TRANSCANADA HYDRO NORTHEAST INC.

ILP Study 21
American Shad Telemetry Study

Study Report

In support of Federal Energy Regulatory Commission Relicensing of:

Wilder Hydroelectric Project (FERC Project No. 1892-026)
Bellows Falls Hydroelectric Project (FERC Project No. 1855-045)
Vernon Hydroelectric Project (FERC Project No. 1904-073)

Prepared for

TransCanada Hydro Northeast Inc.
4 Park Street, Suite 402
Concord, NH 03301

Prepared by

Normandeau Associates, Inc.
25 Nashua Road
Bedford, NH 03110

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EXECUTIVE SUMMARY

The goals of this study were to characterize the effects, if any, of TransCanada project operations on behavior, approach routes, passage success, survival, and residency time by adult American Shad (*Alosa sapidissima*) as they move through the Vernon project during both upstream and downstream migrations; and to characterize whether project operations affect shad spawning site use and availability, spawning habitat quantity and quality, and spawning activity in the river reaches from downstream of Vernon dam to Bellows Falls dam.

The study was conducted in the spring of 2015 to assess near-field attraction to, and entrance efficiency of the Vernon fishway; assess internal efficiency of the Vernon fishway; assess upstream migration beyond Vernon dam up to the Bellows Falls project; characterize project operational effects on post-spawn downstream migration route selection, passage efficiency, downstream passage timing/residence, and survival related to the Vernon project; identify areas that American Shad use for spawning; assess effects of project operations on identified spawning areas; and quantify spawning activity.

Fish used for this study were collected from the Holyoke fishway. One hundred fish were tagged with either a PIT tag or both a radio and PIT tag ("dual-tagged") and were released in Northfield, MA approximately 9.5 river miles downstream of the Vernon dam. Additional tagged shad were released farther downstream in a similar study conducted by FirstLight. The sample size of fish detected in the study area was 138 and 75.4% (N=104) entered the fishway. Of those that entered, 51% (N=53) passed to the forebay.

The effectiveness of the fishway of attracting shad was 51.4% which is within the broad range of attraction effectiveness values (11.0%-73.0%) observed at other facilities where similar studies were conducted (e.g., Normandeau, 2008; Normandeau and Gomez and Sullivan, 2012). Efficiency of the fishway (based on the number of fish that entered the fishway and were detected at the counting house window) was 67.3%, comparable to the 68.5% counted in Study 17 (Upstream Passage of Riverine Fish Species Assessment, Normandeau, 2016). Overall fishway effectiveness (percent of shad exiting the fishway that entered the fishway) was 51.0% which is within the range (40-60%) of the management objective in the Connecticut River Atlantic Salmon Commission (CRASC) management plan for shad in the Connecticut River (CRASC, 1992).

Twenty-two (64.7%) of the 34 dual-tagged shad that arrived in the study area but did not enter the fishway were located through manual monitoring downstream of the study area on one or more occasions throughout the study period indicating that they may have remained in the area to spawn.

To assess upstream migration above Vernon dam, 65 radio-tagged shad were monitored. All fish were detected upstream on at least one occasion aside from detection at the monitors located in the Vernon forebay. Eighteen (32.1%) shad migrated to the Bellows Falls tailrace. Fifty-four shad were later re-located in the

Vernon forebay as part of the downstream passage evaluation. Downstream passage was documented for 44 (81.5%) of these shad. Most (N=11, 25%) passed through the fish pipe, nine passed through turbine Units 5 - 8, three passed through turbine Units 9-10, seven passed through turbine Units 1 - 4, five passed via an unknown route, and nine utilized the spillway.

Sixty trawl sampling events occurred on 30 nights between May 26 and July 2, 2015 in the Vernon impoundment and within the study reach downstream of Vernon dam. One hundred twenty individual ichthyoplankton net samples were collected and 792 shad eggs and larvae were collected. Of these, 774 (98%) were eggs, nine (1%) were yolk sack larvae, and nine (1%) were post yolk sack larvae. Shad eggs and/or larvae were collected in 46 (38.3%) samples at 31 (51.2%) trawl locations. Eggs and/or larvae were collected during a wide range of project discharge flows ranging from normal project operations to high water flows, and collections occurred throughout the study area in close proximity spatially and temporally to locations where they were not collected (and hence during the same operational periods). Therefore, this information supports TransCanada's position that project operations do not have an effect on American Shad spawning behavior, spawning habitat use, areal extent, quality of those spawning areas, and spawning activity in terms of egg deposition in those areas.

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cfs	cubic feet per second
CRASC	Connecticut River Atlantic Salmon Commission
CRWC	Connecticut River Watershed Council
°C	degrees Celsius
DO	dissolved oxygen
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Power Resources
ft	Feet or foot
ft/s	feet per second
FWS	U.S. Department of Interior, Fish and Wildlife Service
ILP	Integrated Licensing Process
mg/l	milligrams per liter
µS/cm	micro-siemens per centimeter
NHDES	New Hampshire Department of Environmental Services
NHFGD	New Hampshire Fish and Game Department
NRCS	Natural Resources Conservation Service
Normandeau	Normandeau Associates, Inc.
NTU	Nephelometric Turbidity Units
RSP	Revised Study Plan
SPD	Study Plan Determination
su	standard units
TransCanada	TransCanada Hydro Northeast Inc.
TU	Trout Unlimited
USGS	U.S. Geologic Survey
VANR	Vermont Agency of Natural Resources
VY	Vermont Yankee Nuclear Power Plant

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1.0 INTRODUCTION

This study report presents the results of the American Shad Telemetry Study (ILP Study 21) conducted in support of Federal Energy Regulatory Commission (FERC) relicensing efforts by TransCanada Hydro Northeast Inc. (TransCanada) for the Wilder Hydroelectric Project (FERC Project No. 1892), Bellows Falls Hydroelectric Project (FERC No. 1855) and the Vernon Hydroelectric Project (FERC No. 1904). TransCanada has initiated the Integrated Licensing Process (ILP) for these projects in order to extend the term of their operating licenses beyond the current expiration date of April 30, 2019 for each project.

In their study requests, FERC, U.S. Department of the Interior-Fish and Wildlife Service (FWS), New Hampshire Department of Environmental Services (NHDES), New Hampshire Fish and Game Department (NHFGD), Vermont Agency of Natural Resources (VANR), Connecticut River Watershed Council (CRWC), and Trout Unlimited (TU) identified two issues related to potential project effects relative to adult American Shad (*Alosa sapidissima*). One issue concerned upstream and downstream adult American Shad passage success on the Connecticut River, leading stakeholders to request a study of shad migration from FirstLight's Cabot Station to upstream of Vernon dam. The second issue pertained to American Shad spawning behavior, spawning habitat use, areal extent, and quality of those spawning areas, and spawning activity in terms of egg deposition in those areas.

Additionally, stakeholders included a request for TransCanada and FirstLight to complete analyses of data collected by USGS on the migration of radio-tagged shad from Turners Falls Project (FERC No. 1889) to Vernon dam and passage efficiency of the Vernon fish ladder.

The Revised Study Plan (RSP) for this study was modified by TransCanada in its December 31, 2013 filing. Modifications were made based on stakeholder agreement during FERC's technical meeting held on November 26, 2013 to discuss impacts of the Vermont Yankee (VY) decommissioning. The following specific changes were made to the RSP.

- a limited review and evaluation of the 2011/2012 USGS data to support this study's design and methodology; and
- temperature tags were no longer needed since their purpose was to record water temperature as shad migrate past Vermont Yankee's thermal discharge.

The RSP for this study was approved without modification by FERC in its February 21, 2014 Study Plan Determination (SPD) except to delay the study until 2015.

2.0 STUDY GOALS AND OBJECTIVES

The goals of this study were to:

- characterize effects, if any, of project operations on behavior, approach routes, passage success, survival, and residency time by adult American Shad as they move through the Vernon project during both upstream and downstream migrations; and
- characterize whether project operations affect American Shad spawning site use and availability, spawning habitat quantity and quality, and spawning activity in the river reaches from downstream of Vernon dam up to the Bellows Falls Project.

The objectives of this study were to:

- assess near-field attraction to, and entrance efficiency of the Vernon fishway;
- assess internal efficiency of the Vernon fishway;
- assess upstream migration beyond Vernon dam up to the Bellows Falls Project;
- characterize project operational effects on post-spawn downstream migration route selection, passage efficiency, downstream passage timing/residence, and survival related to the Vernon Project;
- identify areas that American shad use for spawning;
- assess effects (e.g., water velocity, depths, inundation, and exposure of habitats) of project operations on identified spawning areas; and
- quantify spawning activity.

One original objective in the RSP was to assess upstream passage past VY's discharge; but this objective was no longer applicable since VY ceased operation in 2014 and this study was conducted in 2015.

3.0 STUDY AREA

The study area for the passage characterization portion of this study included the Vernon forebay, tailrace, turbines, fishways (upstream and downstream), and spillway. The study area for the spawning assessment portion of this study included the Vernon tailrace and impoundment, and the Bellows Falls riverine reach (Figure 3.1).

