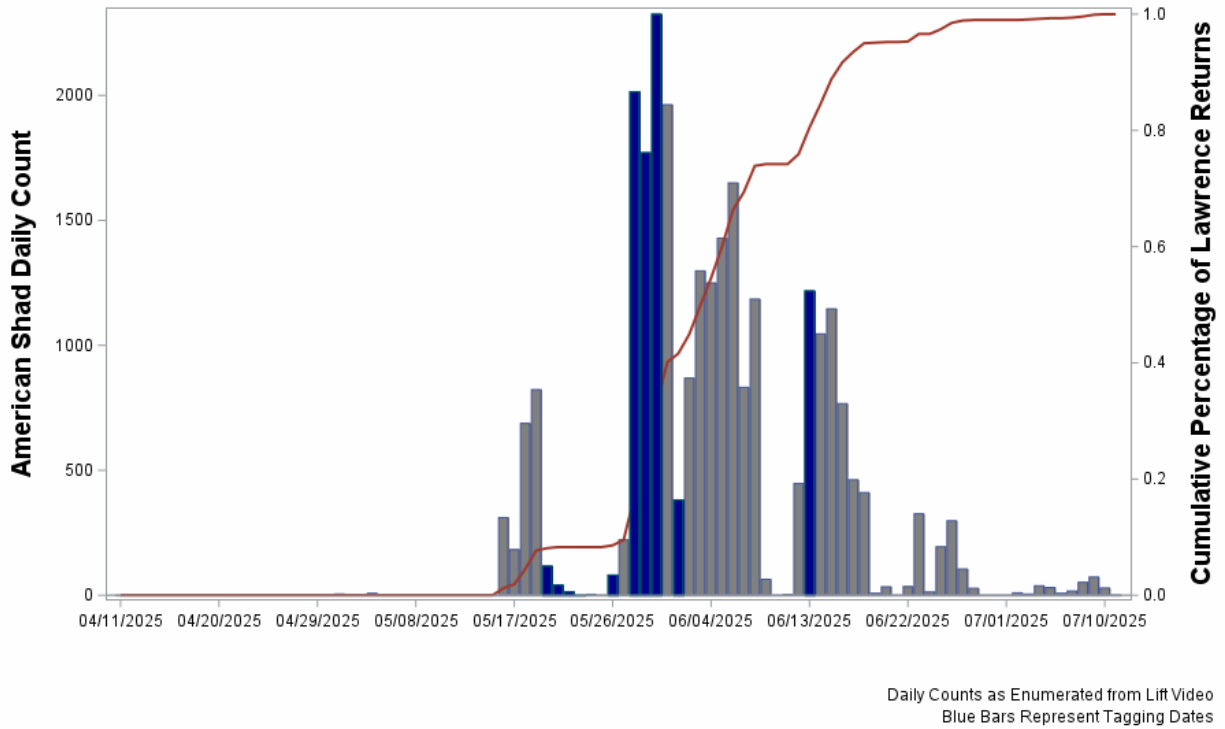
Sea lamprey were collected at the Lawrence fish lift over two dates (June 15 and June 17) and a total of 51 individuals were radio tagged prior to release into the Merrimack River near to the

Lawrence I-495 Bridge (approximately 1.4 miles downstream of Essex Dam; Table 5-3). Sea lamprey ranged in length from 612 to 808 mm (mean = 689) and most individuals tagged (75%) were male.

Sea lamprey were initially observed in the Lawrence fish lift on April 23 with the mid-point of cumulative returns occurring on June 1 (Figure 5-7). Tagging and release of sea lamprey took place on dates corresponding to the 88th–94th percentiles of the 2025 passage returns for that species at the Lawrence lift (i.e., late part of the run).

**Table 5-2. Summary of American shad tagged and released for evaluation of upstream passage at the Lawrence fish lift, 2025.**

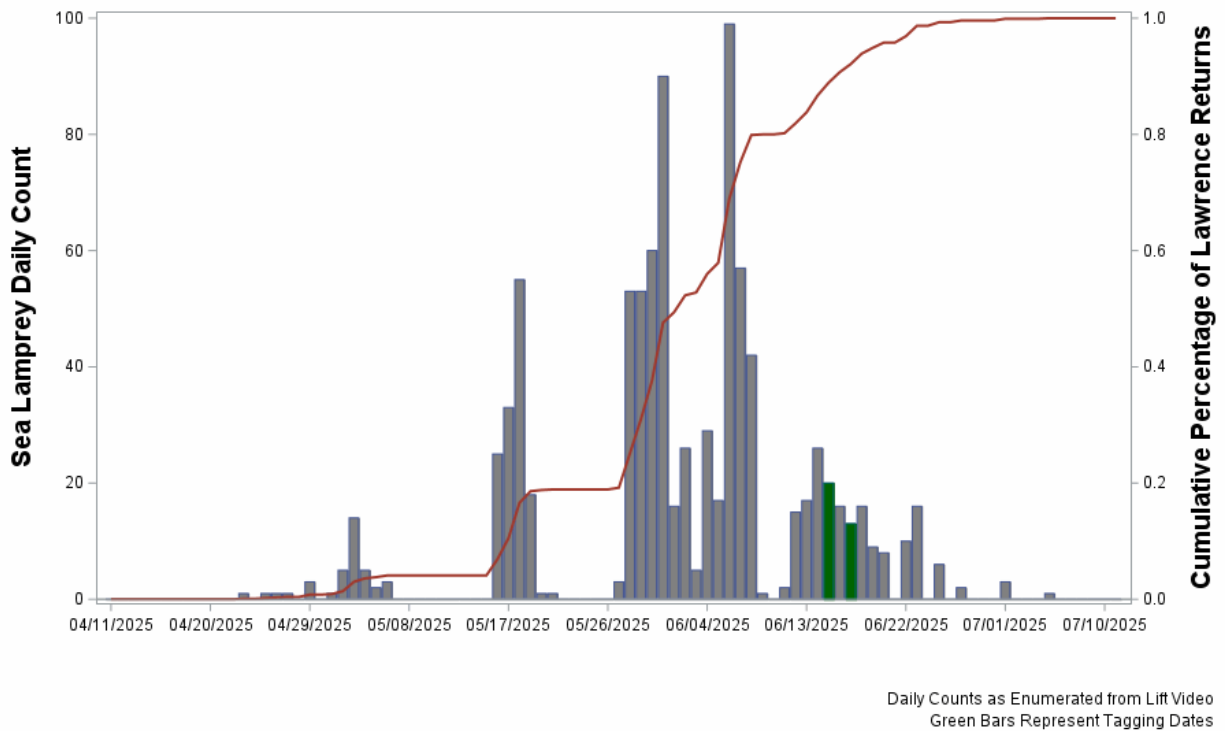
Release Date	No. Fish	Sex		Total Length (mm)		
		%M	%F	Min.	Max.	Mean
20-May	28	71%	29%	415	559	481
21-May	35	54%	46%	427	555	493
22-May	5	80%	20%	466	500	476
23-May	31	61%	39%	416	526	468
26-May	35	83%	17%	397	564	482
28-May	41	80%	20%	413	540	484
29-May	33	79%	21%	381	545	465
30-May	54	89%	11%	405	547	469
1-Jun	45	67%	33%	409	561	479
13-Jun	97	54%	46%	354	568	474
Total	404	69%	31%	354	568	477



**Figure 5-6. Daily count and cumulative percentage of American shad returns to the Lawrence fish lift for the 2025 passage season.**

**Table 5-3. Summary of sea lamprey tagged and released for evaluation of upstream passage at the Lawrence fish lift, 2025.**

Release Date	No. Fish	Sex		Total Length (mm)		
		%M	%F	Min.	Max.	Mean
15-Jun	26	73%	27%	626	808	694
17-Jun	25	76%	24%	612	757	684
Total	51	75%	25%	612	808	689



**Figure 5-7. Daily count and cumulative percentage of sea lamprey returns to the Lawrence fish lift for the 2025 passage season.**

## 5.5 Post-Release Movements

Radio tagged American shad and sea lamprey released into the Merrimack River downstream of Essex Dam were free to (1) move upstream and enter the monitored section of the Merrimack River immediately downstream of the Lawrence powerhouse, or (2) exit the monitored section of the Merrimack River and move downstream and away from the study area. Each radio tagged individual was classified into a unique post-release movement category based on their pattern of detections among the various monitoring stations. The possible classifications included:

- “Approach”: Individual moved upstream of the release location and was determined to have approached Lawrence (based on detection at Station 3).
- “Fallback”: Following release, detections for the individual were limited to Stations 2 and/or 1 located downstream from the release location.
- “No Information”: No valid detection information was recorded for these individuals at any of the receiver stations following release into the Merrimack River.