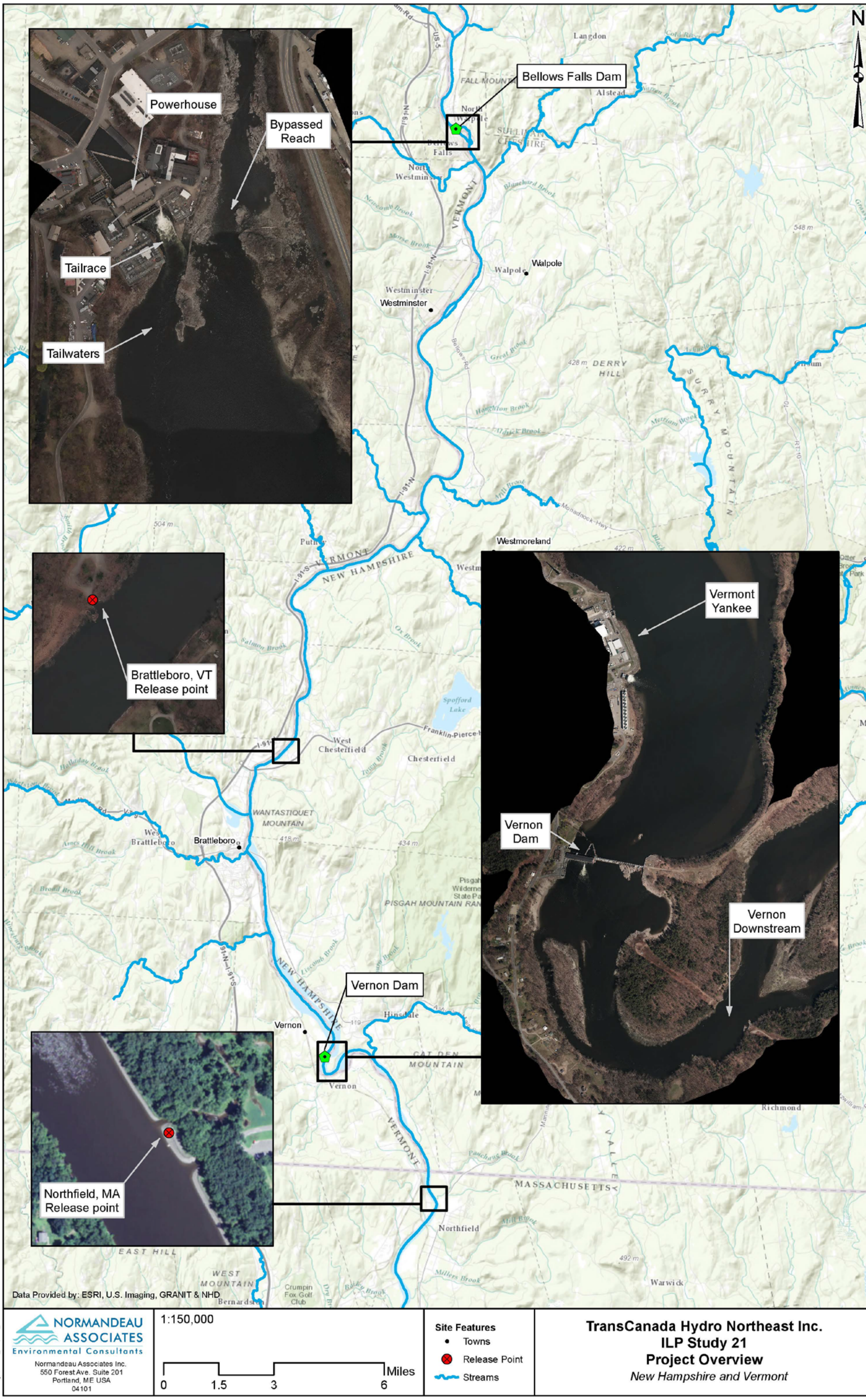

Figure 3.1. Overview of study area including release point for both up and downstream releases.

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4.0 METHODS

4.1 Collection of Test Specimens

This study encompassed three assessments: upstream passage, spawning, and downstream passage. Fish used for the study were collected from two locations, the Holyoke fishway and Vernon fishway. Fish collected at Holyoke were equipped with either passive integrated transponders (PIT tags) or radio and PIT tags (dual tags) and released approximately 9.5 miles downstream of Vernon dam in Northfield, MA. The purpose of this sample group was to assess upstream passage: near-field attraction to the Vernon fishway, entrance efficiency of the fishway, behavior in the fishway, and passage success of shad moving through the Vernon fishway during upstream migration. Behavior in the fishway was assessed via PIT technology; near-field attraction to the fishway and entrance efficiency of the fishway was assessed with radio telemetry; and passage success was assessed with both PIT and radio monitoring methods.

Fish collected at the Vernon fishway were equipped with radio tags and released in the Vernon impoundment to assess spawning and downstream migration. These fish supplemented any dual-tagged fish that passed the Vernon project via the fishway. Radio telemetry, for the most part, was used to achieve these goals. The spawning assessment monitored upstream migration beyond Vernon dam to spawning areas near the Bellows Falls project and identified spawning areas. The downstream migration assessment characterized project operational effects on post-spawn downstream migration route selection, passage efficiency, downstream passage timing, residence time, and survival related to the Vernon project. A single PIT antenna on one downstream passage route augmented the radio telemetry route selection data.

The sample groups for all three assessments were supplemented with shad that had been collected at FirstLight's Cabot station, released for studies at Turners Falls similar to this study, and detected at either the most downstream radio telemetry station for this study (in the Vernon tailrace) or in the fishway. All FirstLight fish were either PIT tagged or dual tagged.

4.1.1 Holyoke Collection and Tagging

All tagged shad that were released at the Northfield, MA, boat access were collected at the Holyoke fishway using their fish trap. After a hopper filled with shad was lifted, the shad were diverted into a sorting tank. Once the appropriate numbers of specimens were separated on each collection day, they were sluiced into the transport truck provided by FWS and filled with river water and salt. Dissolved oxygen was also supplied to the transport tank. Shad were transported from the Holyoke fishway to the Pauchaug Brook boat access, Northfield, MA (river mile 132.5). Transport time was slightly over one hour on each date and all fish were released into the river within 3.3 to 4.5 hours after initial loading at Holyoke (Table 4.1-1).

Table 4.1-1. Summary of shad transport from Holyoke, MA to the Northfield, MA release site, May 2015.

Date	10-May	14-May	28-May
Start of Loading Time	12:23	10:40	09:45
Departure Time	12:45	10:56	10:00
Arrival Time	13:50	12:04	11:15
Release Time	16:51	14:00	13:39
Loading to Release Time	4.5 hrs	3.3 hrs	3.9 hrs
Tank Water Temperature at Capture (°C)	14.5	14.0	18.0
Tank Water Temperature at Arrival (°C)	15.3	14.5	18.4
Tank D.O. at Departure (mg/L)	7.0	6.4	N/A[a]
Tank D.O. at Arrival (mg/L)	14.3	7.9	N/A[a]
Release Water Temperature (°C)	16.1	13.4	17.4
Release Site D.O. (mg/L)	10.7	12.9	9.7
No. of Shad Transported	44	46	25
No. of Shad Dual Tagged	20	20	12
No. Shad PIT Tagged Only	20	20	8

a. D.O meter experienced problems resulting in invalid data.

Individual shad were netted from the transport truck tank and assessed for tagging suitability (e.g., general well-being, no wounds, abrasions, loss of equilibrium). Suitable shad were then transferred into a rubber tote outfitted with fine mesh to immobilize the specimen for tagging and to reduce stress; and unsuitable fish were released. After gathering biological information such as sex and length, a radio tag was orally inserted into the shad's stomach by means of a cannula, guiding it gently through the esophagus. For all shad collected at the Holyoke fishway, a PIT tag was placed below and behind the dorsal fin by making a small (2-mm) incision using a scalpel. The PIT tag was placed horizontally into the incision and gently slid into the specimen's musculature by hand. The tagged shad were then placed into the river. One hundred shad were PIT tagged, 52 of those were also radio tagged.

4.1.2 Vernon Collection and Tagging

Fifty-four shad were collected at the Vernon fishway, radio tagged, and released upstream of Vernon at the Old Ferry boat access, Brattleboro, VT (river mile 147, approximate 5 miles upstream of Vernon dam) for use in the spawning component of the study. Using the diversion door at the Vernon fish trap, shad were diverted into a separate holding area and not allowed to continue migration through the fishway. Once a suitable number of shad were in the trap the trap floor was raised. Shad were netted and placed into the transport truck filled with river water and salt; and dissolved oxygen was applied. This process was repeated until the needed number of specimens was captured. At the release site, individual shad were netted from the transport truck tank and assessed for tagging suitability (e.g., general well-being, no wounds, abrasions, loss of equilibrium). Suitable shad were then transferred into a rubber tote outfitted with fine mesh to immobilize the specimen for tagging and reduce stress; unsuitable fish were released. After gathering biological information such as sex and length, a radio tag was orally inserted into the shad's stomach by means of a cannula, guiding it gently through the esophagus. The tagged shad were then placed into the river. Transport time was less than one hour for all dates and all fish were released into the river within 1.4 to 3.4 hours after initial loading at Vernon (Table 4.1-2).

Table 4.1-2. Summary of shad transport from Vernon fishway to the Brattleboro, VT release site, May 2015.

Date	17-May	17-May	24-May	30-May
Start of Loading Time	11:35-12:53	15:58	15:00	12:00
Departure Time	13:08	16:23	16:15	12:30
Arrival Time	13:50	17:01	16:47	13:20
Release Time	14:15-15:00	17:20	17:30	14:36
Loading to Release Time	3.4 hrs (max)	1.4 hrs	2.5 hrs	2.6 hrs
Tank Water Temperature at Capture (°C)	13.2 (avg)	15.1	14.2	18.0
Tank Water Temperature at Arrival (°C)	14.2	15.6	16.1	18.7
Tank D.O. at Departure (mg/L)	8.3	12.4 (avg)	11.3	N/A[a]
Tank D.O. at Arrival (mg/L)	9.1	12.4	9.8	N/A[a]
Release Water Temperature (°C)	12.7	12.5	14.2	18.8
No. of Shad Transported	13	10	25	20
No. of Shad Radio Tagged	13	7	23	11

a. D.O meter experienced problems resulting in invalid data.

4.2 Radio Telemetry and PIT Equipment

4.2.1 Radio Tags

Coded VHF radio transmitters (radio tags) supplied by Sigma-Eight Inc. (SEI), Newmarket, Ontario, Canada were used for this study. The radio tags (model number TX-PSC-1-80-M) were digitally encoded and transmitted signals on 5 frequencies (channels): 149.720, 149.780, 149.800, 150.440, and 154.540. Each radio tag contained a unique pulse train to allow for individual fish identification (codes). Each cylindrical radio tag measured 9.6mm in diameter, 26mm in length, and had a 12 inch long whip antenna. The radio tags propagated a signal every 2.0 seconds and had a minimum battery life of approximately 113 days. Additionally, they included motion sensing technology; if a radio tag became dormant for 400 code pulses and 12 hours, the rate of the emitted pulse train changed.

4.2.2 PIT Tags

Coded half duplex (HDX) PIT (Passive Integrated Transponder) tags supplied by OREGON RFID (ORFID), Portland, Oregon were used for this study. The HDX PIT tags were encoded by the manufacturer and used 64 data bits. Each cylindrical PIT tag measured 3.65mm in diameter, 32mm long, and weighted 0.8g.

4.2.3 Receivers

Lotek SRX_400 and Lotek SRX_600 telemetry receivers installed with version W7, W30, W31, W32 software, and Sigma-Eight Orion (DSP) telemetry receivers were used to detect radio tags carried by adult shad in this study. Prior to release of fish, background noise levels were determined at the Vernon and Bellows Falls projects during the calibration process. In relation to radio telemetry, background noise is any ambient electromagnetic noise detected by a receiver that is not produced by a radio tag. In general, hydroelectric facilities are noisy electromagnetic environments due to their production and transmission of electricity. Receivers were configured to exclude background noise by utilizing specific features within the receiver's software. Receivers were set to scan each channel for specific time periods, depending on location. When a signal was received, the scan program temporarily suspended and the validity of the signal was verified and either logged or rejected. The receiver measured the duration of a preselected number of pulse intervals and if intervals differed significantly, the signal was rejected. All receivers were time synchronized. Orion telemetry receivers were used in high water velocity areas because they are able to detect broad band signals. When using broad band technology the receiver can listen to up to five frequencies at one time, thus eliminating scan time and ensuring more adequate detections in areas with higher water velocity.

HDX PIT Readers from ORFID were used to detect and read PIT tags. Due to electromagnetic noise each half-duplex reader used a tuning box. By using a tuning box the user is able to calibrate each PIT antenna to exclude background noise and ensure that a quality detection is made. The PIT reader receives the signal transmitted by the PIT tag via the antenna, and then filters, amplifies, decodes, and formats it appropriately for the user.

4.2.4 Antennas

Five types of antennas were used, a PIT wire loop antenna and four radio antennas: Laird P1504 four–element Yagi antennas (4-element antenna), Laird PLC1426 six-element Yagi antennas (6-element antenna), Laird PLC 1429 nine-element Yagi antenna (9-element antenna), and custom made underwater antennas (dropper antenna). All three types of Yagi antennas are aerial antennas that provide directionality and a large reception range (the more elements, the greater the range, i.e., a 9-element antenna has greater range than a 6-element antenna, which has a greater range than a 4-element antenna). Dropper antennas, which are deployed vertically within the water column, are omni-directional and provide limited reception range. They are used to determine discrete movement within a specific location of interest. Dropper antennas are constructed by stripping the shielded end of a 50-OHM RG58A/U coaxial cable, the length of the stripped portion of cable is a multiple of half the wavelength of 150MHz.

The PIT wire loop antennas for PIT readers were used to determine when a fish had passed or came extremely close to discrete areas of passage (within +/-3 ft). All PIT antennas were made from thermoplastic high heat resistant wire (THHN). The purpose of the PIT antenna loop is to create an alternating magnetic field from the reader and then receive a signal back from the PIT tag. The numbers of loops within an antenna will coincide with the magnetic field strength of the antenna. Twin-axial communication cable was used from the tuning boxes to the reader.

4.3 Monitoring Locations and Antenna Arrangement

Monitoring stations were deployed in seven general areas of the study area: upstream of Stebbins Island, Vernon tailrace, Vernon fishway, Vernon spillway, Vernon forebay, Bellows Falls tailrace, and Bellows Falls bypassed reach (Figures 4.3-1 to 4.3-4). With most monitoring stations concentrated near Vernon dam, manual radio telemetry tracking was used to supplement data for the 31.8 mile distance between Vernon dam and Bellows Falls dam and within the study reach downstream of Vernon dam.

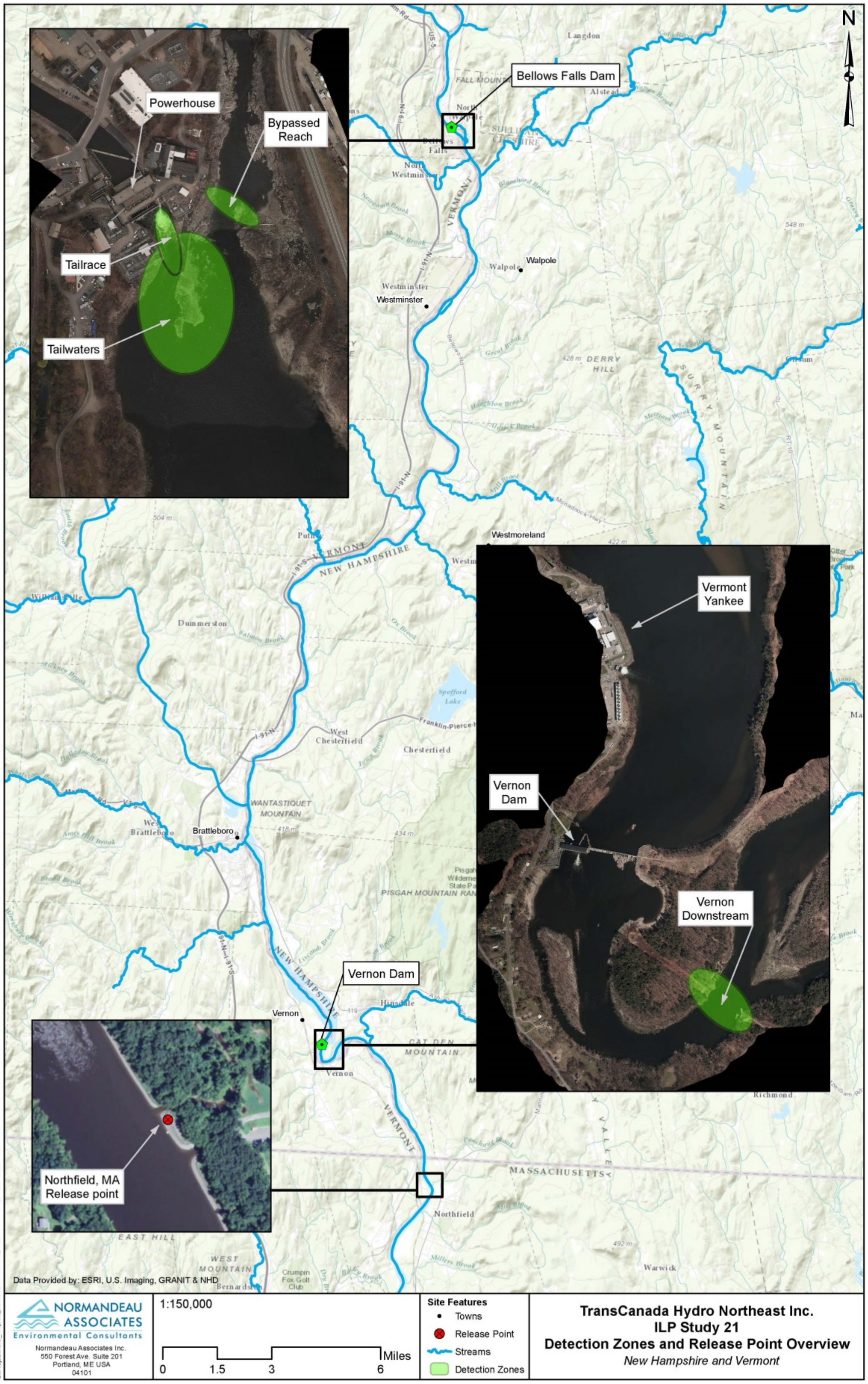

Figure 4.3-1. Detection zones of monitoring stations upstream and downstream of Vernon.

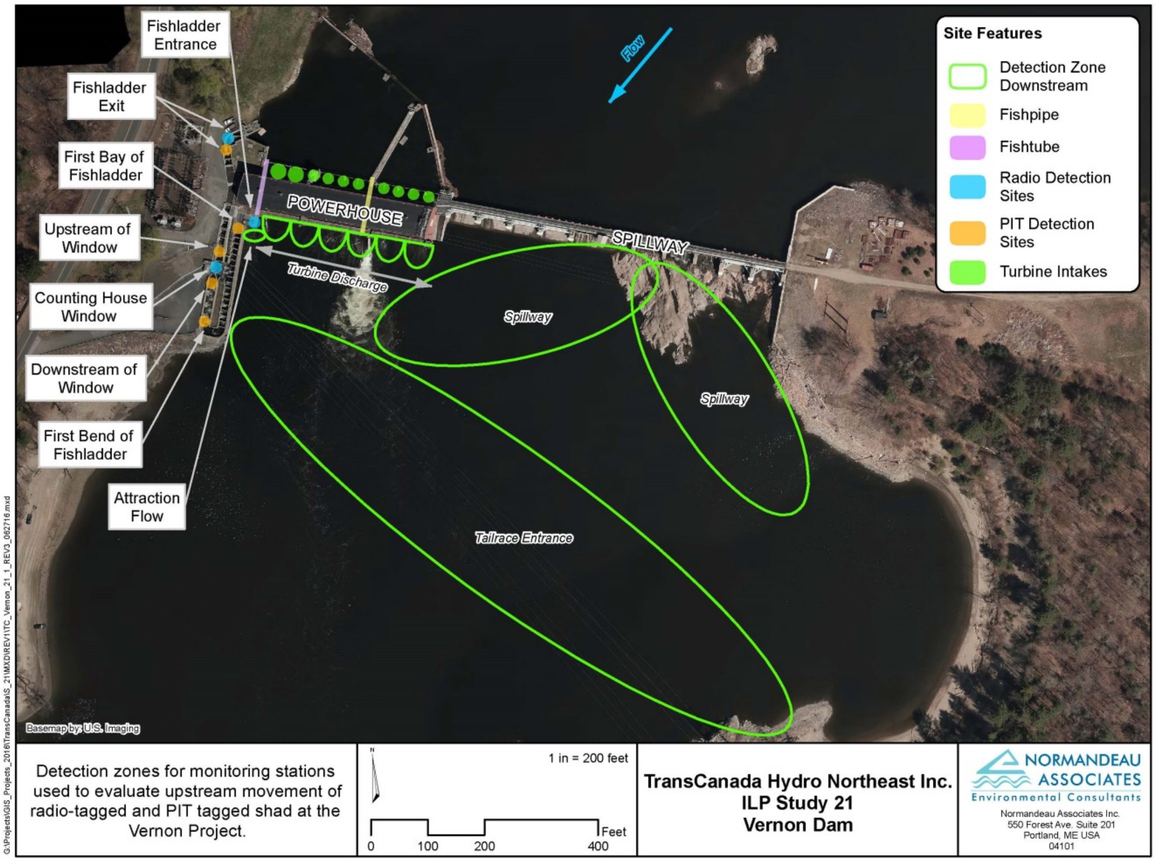

Figure 4.3-2. Detection zones for tailrace and fishway monitoring stations used to evaluate upstream movement of shad with radio or PIT tags at Vernon.