### 5.5.1 American Shad

Of the 404 American shad which were obtained by electrofishing and radio tagged prior to release in the Merrimack River approximately 1.0-1.4 miles downstream of Essex Dam, 13% (53 out of 404) were determined to have approached the Project (i.e., ascended upstream to the point approximately 200 m below the dam [i.e., Station 3]; Table 5-4). When examined by release group, approximately 10 to 13% of tagged shad approached the Project on most dates. The approach rate was highest on the final date of tagging (June 13) where 25% of tagged shad ascended upstream and were detected at Station 3 downstream of Essex Dam. Approximately 75% of tagged shad released downstream of Lawrence exhibited downstream movement and were subsequently detected at monitoring stations in the lower Merrimack River, 2.1 and 6.6 miles downstream of Essex Dam, respectively. For shad with a behavioral classification of “Fallback”, the median duration of time from release until detection at Station 1 (6.6 miles downstream of Essex Dam) was 42.4 hours (Interquartile Range [IQR] = 10.1 to 173.5 hours; Table 5-5). A total of 50 tagged shad were classified as “No Information” and went undetected at all stationary receivers. These individuals may have been predated, regurgitated their transmitters, or succumbed to tagging and handling at locations away from stationary receiver coverage. Individuals classified as “Fallback” or “No Information” did not contribute to the evaluation of the effectiveness of the existing Lawrence fish lift for American shad. As a result, the effectiveness assessment presented in this report is based on the subset of 53 individuals which did approach the Project.

**Table 5-4. Summary of post-release movements for radio tagged American shad released downstream of Lawrence, 2025.**

Release Date	No. Fish	Behavior		
		Approach	Fallback	No Information
20-May	28	3	15	10
21-May	35	4	25	6
22-May	5	1	1	3
23-May	31	2	26	3
26-May	35	1	32	2
28-May	41	4	33	4
29-May	33	3	28	2
30-May	54	7	40	7
1-Jun	45	4	34	7
13-Jun	97	24	67	6
Total	404	53	301	50
Percentage of Total		13.1%	74.5%	12.4%

**Table 5-5. Minimum, 25th percentile, median, 75th percentile, and maximum values for fallback duration by release date for American shad which moved downstream following release at Lawrence, 2025.**

Release Date	Fallback Duration (hours)				
	Min	Q25	Median	Q75	Max
20-May	7.1	7.9	61.6	438.3	558.4
21-May	7.3	31.8	74.6	276.5	744.0
22-May	11.5	11.5	11.5	11.5	11.5
23-May	5.2	8.9	10.5	14.3	397.3
26-May	2.3	8.9	11.2	175.0	636.6
28-May	4.0	8.9	57.1	135.8	610.9
29-May	4.4	7.1	9.8	71.1	417.9
30-May	8.2	53.3	58.6	220.3	825.9
1-Jun	3.6	5.7	9.5	53.3	553.5
13-Jun	8.1	30.8	82.5	228.0	445.9
Total	2.3	10.1	42.4	173.5	825.9

### 5.5.2 Sea Lamprey

Of the 51 sea lamprey collected at the Lawrence fish lift, radio tagged and released into the Merrimack River approximately 1.4 miles downstream of Essex Dam, 71% (36 out of 51) were determined to have approached the Project (i.e., ascended upstream to the point approximately 200 m below the dam; Table 5-6). Approximately 25% of tagged lamprey released downstream of Lawrence moved downstream and were subsequently detected at one or two of the monitoring stations in the lower Merrimack River. Of the thirteen tagged lamprey classified as “Fallback”, all individuals were detected at Station 2 and eight of the thirteen individuals were detected at Station 1 (6.6 miles downstream of Essex Dam). For those individuals, the median duration of time from release until detection at Station 1 was 80.5 hours (IQR = 7.6 to 227.7 hours; Table 5-7). Only two tagged lamprey were classified as “No Information” and went undetected at all stationary receivers. Individuals classified as “Fallback” or “No Information” did not contribute to the evaluation of the effectiveness of the existing Lawrence fish lift for sea lamprey. As a result, the effectiveness assessment presented in this report is based on the subset of 36 individuals which did approach the Project.

**Table 5-6. Summary of post-release movements for radio tagged Sea lamprey released downstream of Lawrence, 2025.**

Release Date	No. Fish	Behavior		
		Approach	Fallback	No Information
15-Jun	26	16	8	2
17-Jun	25	20	5	.
Total	51	36	13	2
Percentage of Total		70.6%	25.5%	3.9%

**Table 5-7. Minimum, 25th percentile, median, 75th percentile, and maximum values for fallback duration by release date for Sea lamprey which moved downstream following release at Lawrence, 2025.**

Release Date	Fallback Duration (hours)				
	Min	Q25	Median	Q75	Max
15-Jun	1.9	7.5	151.0	211.9	243.6
17-Jun	7.8	7.8	10.1	252.1	252.1
Total	1.9	7.6	80.5	227.7	252.1

## 5.6 Upstream Passage Effectiveness

Receiver coverage at Lawrence during 2025 allowed for evaluation of:

- Arrival timing for radio tagged shad and lamprey which moved upstream and entered the Project area (i.e., the reach approximately 200 m downstream of the powerhouse).
- Detailed detection information on tagged shad and lamprey as they:
  - Approached the downstream side of the powerhouse and entered into the nearfield attraction water immediately downstream of the lift entrances.
  - Entered the lower entrance flume via either the primary (river side) or secondary (street side) entrance gates.
  - Passed successfully via the fish lift hopper into the upper exit flume.
  - Departed the upper exit flume and Project forebay followed by entry into and passage through the Project impoundment.

### 5.6.1 American Shad Approach and Residence

A total of 53 radio tagged American shad moved upstream from their initial tag and release location and were determined to have approached the Project based on their detection at the point approximately 200 m downstream of Essex Dam. Approach events for tagged shad occurred over a range of dates from May 23 through June 23 with relative peaks in abundance occurring on June 9 and 19 (Figure 5-8). Initial detections of tagged shad approaching the Project occurred under a range of discharge conditions between 6,798 cfs to 26,214 cfs (mean = 13,953 cfs). Nearly all the initial approach detections for tagged shad at Lawrence occurred during the daylight hours (~0500 to 20:00; Figure 5-9).

Approach duration was calculated as the length of time to move from the release location upstream to the section of the Merrimack River approximately 200 m downstream of Essex Dam. The median approach duration was 189.5 hours (7.9 days; IQR = 122.0 to 266.2 hours; Table 5-8).

The median duration of time at large following the arrival for each radio tagged individual at the Project was 52.6 hours (2.2 days; IQR = 4.3 to 174.5 hours; Table 5-9). For an individual shad, the calculated value for time at large represents the duration from the initial detection at Station 3

until either (1) upstream passage out of the study area via the fish lift, or (2) movement downstream and away from Essex Dam area as determined by the final detection at Station 3. When examined by passage fate (i.e., successful or unsuccessful), the median duration of time at large for shad prior to passing upstream via the fish lift was 83.0 hours (3.5 days), whereas it was 42.6 hours (1.8 days) for radio tagged American shad that approached Lawrence but did not pass upstream of Essex Dam.

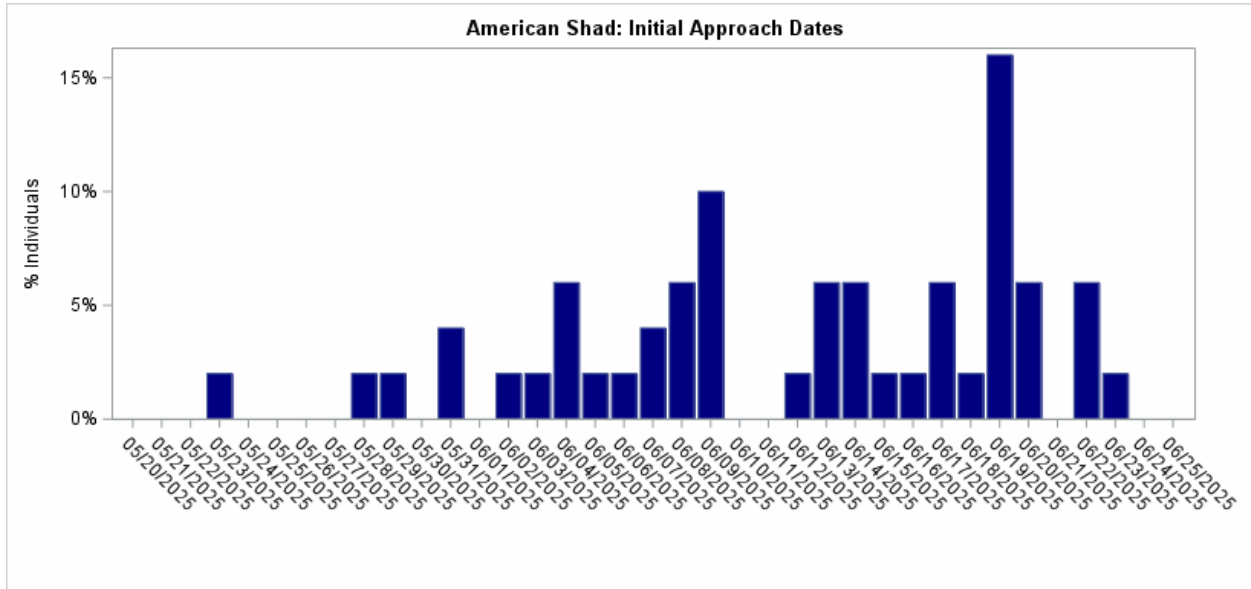


Figure 5-8. Approach timing (i.e., date of initial detection) for radio tagged American shad immediately downstream of the Essex Dam during spring 2025.

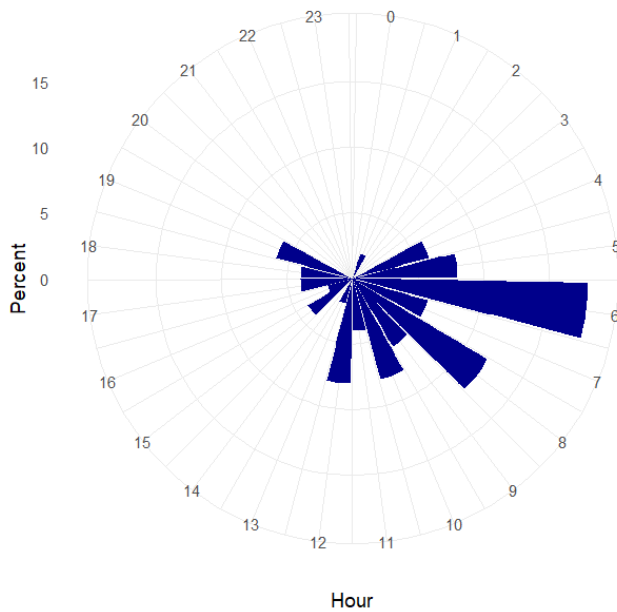


Figure 5-9. Approach timing (i.e., hour of initial detection) for radio tagged American shad immediately downstream of the Essex Dam during spring 2025.

**Table 5-8. Minimum, 25th percentile, median, 75th percentile, and maximum values for approach duration by release date for American shad which moved upstream following release at Lawrence, 2025.**

Release Date	Approach Duration (hours)				
	Min	Q25	Median	Q75	Max
20-May	259.1	259.1	376.4	476.0	476.0
21-May	195.5	215.7	270.8	535.9	766.0
22-May	358.6	358.6	358.6	358.6	358.6
23-May	2.4	2.4	142.5	282.6	282.6
26-May	214.0	214.0	214.0	214.0	214.0
28-May	2.3	62.1	204.6	409.2	531.2
29-May	224.8	224.8	236.5	266.2	266.2
30-May	126.4	183.5	217.6	333.6	472.7
1-Jun	181.4	219.3	266.9	385.7	494.9
13-Jun	2.8	71.7	140.6	153.2	234.5
Total	2.3	122.0	189.5	266.2	766.0

**Table 5-9. Minimum, 25th percentile, median, 75th percentile, and maximum values for time at large duration by release date and passage fate for American shad which moved upstream following release at Lawrence, 2025.**

Release Date	Time at Large Duration (hours)				
	Min	Q25	Median	Q75	Max
20-May	3.0	3.0	4.3	198.1	198.1
21-May	0.6	2.3	124.0	279.6	315.3
22-May	294.1	294.1	294.1	294.1	294.1
23-May	64.1	64.1	260.8	457.6	457.6
26-May	50.0	50.0	50.0	50.0	50.0
28-May	0.3	29.5	118.3	209.8	241.5
29-May	0.6	0.6	5.8	25.0	25.0
30-May	0.4	1.8	21.5	35.2	87.5
1-Jun	<0.1	42.0	127.5	206.8	242.5
13-Jun	0.2	11.0	61.9	127.7	518.6
Total	<0.1	4.3	52.6	174.5	518.6
Passage Fate	Time at Large Duration (hours)				
	Min	Q25	Median	Q75	Max
Unsuccessful	<0.1	4.1	42.6	174.5	518.6
Successful	4.3	41.4	83.0	201.4	315.3
Total	<0.1	4.3	52.6	174.5	518.6

### **Fish Lift Forays**

The full time series of recorded detections for each radio tagged American shad was reviewed and behavioral interactions with the Lawrence fish lift were categorized based on detections at Stations 5 through 9. A total number of passage attempts were quantified for each individual, and the extent of upstream progress for each passage attempt was determined relative to the fixed telemetry receiver stations positioned within the Lawrence fish lift.

Of the 53 radio tagged American shad that were determined to have moved upriver and in the direction of the Essex Dam, 37% (35 out of 53) were observed within the detection field of Station 5, which was calibrated to detect radio tagged fish approaching within ~25 feet of the fish lift entrances. Of those individuals, twelve were subsequently determined to have made at least one upstream passage attempt based on detection at one of the two lift entrances (Station 6 or 7) and five of those individuals (42%; 5 out of 12) successfully passed upstream. For the twelve individuals that entered the Lawrence fish lift, the median number of passage attempts per individual was two and the maximum number of observed passage attempts ranged up to four for a single fish. In all instances, upstream passage attempts at the Lawrence lift were initiated by entry of an individual shad through the river side entrance gate.

The median duration of time for shad to locate the nearfield attraction flow associated with the Lawrence fish lift was 6.6 hours (IQR = 1.3 to 20.3 hours; Table 5-10). Following detection in the nearfield attraction flow, tagged shad were determined to have moved quickly through the entrance gate, doing so in a median duration of 0.01 hours (IQR = <0.01 to 0.03 hours; Table 5-10).

A total of 26 passage attempts were identified for radio tagged shad at the Lawrence fish lift, and each was initiated via movement from the nearfield region (Station 5) to the river side fish lift entrance (Station 6). Table 5-11 summarizes the extent of upstream progress for the full set of fish lift passage attempts observed among radio tagged shad, including those that did and did not result in successful upstream passage. When evaluated moving from downstream to upstream (i.e., from the fishway entrance to the hopper and upstream exit flume), approximately 40% of passage attempts reached the lift hopper (Station 8). Approximately 45% of foray attempts that reached the hopper resulted in a subsequent detection for that individual shad from the upper exit flume (Station 9).

The duration of each passage attempt (or foray) was calculated as either the time from initial detection at the entrance receiver (Station 6) until detection in the upper exit flume (Station 9) for shad successfully passing upstream, or until a subsequent detection was made in the nearfield receiver detection zone (Station 5) for tagged shad failing to pass upstream. When all upstream shad passage attempts at the Lawrence fish lift are considered, the median duration was <0.1 hours (IQR = <0.1 to 0.4 hours; Table 5-12). The median duration for successful upstream passage attempts was 0.7 hours with most of those attempts ranging in duration between 0.6 to 1.0 hours (i.e., IQR).

Figure 5–10 presents the temporal distribution for the onset of all passage attempts for radio tagged shad at the Lawrence fish lift during the 2025 study. Upstream passage attempts for tagged shad were recorded on dates ranging from June 5 through July 4. These dates coincided with the later seasonal peaks in American shad numbers passed at the Lawrence fish lift during 2025 (Figure 5–6). All fish lift passage attempt initiations were observed during the daylight hours with most events (including all of those resulting in successful upstream passage) taking place during the morning (Figure 5–11). Successful passage attempts occurred under a mean total project discharge condition of 9,924 cfs (4,767 cfs turbine; 3,962 cfs spill). Unsuccessful passage attempts were associated with a mean total project discharge condition of 10,099 cfs (5,280 cfs turbine; 4,358 cfs spill).