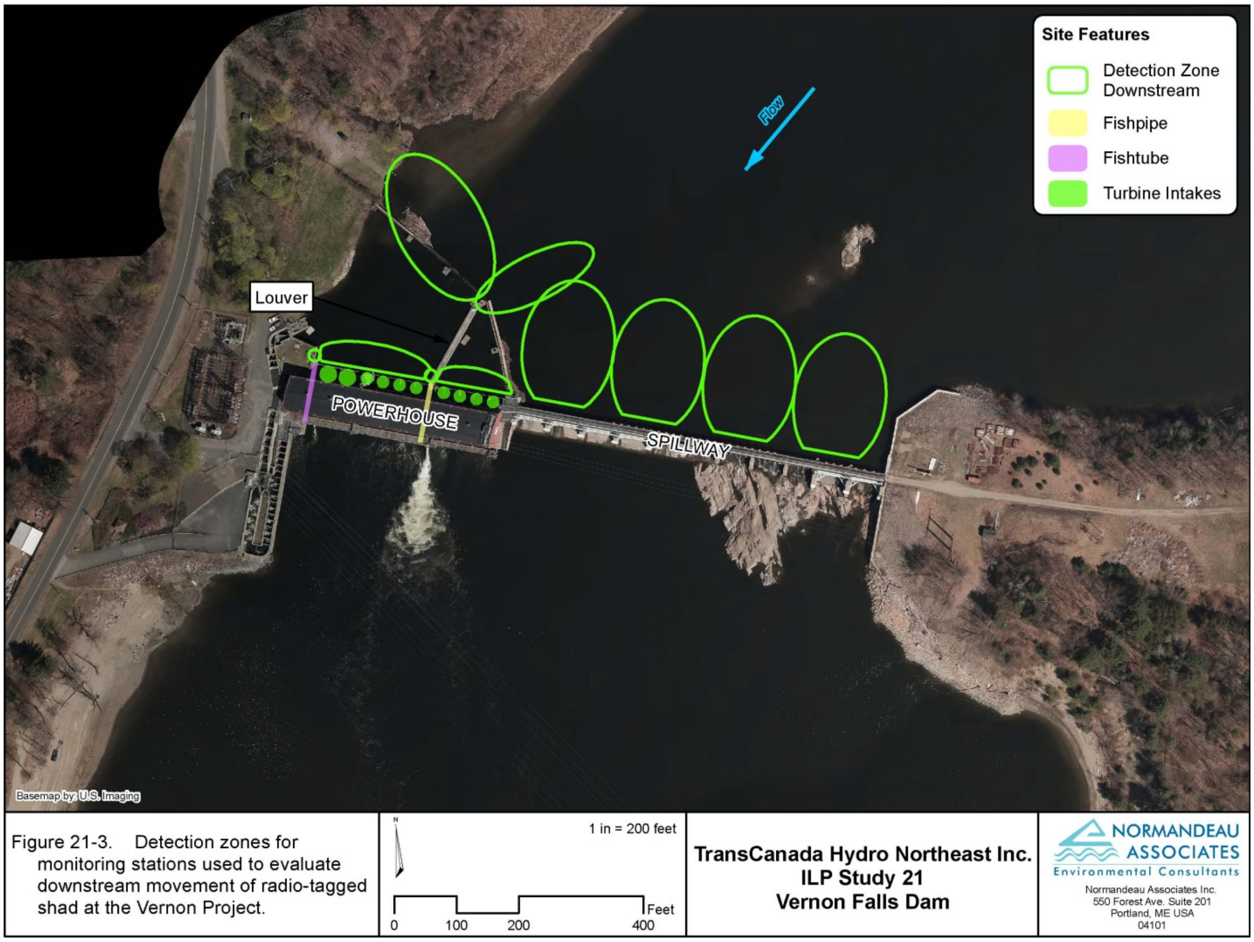

Figure 4.3-3. Detection zones for forebay monitoring stations used to evaluate downstream movement of shad with radio tags at Vernon.

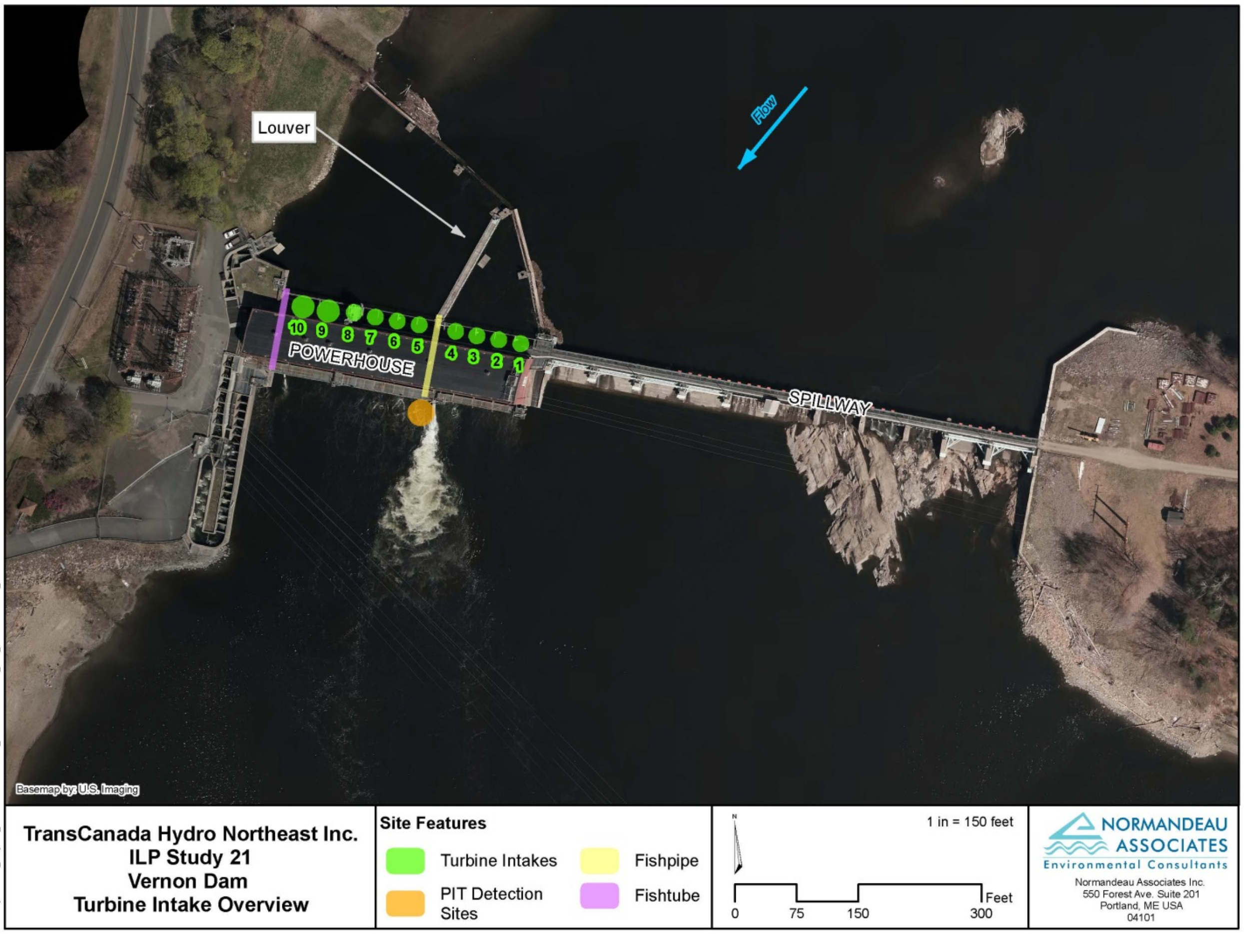

Figure 4.3-4. PIT tag detection zone on the downstream end of the fish pipe downstream passage route.

4.3.1 Downstream Monitoring Station

The downstream monitoring station was located at the Vermont Yankee water quality station #3, approximately 0.75 miles downstream of Vernon dam (Figure 4.3-1), across from a riffle upstream of Stebbins Island. The station consisted of a radio receiver and a 6-element antenna mounted on a staircase oriented towards the east shore. Antenna coverage spanned the width of the river and was used to aid observation of potential spawning habitat around Stebbins Island, identify upstream and downstream movement from the Vernon tailrace, and assist in determining temporal aspects of upstream forays.

4.3.2 Tailrace Monitoring Stations

The Vernon tailrace monitoring stations included the tailrace entrance, turbine discharge, and spillway. Together, these stations monitored the area 50 ft downstream of the discharge from Units 1 through 10, the width of the river from the fishway public viewing window to the east shore and downstream 800 ft, and below the spillway gates west of the rock outcrop (see Figure 4.3-2). These stations identified shad with radio tags present in the tailrace (i.e., “fish available”) for estimating fishway attraction effectiveness. In addition, the tailrace monitoring stations detected any fall back after passage through the Vernon fishway or when released upstream at the Old Ferry boat launch, and downstream migration after spawning. Fall back is a term used to describe the downstream movement some fish display after tagging; some fish resume upstream migration after a short fall back period and some do not. Fall back is likely due to stress incurred from handing and tagging, and is common with shad (see Section 5.2). In this study fall back is also used to describe shad that passed through the fishway and quickly moved back downstream without continuing an upstream migration. A receiver coupled via switchbox to two 4-element antennas was mounted on the tailrace catwalk railing and equally distributed over the west, middle, and east areas over the tailrace discharge with a detection range of 50 ft downstream and 25 ft in each direction for complete coverage of the turbine discharges (Figure 4.3-2).