**Table 5-10. Minimum, 25th percentile, median, 75th percentile, and maximum values for movement duration for American shad which moved upstream following release at Lawrence, 2025.**

Movement	Movement Durations (hours)				
	Min	Q25	Median	Q75	Max
Approach to Nearfield	0.4	1.3	6.6	20.3	196.7
Nearfield to Lift Enter	<0.01	<0.01	0.01	0.03	0.16

**Table 5-11. Percentages of radio tagged American shad foray attempts at the Lawrence fish lift during spring 2025 reaching each upstream station relative to the total number of attempts and the previous steps number of attempts.**

Lawrence Lift	Entrance	Hopper	Upper Flume
	Station 6/7	Station 8	Station 9
No. of Forays Reaching	26	11	5
% of All Forays Reaching	-	42%	19%
% of Forays from Prior Step	-	42%	45%

**Table 5-12. Minimum, 25th percentile, median, 75th percentile, and maximum values for foray duration by passage fate for American shad which moved upstream following release at Lawrence, 2025.**

Passage Fate	Foray Duration (hours)				
	Min	Q25	Median	Q75	Max
Unsuccessful	<0.1	<0.1	<0.1	0.4	31.2
Successful	0.4	0.6	0.7	1.0	3.2
Total	<0.1	<0.1	<0.1	0.7	31.2

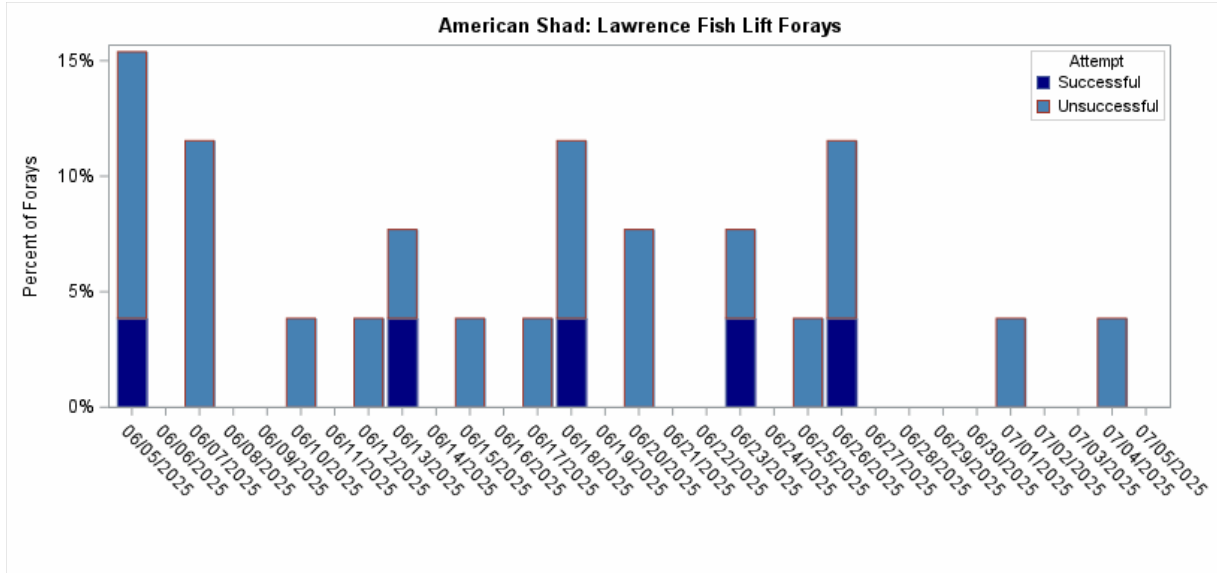


Figure 5-10. Lift entry timing (i.e., date of attempted passage event) for radio tagged American shad immediately downstream of the Essex Dam during spring 2025.

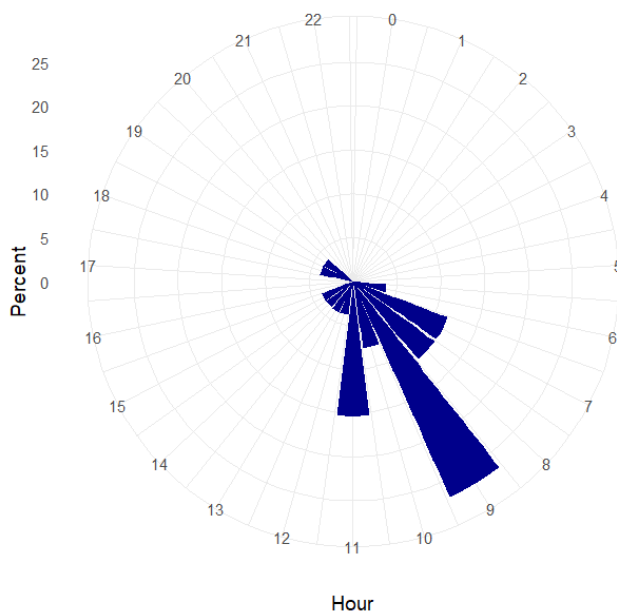


Figure 5-11. Lift entry timing (i.e., hour of attempted passage event) for radio tagged American shad immediately downstream of the Essex Dam during spring 2025.

**Upstream Passage Performance**

A CJS model was developed to assess upstream passage effectiveness of American shad at the Lawrence Project. The encounter histories input into Program MARK to inform this model are included in Appendix A. The CJS model  $\Phi(t)p(t)$  provided the best fit for the observed mark-recapture data representing shad passage at Lawrence, indicating that estimates of passage success

and detection efficiency varied among stations (Table 5-13). Table 5–14 summarizes the stepwise probabilities of success as fish moved upstream from the detection field of the approach receiver (Station 03) to the point upstream at the upstream extent of the Project impoundment (Station 14). Detection probabilities for receiver stations associated with the passage assessment at Lawrence are presented in Table 5–15).

Using the derived parameter values, the estimates of nearfield attraction, fish passage entrance efficiency, and overall fish passage efficiency for American shad at the Lawrence fish lift were estimated as follows:

- Nearfield Attraction: 100.0%
- Entrance Efficiency: 34.3% (95% CI = 20.6-51.2%)
- Overall Passage Efficiency: 9.4% (95% CI = 2.1–18.0%)

Of the five radio tagged shad which successfully passed upstream via the Lawrence fish lift, there were no observed instances of immediate entrainment and discharge back downstream and all individuals successfully passed upstream through the Project impoundment.

**Table 5–13. CJS model selection criteria for the 2025 upstream movement of tagged American shad released downstream of Essex Dam at Lawrence**

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
$\Phi(t) p(t)$	506.86	0.00	1.00	1.00	10	17.56
$\Phi(t) p(.)$	546.00	39.14	0.00	0.00	7	62.89
$\Phi(.) p(t)$	702.28	195.42	0.00	0.00	6	221.22
$\Phi(.) p(.)$	753.35	246.49	0.00	0.00	2	280.43

**Table 5–14. Reach-specific survival probability estimates ( $\Phi$ ), standard errors and 95% confidence intervals for radio tagged American shad released downstream of Essex Dam, 2025**

Station Reach	$\Phi$	SE	95% CI	
Approach to Lower Tailrace	0.660	0.065	0.524	0.774
Lower Tailrace to Nearfield	1.000	-	-	-
Nearfield to Lift Entrance	0.343	0.080	0.206	0.512
Lift Entrance to Lift Hopper	0.667	0.136	0.376	0.869
Lift Hopper to Hopper Exit	0.625	0.171	0.285	0.875
Hopper Exit to Upper Lift Flume Exit	1.000	-	-	-
Upper Lift Flume Exit to Power Canal Exit	1.000	-	-	-
Power Canal Exit to Mid-Impoundment	1.000	-	-	-
Mid-Impoundment to Upper Impoundment	1.000	-	-	-

**Table 5–15. Detection probability estimates ( $p$ ), standard errors and 95% confidence intervals for radio tagged American shad released downstream of Essex Dam, 2025**