4.3.3 Fishway Monitoring Stations

The fishway included both PIT and radio monitoring stations. Radio antennas were located to detect fish in the tailrace near the fishway entrance (“fishway attraction flow”), at the fishway entrance, at the counting house window, and at the fishway exit. PIT antennas were located at the first bay of the fishway, the first bend in the fishway (near the public viewing window), just downstream of the counting house window, just upstream of the counting house window, and at the fishway exit (Figure 4.3-2). All stations except the fishway attraction flow station monitored shad presence and behavior in the fishway. The fishway attraction flow monitoring station was configured to detect fish in the vicinity of the fishway entrance, in the attraction water flow field. This receiver was coupled to a switchbox using an underwater dropper antenna at the fishway entrance and to a 4-element antenna with a detection area of approximately 30 ft paralleling the attraction flow to provide coverage within the immediate zone of attraction. Together these two antennas were able to identify the presence of radio-tagged shad within the vicinity of the fishway entrance and immediately inside.

The first bay of the fishway is split into two entrances side by side with a concrete wall separating them. Thus, two PIT antennas coupled to a multi-antenna PIT reader were deployed. Each antenna was calibrated to detect the presence of PIT-tagged shad entering the fishway and to identify which side was used, however, it was determined once all data had been collected that the multi-reader, although calibrated, lacked sensitivity compared to the single readers used at the remaining sites. This resulted in a lower number of PIT-tagged fish detected at the fishway entrance versus the number detected at the first bend in the fishway. As a result, detections at the fishway entrance were only used to calculate proportional entry into the fishway relative to station flows and operating conditions (Section 5.3.1).

The PIT antenna at the first bend of the fishway monitored the presence of PIT-tagged shad as they proceeded through the fishway. This single antenna loop was powered by a single antenna PIT reader. A PIT antenna and an underwater dropper radio antenna monitored the zone immediately downstream of the counting house window. The underwater dropper antenna monitored for the presence of radio-tagged shad as they approached the counting house window. The PIT antenna, driven by a single antenna PIT reader, monitored for the presence of PIT-tagged shad as they approached the counting house window. Upstream of the counting house window a PIT antenna monitored for the presence of PIT-tagged shad as they proceeded past the window where the fishway becomes a vertical slot. The single PIT antenna was driven by a single antenna PIT reader.

The fishway exit monitoring stations consisted of a PIT antenna, driven by a single antenna PIT tag reader and an underwater dropper radio antenna driven by a single radio telemetry receiver. These antennas were calibrated to detect radio and PIT-tagged shad at the exit of the fishway.

4.3.4 Spillway Monitoring Station

The spillway monitoring station was deployed in the center of the spillway bridge. This station monitored for the presence of radio-tagged shad within the spillway and consisted of two 4-element antennas mounted onto the railing. Both antennas were coupled to a switchbox and driven by a single receiver. Each antenna was angled to the southwest and southeast to maximize coverage of the spillway. The station was calibrated to detect radio-tagged shad within 100 ft of the spillway (Figure 4.3-2).

4.3.5 Forebay Monitoring Stations

The forebay was monitored in five sections: spillway, turbine intake structures, fish pipe, fish tube, and the louver array. Each section monitored a particular downstream passage route (Figure 4.3-3).

The spillway forebay station consisted of four 4-element antennas evenly placed across the 600-foot bridge. The four antennas were coupled by a switchbox to one receiver. Each antenna monitored an area out to 100 ft. This monitoring station detected the presence of radio-tagged shad in the forebay area.

The turbine intakes were divided into three separate stations for overall coverage: Units 1-4, Units 5-8, and Units 9-10. Units 1-8 each had a single dropper antenna. Units 9-10, due to their size and dual intake gate required two droppers per unit. Dropper length varied due to the different sizes of the turbines. Units 1-4 were combined via a ZFSC combiner then to an Orion telemetry receiver. The same method of combining antennas was used on Units 5-8 and on Units 9-10. These three receivers were calibrated to monitor radio-tagged shad within the turbine intakes.

The fish pipe is located between Units 4 and 5 and serves as the primary downstream passage bypass. To monitor fish using this downstream passage route, a single underwater dropper antenna, attached to a radio receiver, was installed in the upstream corner of the tube. At the exit of the fish pipe a single PIT antenna was installed to detect PIT-tagged shad passing via this route. Due to high flow volume through the fish pipe a boxed wood frame was built around the fish pipe and the looped antenna attached to it (Figures 4.3-3 and 4.3-4).

The fish tube is located to the west of Unit 10 and serves as a secondary downstream fish bypass. This monitoring station consisted of a radio receiver and a single underwater dropper antenna. The dropper was oriented toward the first 10 feet into the fish tube to monitor for the presence of downstream movement of radio-tagged shad.

On the louver array, a single radio receiver was installed with two 4-element antennas coupled via a switchbox. The antennas were mounted to the railing of the louver on each corner of the upstream end. The first antenna was oriented north-northwest and calibrated to detect shad moving out of the forebay after having exited the fishway, and the approach path into the forebay. The second antenna was oriented northeast and was calibrated to monitor any radio-tagged shad to the east of the diversion boom (Figure 4.3-3).

4.3.6 Bellows Falls Monitoring Stations

The Bellows Falls tailrace monitoring station identified radio-tagged shad in the immediate tailwaters and the tailrace of the Bellows Falls powerhouse. A 4-element antenna was mounted on the fishway catwalk in the center of the turbine discharge and a 6-element antenna was mounted to a railing outside the switchyard oriented to observe across 600 feet parallel to the tailrace. These two antennas were coupled via a switchbox to a single receiver (Figure 4.3-1).

The Bellows Falls bypassed reach monitoring station consisted of a single 4-element antenna mounted to the outside of the switchyard fence and joined to a single receiver. This station covered the width of the bypassed reach and monitored for radio-tagged shad that might use this reach (Figure 4.3-1).

4.4 Data Collection and Analysis

Data was stored in receivers as either a single event or a period of multiple events. Radio-tagged shad must be within the detection area for a given period of time in order for it to be recorded as a continuous event. Single events greater than five minutes apart were recorded individually. Each data event included start date, start time, channel, code, average pulse rate, average signal strength, end date, and end time. Data was downloaded from receivers three times per week throughout the study period with a laptop computer and stored on a hard drive and flash drive. Backup copies of all telemetry data were made prior to receiver initialization. Data was then consolidated into a PC database for review and verification including examining data for stationary signals.

To examine the performance of the Vernon fishway the following three metrics were calculated:

- Fishway Attraction Effectiveness: the proportion of fish that enter a fishway in relation to the total number of fish available. For this study, "the number of fish available" is the number of dual-tagged shad detected entering the study area at the downstream monitoring station above Stebbins Island located at the Vermont Yankee water sampling station (Figures 4.3-1 and 4.3-2). The combined antenna arrays downstream of Vernon dam covered the width of the tailrace from the base of the dam to the area above Stebbins Island. Only dual-tagged fish were used to calculate this metric since the number of PIT-tagged fish entering the study area is unknown (the initial-detection PIT station was in the fishway entrance).
- Upstream Fish Passage Efficiency: the proportion of fish that entered the fishway and passed the counting house window in relation to the total number that entered the fishway. Both PIT and dual tag fish were used to calculate this metric.
- Upstream Fish Passage Effectiveness: the proportion of fish that entered the fishway and passed upstream, past the fishway exit antennas, and remained upstream for longer than 48 hours relative to the total number that entered the fishway. Both PIT and dual tag fish were used to calculate this metric.

4.5 Manual Tracking

Manual tracking by boat was performed for all release groups to supplement tracking data collected from the fixed monitoring stations and to identify areas for shad egg and larvae sampling. The reach downstream of Vernon dam was surveyed every other day to the southern end of Stebbins Island. On occasion, as the study progressed, manual tracking was extended downstream to the release point at Northfield, MA. After radio-tagged shad were released above Vernon dam or had passed via the fishway, the approximate 31.8-mile stretch of river between Vernon dam and Bellows Falls dam was surveyed 5 days each week. When radio-tagged shad were located, GPS coordinates, date, time, and fish status (actively moving or stationary) were recorded to supplement data from the fixed stations.

4.6 Ichthyoplankton Sampling

Night time ichthyoplankton sampling for shad eggs and larvae was conducted over a six-week period from late May to early July with sixty sampling events. Two ichthyoplankton nets were towed during each sampling event, one on each side of the boat, for a total of 120 samples. Nets were towed at varying depths depending upon environmental conditions and habitat. In shallow water habitats nets were fished 1 to 1.5 ft below the surface and in deeper habitats the nets were fished at near mid-depth of the water column.

Environmental parameters were measured before each sample was taken. Surface water temperature, dissolved oxygen, pH, conductivity, and turbidity data were collected using a YSI sonde 6920 and a handset YSI model 650MDS. Station depth readings were taken using a YSI sonde 6920 and a handset YSI model 650MDS or a sounding line. Date, time, location, substrate type, water velocity, shad splashes (spawning activity), and pertinent comments were recorded.

All samples were collected with a 0.5-m plankton net (0.5-mm mesh) equipped with a General Oceanics model 2030 flow meter. The two nets were towed behind the boat, heading upstream for approximately 30 minutes to 1 hour duration. For surface samples, floats were fixed to the top of the net to ensure the net would filter water 1 to 1.5 feet below the surface.

To locate potential spawning areas for ichthyoplankton sampling, radio telemetry via manual tracking was used to detect shad. Once a fish was located the boat was anchored and the ichthyoplankton nets were fished off the stern. After the sampling was finished the nets were pulled and the contents carefully washed into one-quart sampling jars. The contents of the sample were preserved using 6-8% formalin. Jars were labeled and sealed for delivery to Normandeau's Bedford, NH laboratory for sorting and identification.

The volume of water that was filtered for each sample was measured using the difference in rotor spins by the flow meter. When recording the difference in counts for each sample, a sample volume (m^3) could be calculated by using the following formulas:

A. Distance in meters =

$$\frac{\text{Difference in counts x Rotor constant}^{a}}{999{,}999}$$

B. Volume of water filtered (m^3) =

$$\frac{3.14\ (\text{net diameter in m}^{2})\ \text{X Distance in meters}}{4}$$

a. Rotor constant (standard speed rotor) = 26,873; rotor constant (low speed rotor) = 57,560

5.0 RESULTS

5.1 Tagging and Release Data

A total of 100 adult American Shad were collected from the fish lift facilities at Holyoke dam. All fish were PIT tagged and 52 were also radio tagged ("dual tagged"). Tagged shad were released in three separate release groups at the Pauchaug Brook boat access located in Northfield, MA (Table 5.1-1). During the course of this study FirstLight was conducting a similar shad spawning and migration study. They released 397 dual-tagged shad and 396 PIT-tagged shad in three general areas below Vernon dam: Turners Falls impoundment, below Cabot Station, and Holyoke impoundment. As agreed, those shad would become a part of this study if detected within this study's area. Tag and release data for shad that entered the Vernon study area from both studies are included in Appendix A (appendices filed separately in Excel format).

To supplement evaluation of shad upstream of the Vernon project for the spawning portion of the study, an additional 54 individuals were captured at the Vernon fish trap, radio-tagged, and released at the Old Ferry boat launch, located in Brattleboro, VT approximately 11.3 river miles upstream of Vernon dam (Table 5.1-2).

Table 5.1-1. Summary of TransCanada tagged adult American Shad released at the Pauchaug Brook boat access downstream of Vernon dam, spring 2015.

Release Group	Shad Run Segment	Collection Location	Release Date	No. Released	Tag Type	No. Tagged	Sex and No. of Tagged Shad		Release Water Temp. °C
1	Early	Holyoke Fish lift	10-May	40	PIT	20	M	21	16.1
					Radio & PIT	20	F	19	
2	Mid	Holyoke Fish lift	14-May	40	PIT	20	M	26	13.4
					Radio & PIT	20	F	14	
3	Late	Holyoke Fish lift	28-May	20	PIT	8	M	3	17.4
					Radio & PIT	12	F	17	
Total = 100					**PIT**	**48**	**M**	**50**	
					Radio & PIT	**52**	**F**	**50**	

Table 5.1-2. Summary of TransCanada radio-tagged adult American Shad released at the Old Ferry boat launch upstream of Vernon dam, spring 2015.

Release Group	Shad Run Segment	Collection Location	Release Dates	Number Released	Sex and No. of Tagged Shad		Release Water Temp. °C
1	Early	Vernon Fish Trap	17-May	20	M	16	12.7
					F	4	
2	Mid	Vernon Fish Trap	24-May	23	M	16	14.2
					F	7	
3	Late	Vernon Fish Trap	30-May	11	M	5	18.8
					F	6	
Total = 54					**M**	**37**	
					F	**17**	

5.2 Upstream Passage Results

The proportion of each release group that arrived at Vernon varied more for dual-tagged fish than for PIT-tagged fish (Table 5.2-1). Dual-tagged fish released on May 14 had the lowest arrival rate of 25% while those released on May 28 had the highest (50%). PIT-tagged fish released on May 14 had a higher arrival rate than dual-tagged fish released on that date (30%) while PIT-tagged fish released on May 28 had a slightly lower arrival rate than dual-tagged fish released on that same date (37.5%). There was no difference in tagging technique used and the cause of these differences is unknown. There are many possible explanations such as different groups of shad arriving at Holyoke may have spent longer in the river prior to collection; or some may have been stressed differently at collection due to the number of fish collected in the Holyoke fish lift hopper at any one time. The number of tagged shad entering the study area for the upstream and fishway passage assessments was somewhat low but similar for each tag type: 18 (34.6%) of the dual-tagged shad and 16 (33.3%) of the PIT-tagged shad.

Table 5.2-1. Arrival of TransCanada released shad to the Vernon study area.

Release Date	Water Temp °C	No. Released	No. Arrived	% Arrived
Dual Tag				
10-May	16.1	20	7	35.0%
14-May	13.4	20	5	25.0%
28-May	14.2	12	6	50.0%
Total		**52**	**18**	**34.6%**
PIT Tag				
10-May	16.1	20	7	35.0%
14-May	13.4	20	6	30.0%
28-May	14.2	8	3	37.5%
Total		**48**	**16**	**33.3%**
All Tagged Fish				
10-May	16.1	40	14	35.0%
14-May	13.4	40	11	27.5%
28-May	14.2	20	9	45.0%
Total		**100**	**34**	**34.0%**

From the FirstLight study, an additional 52 (13.1% of 397 released at all FirstLight sites) dual-tagged fish and another 52 (13.1% of 396 released at all FirstLight sites) PIT-tagged fish were detected in the Vernon study area.

One hundred fourteen (62%) of the 184 dual-tagged shad released into the Turners Falls impoundment for both studies combined were not detected by stationary receivers in the study area, but 46 of these fish (22 for this study, 24 for the FirstLight study) were later located downstream of the study area in the impoundment through manual monitoring conducted as part of the spawning study and/or by FirstLight, indicating that they may have found suitable spawning habitat downstream of Vernon dam. The remaining 68 fish (60%) were not detected in the impoundment. Literature review indicates that a certain proportion of radio-tagged shad fall back downstream shortly after tag and release with little or no subsequent upstream movement (e.g., Legget, 1976; RMC, 1990; Sprankle, 2005; Olney et al., 2006; Normandeau, 2011; 2012). Depending upon site-specific characteristics and prevailing hydrological conditions, post-tagging stress has consistently been reported to affect migrational behavior for up to 40% of American Shad; and can reportedly range widely from less than 10% to 100% (Frank et al., 2009; Barry and Kynard, 1986). Results of this study are therefore generally consistent with expected rates for fall back.

In total, 70 dual-tagged fish were available to assess behavior in the study area, approach to the fishway, and forays into the fishway. Sixty-eight PIT-tagged fish were detected at the PIT monitor located in the first bend of the fishway, although only 39 were detected at the fishway entrance due to the lower sensitivity of the PIT receiver there (see Section 4.3.3 for discussion of antenna sensitivity that led to the low number detected at the entrance). Of the 70 dual-tagged fish entering the study area, 36 entered the fishway. Therefore, 104 tagged fish were available to assess within the fishway (36 dual tag, 68 PIT tag) (Table 5.2-2). Fifty-three (12 dual tag, 41 PIT tag) ultimately passed the fishway and remained upstream of the fishway for at least 48 hours.

Table 5.2-2. Summary of all adult shad detections at the Vernon fishway, spring 2015.

	Detected in Study Area		Detected at Attraction Flow		First Detection Point in Fishway[a]		Detected at or Downstream of Counting House Window		Detected Upstream of Counting House Window		Detected at Fishway Exit		
	No.	% of Total Released	No.	Fishway Attraction Effectiveness[b]	No.	% of Those Detected at Attraction Flow	No.	% of Those Detected at First Detection Point in Fishway	No.	Upstream Passage Efficiency[c]	No.	% of Those Upstream of Counting House Window	Upstream Fish Passage Effectiveness[d]
Dual-Tag	**70**	**15.6%**	**36**	**51.4%**	**36**	**100%**	**20**	**55.6%**	**18**	**50.0%**	**12**	**66.7%**	**33.3%**
FL	52	13.1%	24	46.2%	24	100%	11	45.8%	10	41.7%	8	80.0%	33.3%
TC	18	34.6%	12	66.7%	12	100%	9	75.0%	8	66.7%	4	50.0%	33.3%
PIT-Tag	**n/a**	**n/a**	**n/a**	**n/a**	**68**	**n/a**	**52**	**76.5%**	**52**	**76.5%**	**41**	**78.8%**	**60.3%**
FL	n/a	n/a	n/a	n/a	52	n/a	44	84.6%	44	84.6%	34	77.3%	65.4%
TC	n/a	n/a	n/a	n/a	16	n/a	8	50.0%	8	50.0%	7	87.5%	43.8%
TOTAL	**70**	**15.6%**	**36**	**51.4%**	**104**	**n/a**	**72**	**69.2%**	**70**	**67.3%**	**53**	**75.7%**	**51.0%**
FL	52	13.1%	24	46.2%	76	n/a	55	72.4%	54	71.1%	42	77.8%	55.3%
TC	18	34.6%	12	66.7%	28	n/a	17	60.7%	16	57.1%	11	68.8%	39.3%
Sex (% of those detected at each previous monitoring station)													
	No.[e]	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**% of those detected in fishway**
Male	35	50.0%	19	52.8%	59	56.7%	42	58.3%	42	60.0%	32	60.4%	54.2%
Female	35	50.0%	17	47.2%	45	43.3%	30	41.7%	28	40.0%	21	39.6%	46.7%
Size (mm)													
Minimum	380		380		380		380		380		380		
Maximum	566		546		543		542		542		535		
Average	497		491		486		485		484		480		
Median	498		494		493		495		493		487		

a. First detection point used for PIT-tagged fish was either the fishway entrance (39 detected) or the first bend (68 detected), since not all were detected at the entrance.
b. Fishway Attraction Effectiveness = the percentage of dual-tagged fish detected in the study area that entered the fishway.
c. Upstream Passage Efficiency = the percentage of fish detected at the first detection point in the fishway that passed above the counting house window.
d. Upstream Passage Effectiveness = the percentage of fish detected at the first detection point in the fishway that were detected at the fishway exit and remained upstream for 48 hours.
e. Sex of fish detected in study area: male=7.3% of all male fish released by TransCanada and FirstLight, female=8.4% of all female fish released by TransCanada and FirstLight.

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5.3 Immigrating Shad Behavior in the Study Area

5.3.1 Travel Time and Forays into Fishway

Dual Tag Shad

Average travel time for dual-tagged shad to reach the downstream monitoring station after release was 8 days, 22 hours, 14 minutes. In general, shad tagged earlier in the season took longer to move into the study area than those tagged later in the season. Average travel time from release to initial detection in the fishway entrance for dual-tagged shad was 10 days, 10 hours, and 41 minutes and average time from the fishway entrance to exit was 7 hours, 58 minutes (Table 5.3-3).

Table 5.3-3. Travel time (average, minimum, maximum, and median) for dual-tagged shad to reach monitoring stations.