Monitoring Station	$P$	SE	95% CI	
<i>Station 3 (Approach)</i>	1.000	-	-	-
<i>Station 4 (Tailrace)</i>	1.000	-	-	-
<i>Station 5 (Nearfield)</i>	1.000	-	-	-
<i>Station 6 (Lift Entrance)</i>	1.000	-	-	-
<i>Station 8 (Hopper)</i>	1.000	-	-	-
<i>Station 9 (Hopper Exit)</i>	0.400	0.219	0.100	0.800
<i>Station 10 (Upper Flume Exit)</i>	0.600	0.219	0.200	0.900
<i>Station 12 (Power Canal Exit)</i>	0.600	0.219	0.200	0.900
<i>Station 13 (Mid-Impoundment)</i>	0.400	0.219	0.100	0.800
<i>Station 14 (Upper Impoundment)</i>	1.000	-	-	-

## 5.6.2 Sea Lamprey

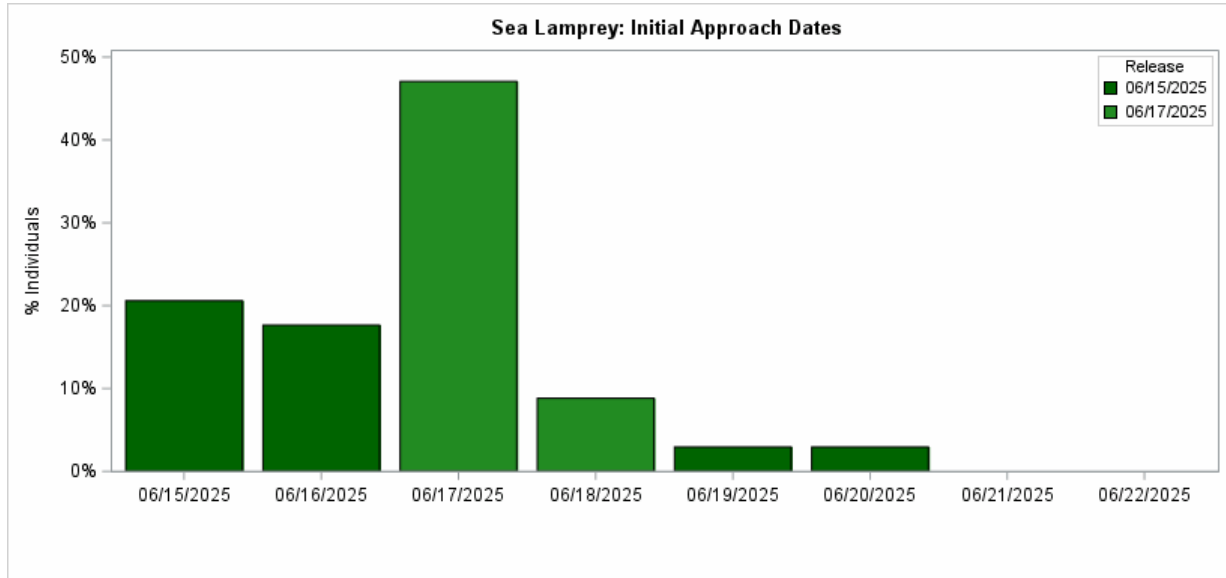
### Approach and Residence

A total of 36 radio tagged sea lamprey moved upstream from their initial tag and release location and were determined to have approached the Project based on their detection at the point approximately 200 m downstream of Essex Dam. Approach events for tagged lamprey occurred over a short span of dates (June 15 to June 20) and near to the dates of release downstream of Lawrence (i.e., June 15 and 17; Figure 5-12). Initial detections of tagged sea lamprey approaching the Project occurred under discharge conditions between 7,844 cfs to 8,496 cfs (mean = 8,486 cfs). Nearly all the initial approach detections for radio tagged sea lamprey at Lawrence occurred during the late afternoon or nighttime hours (~1600 to 0300; Figure 5–13).

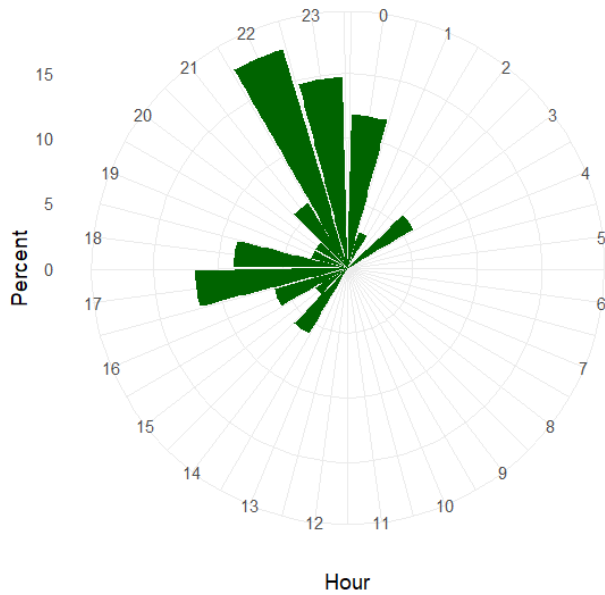
Approach duration was calculated as the length of time to move from the release location upstream to the section of the Merrimack River approximately 200 m downstream of Essex Dam. Tagged sea lamprey approaching Lawrence from the release site did so quickly. The median approach duration for tagged sea lamprey to ascend from the release location at the Lawrence I-495 Bridge to the Project area was 6.8 hours (IQR = 2.8 to 11.6 hours; Table 5–16).

The median duration of time at large following the arrival for all radio tagged sea lamprey at the Project was 72.9 hours (3.0 days; IQR = 52.5 to 118.9 hours; Table 5–17). On an individual basis, the calculated value for time at large represents the duration from the initial detection at Station 3 until either (1) upstream passage out of the study area via the fish lift, or (2) movement downstream and away from Essex Dam area as determined by the final detection at Station 3. Of the radio tagged sea lamprey determined to have approached Lawrence, only one individual successfully passed upstream via the fish lift, doing so in 15.9 hours after initial detection. Radio tagged sea lamprey which successfully approached the Project but did not successfully pass upstream via the

lift were present in the downstream region for a median duration of 74.9 hours (IQR = 52.6 to 118.9 hours; Table 5-17).



**Figure 5-12. Approach timing (i.e., date of initial detection) for radio tagged sea lamprey immediately downstream of the Essex Dam during spring 2025.**



**Figure 5-13. Approach timing (i.e., hour of initial detection) for radio tagged sea lamprey immediately downstream of the Essex Dam during spring 2025.**

**Table 5-16. Minimum, 25th percentile, median, 75th percentile, and maximum values for approach duration by release date for sea lamprey which moved upstream following release at Lawrence, 2025.**

Release Date	Approach Duration (hours)				
	Min	Q25	Median	Q75	Max
15-Jun	2.4	6.9	9.4	32.0	105.2
17-Jun	1.4	2.3	3.4	8.1	12.7
Total	1.4	2.8	6.8	11.6	105.2

**Table 5-17. Minimum, 25th percentile, median, 75th percentile, and maximum values for time at large duration by release date and passage fate for sea lamprey which moved upstream following release at Lawrence, 2025.**

Release Date	Time at Large Duration (hours)				
	Min	Q25	Median	Q75	Max
15-Jun	3.2	39.9	70.9	118.4	207.6
17-Jun	14.9	52.5	74.9	124.3	192.3
Total	3.2	52.5	72.9	118.9	207.6
Passage Fate	Time at Large Duration (hours)				
	Min	Q25	Median	Q75	Max
Unsuccessful	3.2	52.6	74.9	118.9	207.6
Successful	15.9	15.9	15.9	15.9	15.9
Total	3.2	52.5	72.9	118.9	207.6

### **Fish Lift Forays**

The full time series of recorded detections for each radio tagged sea lamprey was reviewed and behavioral interactions with the Lawrence fish lift were categorized based on detections at Stations 5 through 9. A total number of passage attempts were quantified for each individual, and the extent of upstream progress for each passage attempt was determined relative to the fixed telemetry receiver stations positioned within the Lawrence fish lift.

Of the 36 radio tagged sea lamprey determined to have moved upriver and in the direction of the Essex Dam, 97% (35 out of 36) were observed within the detection field of Station 5, which was calibrated to detect radio tagged fish approaching within ~25 feet of the fish lift entrances. Of those individuals, 28 were subsequently determined to have made at least one upstream passage attempt based on detection at one of the two lift entrances (Station 6 or 7) and one of those individuals (4%; 1 out of 28) successfully passed upstream. For the 28 individuals that entered the Lawrence fish lift, the median number of passage attempts per individual was two and the maximum number of observed passage attempts ranged up to nine for a single fish. In all instances, sea lamprey upstream passage attempts at the Lawrence fish lift were initiated by the entry of an individual through the primary (river side) entrance gate.