Dual Tag Monitoring Station	Average	Min	Max	Median
From Release to Stebbins Island Receiver	8 d 22 h 14 m	1 d 4 h 37 m	22 d 17 h 15 m	8 d 12 h 5 m
From Release to Tailrace	9 d 2 h 48 m	1 d 14 h 27 m	24 d 15 h 1 m	8 d 13 h 41 m
From Release to Attraction Flow	9 d 6 h 56 m	1 d 15 h 54 m	24 d 15 h 13 m	9 d 5 h 35 m
From Release to Fishway Entrance	10 d 10 h 41 m	2 d 2 h	18 d 6 h 28 m	10 d 13 h 34 m
From Tailrace to Attraction Flow	2 d 13 h 32 m	22 m	10 d 9 h 4 m	20 h 5 m
From Attraction Flow to Fishway Entrance	52 m	<1 m	10 h 24 m	10 m
From Fishway Entrance to Viewing Window	6 h 14 m	15 m	2 d 1 h 11 m	2 h 24 m
From Viewing Window to Fishway Exit	1 h 57 m	1 h	4 h 55 m	1 h 41 m
From Tailrace to Fishway Exit	4 d 16 h 46 m	4 h 21 m	17 d 8 h 32 m	3 d 27 m
From Fishway Entrance to Fishway Exit	7 h 58 m	2 h 14 m	2 d 3 h 12 m	3 h 31 m

Thirty-six of the 70 dual-tagged shad detected in the Vernon study area were also detected in the fishway entrance monitoring station, indicating a 51.4% Fishway Attraction Effectiveness (Table 5.2-2). Nine of these (25%) had been released by FirstLight downstream of the Turners Falls impoundment at Cabot or Holyoke. Fishway Attraction Effectiveness cannot be calculated for PIT-tagged fish since the number of PIT-tagged fish entering the tailrace area cannot be determined.

The 36 dual-tagged fish detected at the fishway entrance monitor made a total of 94 forays into the fishway as detected at the fishway entrance monitoring station (Figure 5.3-1). A foray was defined as a maximum 4-hour period in which a fish passed the entrance or first bay receivers and either dropped back into the tailrace from there or continued up in the fishway and then dropped back to the tailrace; if the foray exceeded four hours without the fish backing out of the fishway, it was counted as a single foray. One fish made 34 forays, and 17 fish made single forays. Eighteen were detected at least one time at the counting house window monitoring station. The average time from detection in the tailrace to detection at the attraction flow was 2 days, 13 hours, 32 minutes; median time was 20 hours, 50 minutes (Table 5.3-3). It should be noted that fishway attraction flow (additional flow to the fishway, metered into the entrance bay) did not operate at night under existing fishway operating protocols. Seven of the nine dual-tagged fish that made one or more forays when attraction water was not operating also made forays when attraction flow was operating. Two ultimately passed, one on a foray when attraction flow was operating and the other on its successful foray when attraction flow was not operating. All remaining dual-tag fish that passed made their successful foray with attraction flow operating.

There was no appreciable difference in total station discharges during times when attraction flow was or was not operating as flows ranged from 2,640 cfs to spill flows, and from 1,875 cfs to spill flows, respectively, during those times (average flow was 9,422 cfs and 9,518 cfs, respectively). The average time from fishway entry to exit was 7 hours, 58 minutes; median time was 3 hours, 31 minutes.

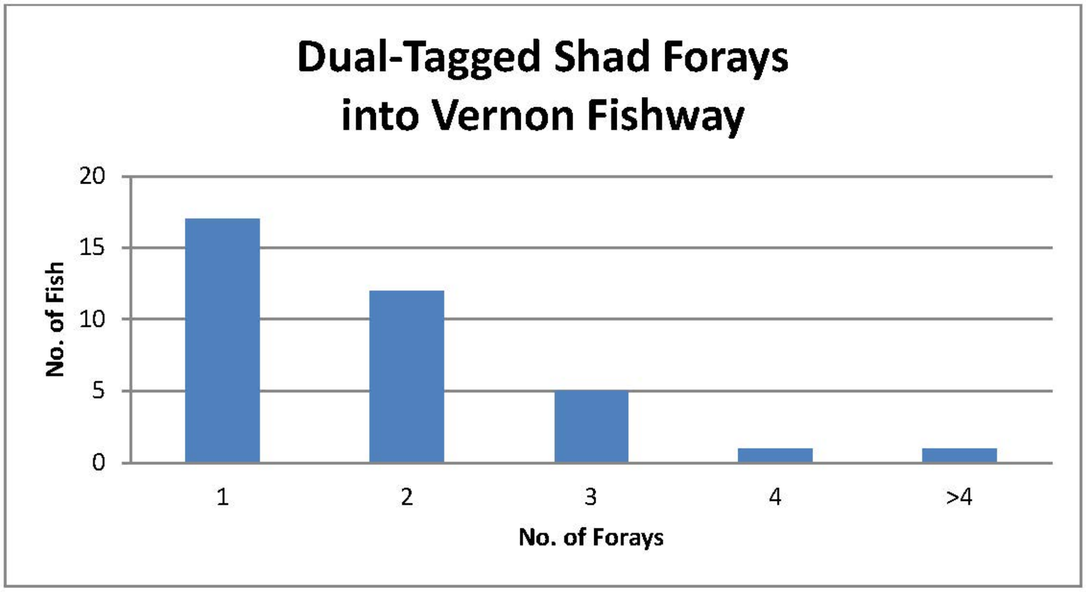

Figure 5.3-1. Forays by dual-tagged shad into the Vernon fishway, spring 2015.

PIT Tag Shad

Sixty-eight PIT-tagged shad were detected and monitored in the fishway. A total of 65 forays were made within the fishway (Figure 5.3-2). This number includes those detected at the entrance monitor (N=39 of 68) or first detected at the monitor located at the first bend (due to the low sensitivity of the entrance PIT monitor; N=68).

Average travel time for PIT-tagged shad to reach the fishway entrance monitoring station after release was 8 days, 19 hours, 25 minutes based on the 39 fish detected there. Of those, four fish (10%) made forays when attraction flow was not operating and two of those also made forays when attraction flow was operating. One of the four ultimately passed upon its single foray when attraction flow was not operating. When attraction flow was not operating, forays occurred when station discharge flows ranged from 1,868 cfs to 10,198 cfs (average = 4,074 cfs). When attraction flow was operating, forays occurred at flows ranging from 2,114 cfs to 22,270 cfs (average = 6,650). The remaining 28 fish that ultimately passed (of the 39 detected at the entrance) made all successful and unsuccessful forays when attraction flow was operating.

Table 5.3-4. Travel time (average, minimum, maximum, and median) for all PIT-tagged shad to reach Vernon fishway and within the fishway.

PIT-Tagged Shad Travel Zones	Average	Min	Max	Median
From Release to Fishway Entrance[a]	8 d 19 h 25 m	2 d 1h 6 m	18 d22 h 48 m	8 d 12 h 3 m
From Release to First Fishway Bend[b]	10 d 21 h 49 m	2 d 1 h 27 m	30 d 18 h 1 m	8 d 16 h 37 m
From Fishway Entrance to First Fishway Bend[a]	19 h 46 m	21 m	4 d 3 h 57 m	2 h 42 m
From First Fishway Bend to Downstream of Counting House Window	11 m	2 m	1 h 52 m	6 m
From Downstream of Counting House Window to Upstream of Counting House Window	20 m	3 m	1 h 38 m	9 m
From Upstream of Counting House Window to Exit	20 h 48 m	32 m	1 d 8 h 40 m	1 h 16 m
From Fishway Entrance to Fishway exit	16 h 35 m	1h 7 m	4 d 5 h 28 m	3 h 56 m
From Release to Fishway Exit	10 d 4 h 58 m	3 d 12 h 38 m	20 d 17 h 48 m	9 d 18 h 40 m

a. For the number of PIT-only tagged fish detected at the entrance only (N=39).

b. For the number of PIT-only tagged fish detected at the first bend (N=68).

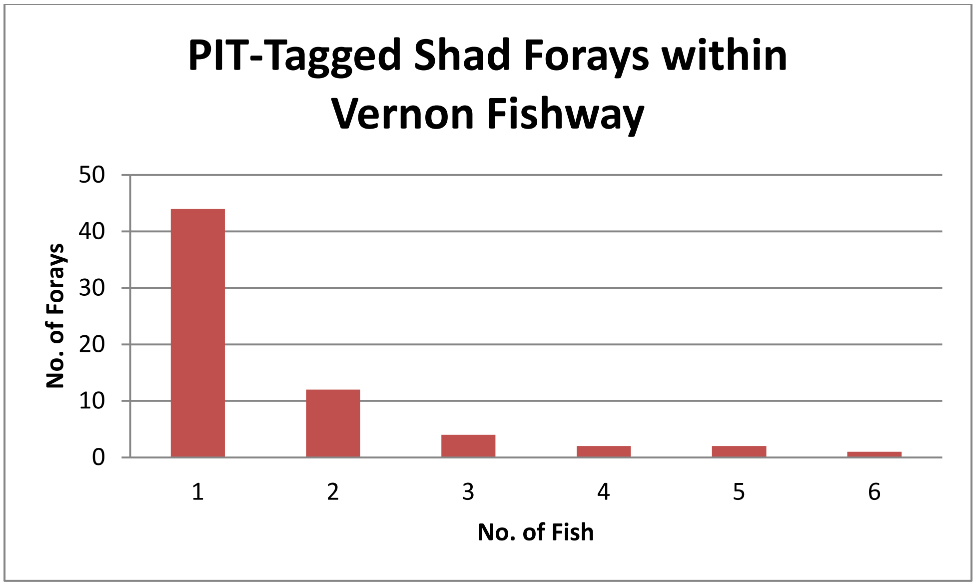

Figure 5.3-2. Forays by PIT-tagged shad detected within the Vernon fishway, spring 2015.

5.3.2 Upstream Fish Passage Efficiency and Effectiveness

Of the 104 fish entering the fishway, 70 were detected passing the counting house window for an Upstream Fish Passage Efficiency of 67.3% (Table 5.2-2). Travel time between these two detection points for fish detected at the entrance ranged from 2 minutes to 4 days, 2 hours, 3 minutes; median time was 2 hours, 28 minutes.