The median duration of time for tagged sea lamprey to locate the nearfield attraction flow region associated with the Lawrence fish lift entrances was 0.8 hours (IQR = 0.6 to 1.4 hours; Table 5-18). Following arrival in the nearfield attraction flow region, radio tagged sea lamprey moved quickly through the entrance gate, doing so in a median duration of 0.04 hours (IQR = 0.01 to 0.1 hours; Table 5-18).

A total of 62 passage attempts were identified for radio tagged sea lamprey at the Lawrence fish lift, and each was initiated via movement from the nearfield region (Station 5) to the river side fish lift entrance (Station 6). Table 5–19 summarizes the extent of upstream progress for the full set of lamprey passage attempts, including those that did and did not result in successful upstream passage. When evaluated moving from downstream to upstream (i.e., from the fishway entrance to the hopper and upstream exit flume), approximately 55% of passage attempts reached the lift hopper (Station 8). However, only 3% of foray attempts that reached the hopper resulted in a subsequent detection for that individual sea lamprey from the upper exit flume (Station 9).

The duration of each passage attempt (or foray) was calculated as the time from initial detection at the entrance receiver (Station 6) until a subsequent detection was made in the nearfield receiver detection zone (Station 5) for sea lamprey failing to pass upstream. When all unsuccessful sea lamprey passage attempts at the Lawrence fish lift are considered, the median duration was 0.6 hours (IQR = <0.1 to 4.6 hours; Table 5–20). The single tagged sea lamprey which successfully ascended upstream via the Lawrence fish lift was present within the lower entrance flume for 1.6 hours prior to passage.

Figure 5–14 presents the temporal distribution for the onset of all passage attempts for radio tagged sea lamprey at the Lawrence fish lift during the 2025 study and attempts were documented between the dates of June 15 (i.e., the first release date for tagged sea lamprey) and June 24 (i.e., very near to the end of the seasonal run for lamprey as recorded at the Lawrence fish lift – see Figure 5-7). Greater than 70% of fish lift passage attempt initiations for sea lamprey took place during the late evening and overnight hours (1800 to 0100 (Figure 5-15). Sea lamprey passage attempts occurred under a mean total project discharge condition of 8,604 cfs (6,382 cfs turbine; 1,761 cfs spill).

**Table 5-18. Minimum, 25th percentile, median, 75th percentile, and maximum values for movement duration for sea lamprey which moved upstream following release at Lawrence, 2025.**

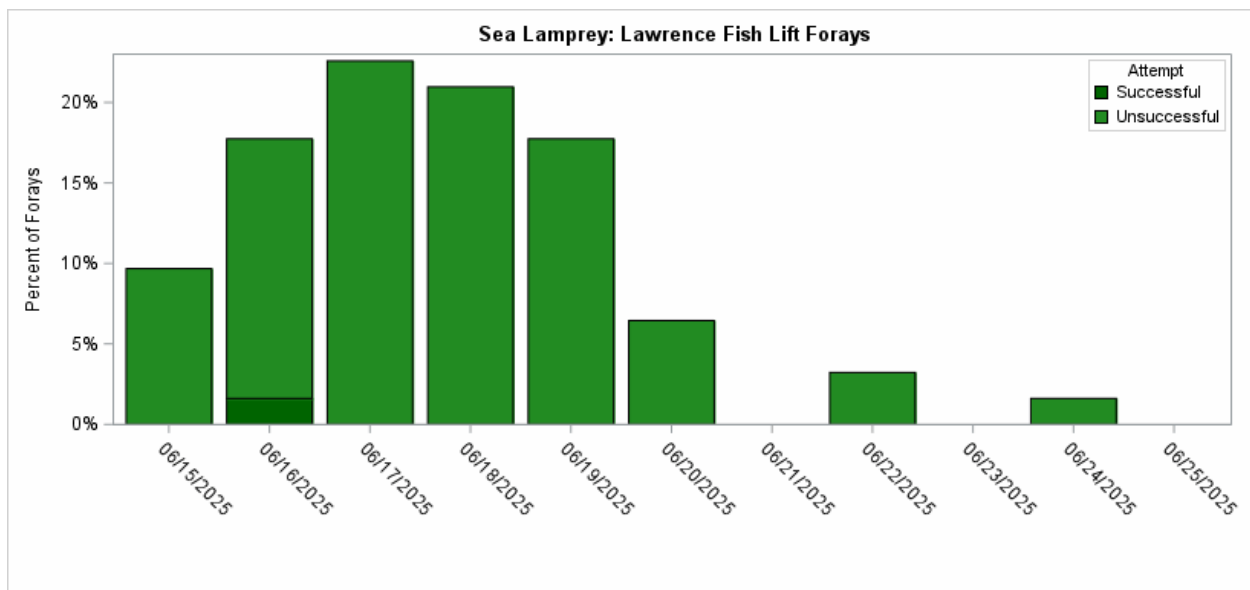
Movement	Movement Durations (hours)				
	Min	Q25	Median	Q75	Max
Approach to Nearfield	0.4	0.6	0.8	1.4	20.6
Nearfield to Lift Enter	<0.01	0.01	0.04	0.1	24.0

**Table 5-19. Percentages of radio tagged sea lamprey foray attempts at the Lawrence fish lift during spring 2025 reaching each upstream station relative to the total number of attempts and the previous steps number of attempts.**

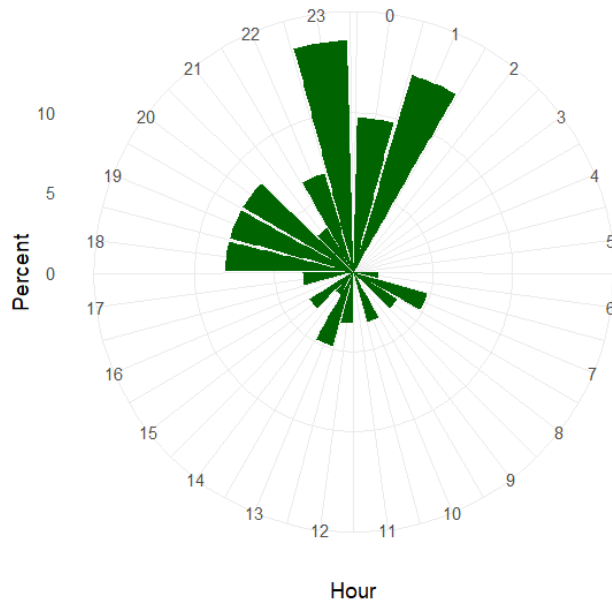
Lawrence Lift	Entrance	Hopper	Upper Flume
	Station 6/7	Station 8	Station 9
No. of Forays Reaching	62	34	1
% of All Forays Reaching	-	55%	2%
% of Forays from Prior Step	-	55%	3%

**Table 5-20. Minimum, 25th percentile, median, 75th percentile, and maximum values for foray duration by passage fate for sea lamprey which moved upstream following release at Lawrence, 2025.**

Passage Fate	Foray Duration (hours)				
	Min	Q25	Median	Q75	Max
Unsuccessful	<0.1	<0.1	0.6	4.6	43.7
Successful	1.6	1.6	1.6	1.6	1.6
Total	<0.1	<0.1	0.6	4.6	43.7



**Figure 5-14. Lift entry timing (i.e., date of attempted passage event) for radio tagged sea lamprey immediately downstream of the Essex Dam during spring 2025.**



**Figure 5-15. Lift entry timing (i.e., hour of attempted passage event) for radio tagged sea lamprey immediately downstream of the Essex Dam during spring 2025.**

### **Upstream Passage Performance**

A CJS model was developed to assess upstream passage effectiveness for sea lamprey at the Lawrence Project. The encounter histories input into Program MARK to inform this model are included in Appendix A. The CJS model  $\Phi(t)p(t)$  provided the best fit for the observed mark-recapture data representing lamprey passage at Lawrence, indicating that estimates of passage success and detection efficiency varied among stations (Table 5-21). Table 5-22 summarizes the stepwise probabilities of success as fish moved upstream from the detection field of the approach receiver (Station 03) to the point upstream at the upstream extent of the Project impoundment (Station 14). Detection probabilities for receiver stations associated with the passage assessment at Lawrence are presented in Table 5-23).

Using the derived parameter values, the estimates of nearfield attraction, fish passage entrance efficiency, and overall fish passage efficiency for sea lamprey at the Lawrence fish lift were estimated as follows:

- Nearfield Attraction: 100.0%
- Entrance Efficiency: 80% (95% CI = 63.6-90.2%)
- Overall Passage Efficiency: 2.8% (95% CI = 0.1-9.4%)

For the single radio tagged sea lamprey which successfully passed upstream via the Lawrence fish lift, there was no observed instance of immediate entrainment and discharge back downstream and that individual successfully passed upstream through the Project impoundment

**Table 5–21. CJS model selection criteria for the 2025 upstream movement of tagged sea lamprey released downstream of Essex Dam at Lawrence**

Model	AICc	Delta AICc	AICc Weight	Model Likelihood	No. Parameters	Deviance
<i>Phi(t) p(t)</i>	506.86	0.00	1.00	1.00	10	17.56
<i>Phi(t) p(.)</i>	546.00	39.14	0.00	0.00	7	62.89
<i>Phi(.) p(t)</i>	702.28	195.42	0.00	0.00	6	221.22
<i>Phi(.) p(.)</i>	753.35	246.49	0.00	0.00	2	280.43

**Table 5–22. Reach-specific survival probability estimates (*Phi*), standard errors and 95% confidence intervals for radio tagged sea lamprey released downstream of Essex Dam, 2025**

Station Reach	<i>Phi</i>	SE	95% CI	
<i>Approach to Lower Tailrace</i>	0.660	0.065	0.524	0.774
<i>Lower Tailrace to Nearfield</i>	1.000	-	-	-
<i>Nearfield to Lift Entrance</i>	0.343	0.080	0.206	0.512
<i>Lift Entrance to Lift Hopper</i>	0.667	0.136	0.376	0.869
<i>Lift Hopper to Hopper Exit</i>	0.625	0.171	0.285	0.875
<i>Hopper Exit to Upper Lift Flume Exit</i>	1.000	-	-	-
<i>Upper Lift Flume Exit to Power Canal Exit</i>	1.000	-	-	-
<i>Power Canal Exit to Mid-Impoundment</i>	1.000	-	-	-
<i>Mid-Impoundment to Upper Impoundment</i>	1.000	-	-	-

**Table 5–23. Detection probability estimates (*p*), standard errors and 95% confidence intervals for radio tagged sea lamprey released downstream of Essex Dam, 2025**

Monitoring Station	<i>P</i>	SE	95% CI	
<i>Station 3 (Approach)</i>	1.000	-	-	-
<i>Station 4 (Tailrace)</i>	1.000	-	-	-
<i>Station 5 (Nearfield)</i>	1.000	-	-	-
<i>Station 6 (Lift Entrance)</i>	1.000	-	-	-
<i>Station 8 (Hopper)</i>	1.000	-	-	-
<i>Station 9 (Hopper Exit)</i>	0.400	0.219	0.100	0.800
<i>Station 10 (Upper Flume Exit)</i>	0.600	0.219	0.200	0.900
<i>Station 12 (Power Canal Exit)</i>	0.600	0.219	0.200	0.900
<i>Station 13 (Mid-Impoundment)</i>	0.400	0.219	0.100	0.800
<i>Station 14 (Upper Impoundment)</i>	1.000	-	-	-

## 6 Summary

As outlined in their April 10, 2024 RSP and approved with modification by FERC in their May 10, 2024 SPD, Essex conducted the Upstream Anadromous Fish Passage Assessment during the 2025 spring diadromous fish passage season at Lawrence. A total of 404 American shad and 51 sea lamprey were radio tagged and released within the section of the Merrimack River downstream of Essex Dam extending from just upstream of the confluence with the Spicket River to the Lawrence I-495 Bridge (approximately 1.0 to 1.4 miles downstream of Essex Dam). Collection efforts varied by species with American shad collected from the Merrimack River via boat electrofish sampling and sea lamprey obtained from the Lawrence fish lift. Releases of tagged fish took place over a range of dates: between May 20 and June 13 for American shad and on June 15 and 17 for sea lamprey. Movements of tagged fish were monitored via a series of telemetry receivers installed both at the Essex Dam and Lawrence fish lift to points approximately 10 miles upstream of Essex Dam to 6.6 miles downstream of Essex Dam.

Merrimack River flow conditions were relatively high during the majority of the upstream passage assessment, with inflow consistently in excess of the 25% monthly flow exceedance conditions for both May and June. Merrimack River flows peaked on May 11 and flows in excess of 25,000 cfs resulting in the termination of fish lift operation for a seven-day period from May 9 through May 15. Spill flows over the inflatable dam sections were present from prior to the onset of the release of tagged shad and lamprey until late June. For the period of time where tagged shad and lamprey were at large (i.e., May 20 to July 15), the fish lift operated daily with most dates consisting of a series of hourly lifts starting around 0800 and ending at 1600. Diadromous fish had access to the lower flume via the river side entrance for the majority of the passage study.

Despite a high rate of fallback following tagging and release (~75% of individuals), a subset of 53 radio tagged shad moved upstream and interacted with the receiver array at the Lawrence fish lift and as a result were available to inform on passage effectiveness. Approach events for tagged shad occurred over a range of dates from May 23 through June 23, peaking during mid-June. Upon arrival at Lawrence, the median duration of time spent downstream prior to either upstream passage or movement downstream and away from the Project was 52.6 hours. Upstream passage attempts at Lawrence were recorded for twelve tagged shad which made a total of 26 unique passage attempts at the lift. Approximately 40% of passage attempts by shad reached the lift hopper with 45% of those attempts resulting in successful upstream passage. When all successful shad passage attempts at the Lawrence fish lift are considered, the median foray duration was 0.7 hours. All fish lift passage attempts were initiated by tagged American shad during the daylight hours with most events taking place during the morning. Regarding the component of tagged shad which did not ascend upstream to the fish lift, observations of individuals carrying acoustic transmitters and monitored as part of the Diadromous Fish Behavior, Movement, and Project Interaction Study (i.e., Project Interaction Study), indicated that adult shad showed a tendency to spend a larger percentage of time at large in the downstream end of the reach from Essex Dam to the Lawrence

I-495 Bridge. A similar observation was also noted for Blueback Herring during the Project Interaction Study and both species were tagged during the latter part of May and early June. High flow conditions, which prevented tagging during early to mid-portion of May and persisted well into June, were likely an influence on upstream movement of both species through the 1.0-1.4 mile reach between the tagging location and the fish lift.

Nearfield attraction for tagged American shad (i.e., the probability to move from the downstream end of the tailrace channel to the attraction water region located immediately adjacent to the entrance gates of the lower fish lift entrance flume was high with 100% of tagged shad which reached Station 4 ascending to Station 5. However, the entrance efficiency for tagged shad was only 34.3%, demonstrating a reluctance of fish to move from the nearfield attraction water region through the entrance gate and into the lower entrance flume. Overall passage effectiveness was evaluated as the probability of a tagged shad initially detected at the point approximately 200 m downstream of the fish lift to successfully move upstream and reach the exit from the power canal (i.e., enter the lower impoundment). For shad, the overall passage effectiveness rate was calculated at 9.4%. When evaluated by components, the probability for shad to move from the initial approach area 200 m downstream of the dam to the area at the immediate downstream end of the tailrace channel was 66.0%: likely influenced by competing spill flow over the inflatable dam sections for the duration of the residence period for tagged shad downstream of the dam. The poor entrance efficiency and failure of individual shad to move from the entrance to the hopper (33.3% failure rate) and for those in the hopper to be successfully lifted (37.5% failure rate) also influenced the overall performance of the Lawrence lift for upstream shad passage. For the subset of shad exiting the Project power canal, all individuals ascended upstream to the upper extent of the Lawrence impoundment.

The majority of tagged sea lamprey released downstream of Essex Dam (71%) moved quickly upstream following release with a median duration of time from release until arrival of 6.8 hours. All arrivals of tagged sea lamprey in the region extending up to 200 m downstream of the dam took place over a six-day window between June 15 and 20 with arrivals at the dam occurring during the late afternoon and nighttime hours. Upon arrival at Lawrence, the median duration of time spent downstream prior to either upstream passage or movement downstream and away from the Project was 72.9 hours. Upstream passage attempts at Lawrence were recorded for 28 tagged lamprey which made a total of 62 unique passage attempts at the lift. Although 55% of passage attempts by sea lamprey reached the lift hopper, only 3% of those attempts resulted in successful upstream passage. Nearly all (81%) sea lamprey passage attempts took place outside of the regular hours of operation for the Lawrence fish lift (i.e., after 1600 and before 0800).

Similar to observations for tagged American shad, the nearfield attraction for tagged sea lamprey was high with 100% of the individuals which reached Station 4 ascending to Station 5. Entrance efficiency for tagged lamprey was 80%, indicating that the species is locating the entrance and

moving upstream and into the lower entrance flume of the lift facility. However, the overall passage effectiveness for lamprey (i.e., the probability of a tagged individual initially detected at the point approximately 200 m downstream of the fish lift to successfully move upstream and reach the exit from the power canal) was only 2.8%. When the overall passage effectiveness is evaluated by its components, the probability for tagged lamprey to move from the initial approach area 200 m downstream of the dam to the area at the immediate downstream end of the tailrace channel was high (97.2%). Similarly, once in the lower entrance flume, tagged lamprey successfully transitioned from the entrance upstream into the hopper area (89.3% success rate). However, the probability for tagged lamprey to successfully transition from entry in the hopper to release at the upstream end of the upper exit flume was poor (4.0%). Overall, sea lamprey are successfully locating the Lawrence fish lift entrance and navigating upstream to the hopper. However, the short duration of entry attempts into the downstream entrance flume coupled with the high percentage of attempts occurring outside of normal hours of daily lift operations impacts the estimate of overall effectiveness. The single sea lamprey successfully passing at the Lawrence fish lift was subsequently detected at the upstream end of the Lawrence impoundment.

## 7 Variances from the FERC Approved Study Plan

The Upstream Anadromous Fish Passage Assessment was conducted following the methodology described in the April 10, 2024, RSP and approved by FERC with modifications in their May 10, 2024, SPD with several exceptions:

- The RSP identified that the Upstream Anadromous Fish Passage Assessment would be conducted with both entrances (river side and street side) to the lower entrance flume of the Lawrence fish lift open. As described in Section 5.2 of this report, Essex (in agreement with the MRTC) followed standard gate operating procedures for the two gates during the 2025 study. The two gates were both operationally available for the duration of the study and prioritization was given to the river side entrance gate under tailwater conditions which permitted at least three feet of water depth at the entrance. Use of the street side gate was limited to periods when the target three-foot minimum entrance depth could not be met at the river side entrance.
- In the May 10, 2024 SPD, FERC identified a target sample size of radio tagged American shad of 430 individuals. Tagging efforts for shad were timed to coincide with manageable flow conditions for safe and effective electrofish sampling downstream of the Project and a total of 404 American shad were successfully tagged and released during this study.

## 8 Literature Cited

Normandeau Associates, Inc. (Normandeau). 1996. Lawrence Hydroelectric Project Internal Fish Lift Efficiency Monitoring Program – Spring 1994 and 1995. Report prepared for Lawrence Hydroelectric Associates.

## Appendix A: Encounter Histories for CJS Mark-Recapture Models

**Encounter History Order:** Release, Station 3, Station 4, Station 5, Station 6/7, Station 8, Station 9, Station 10, Station 12, Station 13, Station 14, Station 15

Sea Lamprey	
History	Count
100000000000	15
110000000000	1
110100000000	2
110110000000	1
110111000000	3
111100000000	5
111110000000	2
111111000000	21
111111111011	1

American Shad	
History	Count
100000000000	351
110000000000	18
111100000000	23
111110000000	4
111111000000	3
111111001010	1
111111001111	1
111111010011	1
111111110010	1
111111111111	1

## **Appendix B: Agency Consultation Regarding 2025 Lift Entrance Operation**

**From:** [Richard Malloy](#)  
**To:** [Benjamin German - NOAA Federal](#)  
**Cc:** [Gahagan, Ben \(FWE\)](#); [ben.gahagan](#); [Bjorn Lake](#); [Sojkowski, Bryan](#); [Christopher Boelke - NOAA Federal](#); [Masterson, Jaime](#); [Holbeche, Joseph \(FWE\)](#); [Keith McGilvray](#); [Hogan, Kenneth J](#); [Carpenter, Matthew](#); [Nick Anderson - NOAA Federal](#); [Peter Lamothe](#); [Rebecca.quinones \(Rebecca.quinones@mass.gov\)](#); [Ritz, Thornton A \(FWE\)](#); [Kevin Webb](#)  
**Subject:** Re: Lawrence Fishway Operations for the 2025 Passage Season  
**Date:** Thursday, March 13, 2025 4:18:35 PM

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Received, thanks Ben.

Richard

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**From:** Benjamin German - NOAA Federal <[benjamin.german@noaa.gov](mailto:benjamin.german@noaa.gov)>  
**Sent:** Thursday, March 13, 2025 3:39 PM  
**To:** Richard Malloy <[RMalloy@patriothydro.com](mailto:RMalloy@patriothydro.com)>  
**Cc:** Gahagan, Ben (FWE) <[ben.gahagan@mass.gov](mailto:ben.gahagan@mass.gov)>; [ben.gahagan@state.ma.us](mailto:ben.gahagan@state.ma.us); Bjorn Lake <[bjorn.lake@noaa.gov](mailto:bjorn.lake@noaa.gov)>; Sojkowski, Bryan <[bryan\\_sojkowski@fws.gov](mailto:bryan_sojkowski@fws.gov)>; Christopher Boelke - NOAA Federal <[christopher.boelke@noaa.gov](mailto:christopher.boelke@noaa.gov)>; Masterson, Jaime <[jaime\\_masterson@fws.gov](mailto:jaime_masterson@fws.gov)>; Holbeche, Joseph (FWE) <[joseph.holbeche@mass.gov](mailto:joseph.holbeche@mass.gov)>; Keith McGilvray <[keith\\_mcgilvray@fws.gov](mailto:keith_mcgilvray@fws.gov)>; Hogan, Kenneth J <[kenneth\\_hogan@fws.gov](mailto:kenneth_hogan@fws.gov)>; Carpenter, Matthew <[mathew.a.carpenter@wildlife.nh.gov](mailto:mathew.a.carpenter@wildlife.nh.gov)>; Nick Anderson - NOAA Federal <[nick.anderson@noaa.gov](mailto:nick.anderson@noaa.gov)>; Peter Lamothe <[peter\\_lamothe@fws.gov](mailto:peter_lamothe@fws.gov)>; Rebecca.quinones (Rebecca.quinones@mass.gov) <[rebecca.quinones@mass.gov](mailto:rebecca.quinones@mass.gov)>; Ritz, Thornton A (FWE) <[thornton.a.ritz@mass.gov](mailto:thornton.a.ritz@mass.gov)>; Kevin Webb <[kwebb@patriothydro.com](mailto:kwebb@patriothydro.com)>  
**Subject:** Lawrence Fishway Operations for the 2025 Passage Season

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Good Afternoon Richard,

The MRTC has discussed Lawrence upstream fishway operations for the 2025 passage/study season. We feel it is important for Patriot/Essex Company to have full control over the fishway operations including any potential study variables those operations may introduce. In the past we have recommended operations that have not been attainable for a variety of reasons that are outside our control. Therefore, instead of recommending or requiring any particular operational scenario, below we provide some general operational objectives and leave the operations/methods employed to achieve those objectives entirely to Patriot's discretion.

The key operational objectives of upstream fishway operations are:

1. Maintain a minimum of 3 feet of submergence depth as measured from the tailrace water surface elevation to the gate crest of any gate(s) in use

2. Target a 1 foot differential  $\pm$  3 inches as measured from the entrance channel water surface elevation to the tailrace water surface elevation

In support of these goals, it is important to collect the necessary data on an hourly basis (or coincident with each lift event, if more frequent), throughout the passage season, to verify and evaluate fishway conditions. These data should be collected in a manner consistent with the current data collection protocol (FOMP v5, Appendix C-1), with the addition of all relevant data points for the street side entrance, when operating; these include but are not limited to:

- Headpond water surface elevation
- Unit generation
- Attraction water system settings
- Tailwater water surface elevation
- Entrance galley water surface elevation
- Gate crest elevation of any gate(s) in use

Please feel at liberty to utilize any operational scenario you deem appropriate to achieve these objectives, including components such as timing, gate(s) in use, and AWS adjustments.

Kind regards,

**6 Benjamin German**

*Marine Habitat Resource Specialist*

*Hydropower Coordinator, Greater Atlantic Region*

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