Fifty-three shad subsequently passed into the forebay and remained upstream for more than 48 hours for an overall Upstream Fish Passage Effectiveness of 51% (Table 5.2-2). Travel time from the counting house window to the exit for successfully passed fish ranged from 32 minutes to 1 day, 8 hours, 40 minutes; median time was 1 hour, 19 minutes.

Dual-tagged Shad

Twelve of the 36 dual-tagged shad that entered the fishway successfully passed for an Upstream Fish Passage Effectiveness of these fish of 33.3% (Table 5.2-2). Average time from the tailrace entrance to exit was 7 hours, 58 minutes; and the median time was 3 hours, 31 minutes (Table 5.3-3).

Seven of the 12 (58.3%) dual-tagged shad passed the Vernon fishway on their first foray. The remaining five (41.7%) made one or more unsuccessful forays before passing upstream into the impoundment. One of these made three unsuccessful forays on two different days. The other four made either one or two unsuccessful forays before successful passage. The 24 dual-tagged shad that were detected in the Vernon fishway but never passed made a total of 40 forays into the fishway. One made a total of 34 forays but never passed.

Overall, the average time for a dual-tagged shad to make a repeat foray into the fishway after a failed attempt was 1 day, 18 hours, 5 minutes; with a median time of 17 hours, 5 minutes. Of the 24 dual-tagged shad that entered the fishway but did not pass, 21 attempted one or two forays. Five of the 12 dual-tagged shad that passed the fishway made repeat forays. The average time for these fish to make a repeat foray into the fishway was 2 days, 6 hours, 35 minutes with a median time of 1 day, 18 hours, 36 minutes.

PIT-Tagged Shad

Forty-one of the 68 PIT-tagged shad that entered the fishway successfully passed for an Upstream Fish Passage Effectiveness of these fish of 60.3% (Table 5.2-2). The average time from the fishway entrance to exit was 16 hours, 35 minutes; median time was 3 hours, 56 minutes (Table 5.3-4).

Thirty of the 41 (73.1%) shad with PIT tags successfully passed on their first foray; 9 (21.9%) passed after one unsuccessful attempt; and 1 (2.4%) passed after two unsuccessful attempts. Twenty-seven of the 68 (39.7%) PIT-tagged shad detected within the fishway did not pass. Of these fish, a total of 24 foray attempts where made. Fourteen shad made a single foray attempt. The average foray duration for PIT-tagged shad was 4 hours, 59 minutes.

The average time for a PIT-tagged shad to make a repeat foray into the fishway was 2 days, 8 hours, 16 minutes with a median time of 1 day 1 hour, 35 minutes. Of the 27 PIT-tagged shad that entered the fishway but did not pass, 9 (33.3%) attempted at least one additional foray. The average time for shad that passed the fishway to make a repeat foray into the fishway was 3 days, 14 hours, 30 minutes with a median time of 2 days, 23 hours, 54 minutes.

For all passed shad that displayed multiple forays within the fishway, the median foray duration for PIT-tagged shad was 2 hours, 45 minutes, compared to 5 hours for dual-tagged shad. All 53 shad passing through the fishway remained upstream for longer than 48 hours. Seventy three percent (30 of 41) of passed PIT-tagged shad passed in a single foray and 50% (6 of 12) of passed dual-tagged shad passed in a single foray. A single foray by both PIT and dual-tagged shad was also most common among shad that did not pass the fishway.

5.3.3 Entrance Conditions

Of the 68 PIT-tagged fish that were detected in the first bend of the fishway, only 39 were detected at the fishway entrance (due to low sensitivity of the PIT monitor at that location), thus these fish along with the 36 dual-tagged fish detected at the fishway entrance were included in the calculation of proportional entry into the fishway relative to water temperature, flows, and operating conditions. The remaining 29 fish had no detection time stamp at the fishway entrance and were excluded from the calculation.

Water Temperature

Shad entry into the fishway occurred at water temperatures ranging from 14.7 to 21.4°C (Figure 5.3-3). Both dual-tagged and PIT-tagged shad made successful and unsuccessful forays into the fishway under various water temperatures.

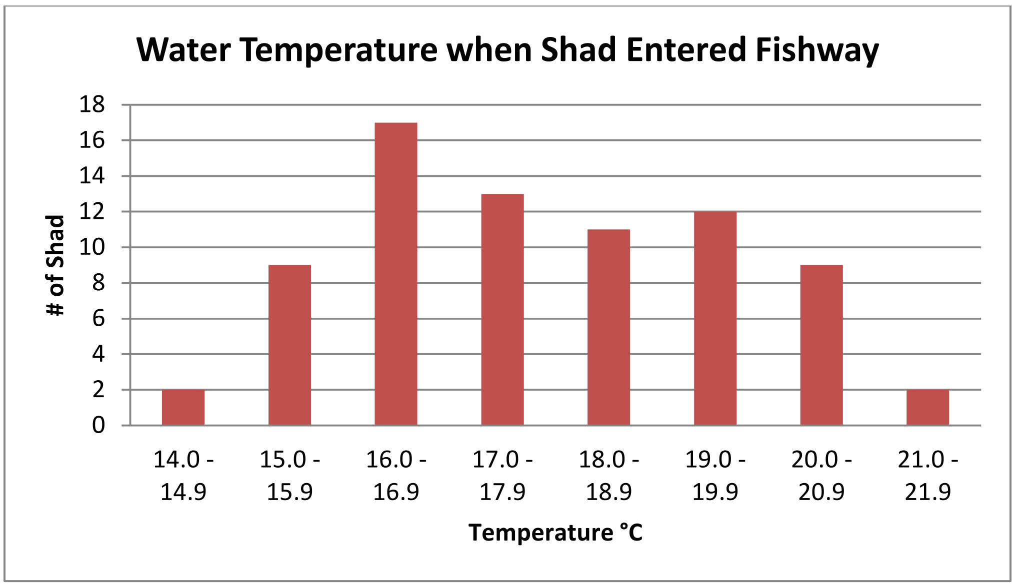

Figure 5.3-3. Water temperatures when tagged shad entered the Vernon fishway, spring 2015.

Passage and Flow

Shad entered the fishway at project discharges ranging from 1,857 to 26,210 cfs and turbine combinations ranging from one to ten units operating. Eighteen (24%) entered in the flow range of 3,000-3,999 cfs, generally with two or three units operating (one entered at 5 units operating with 2 of those at very low discharge). Forty-five (60%) entered at flows between 1,857 and 6,999 cfs, generally with three or four units operating (overall from 1 to 7 units). Two fish (2.7%) entered at flows greater than station nominal generating capacity (Figures 5.3-4, 5.3-5). Two additional fish entered when generation was within nominal generating capacity but one or more spill gates were open at the same time. Five fish (6.7% of the 75 detected at the fishway entrance) entered at night when attraction flow water was off, station discharge ranged from 1,856 cfs to 3,206 cfs, and one or two units were operating (Unit 10 alone, Units 8 and 10 or Units 9 and 10).

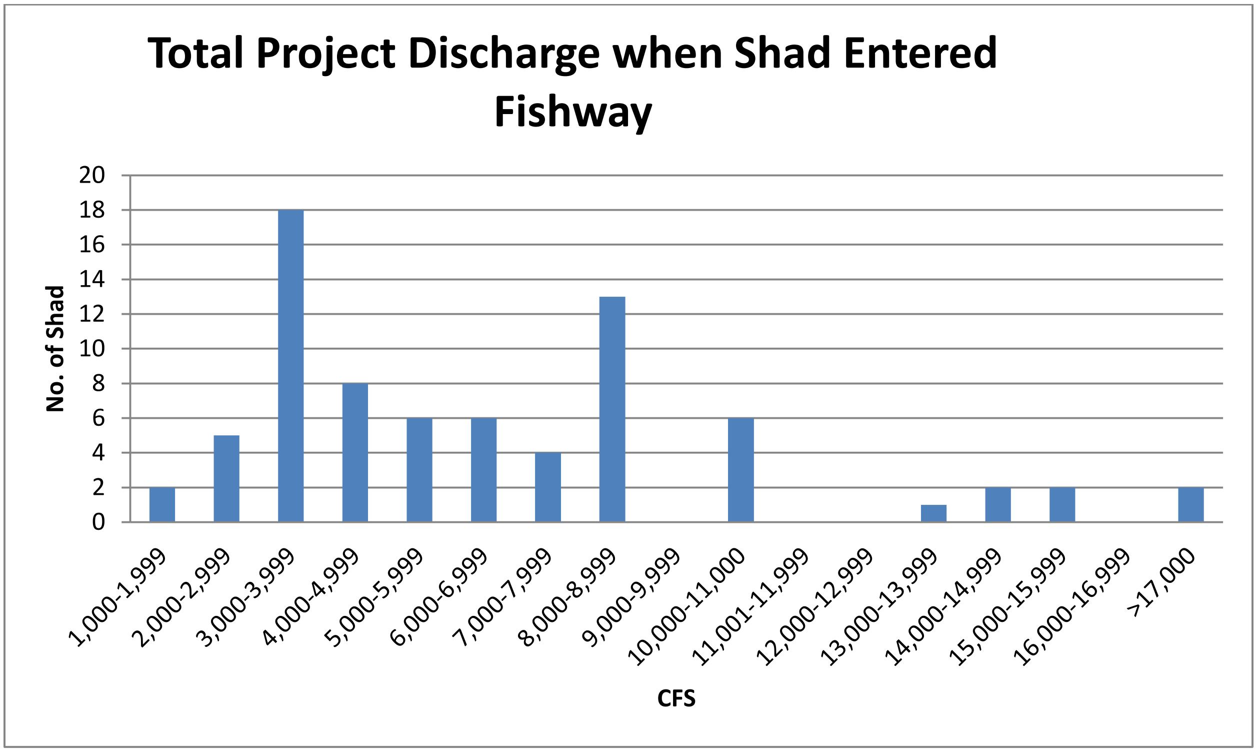

Figure 5.3-4. Station discharge flows when shad entered the Vernon fishway, spring 2015.

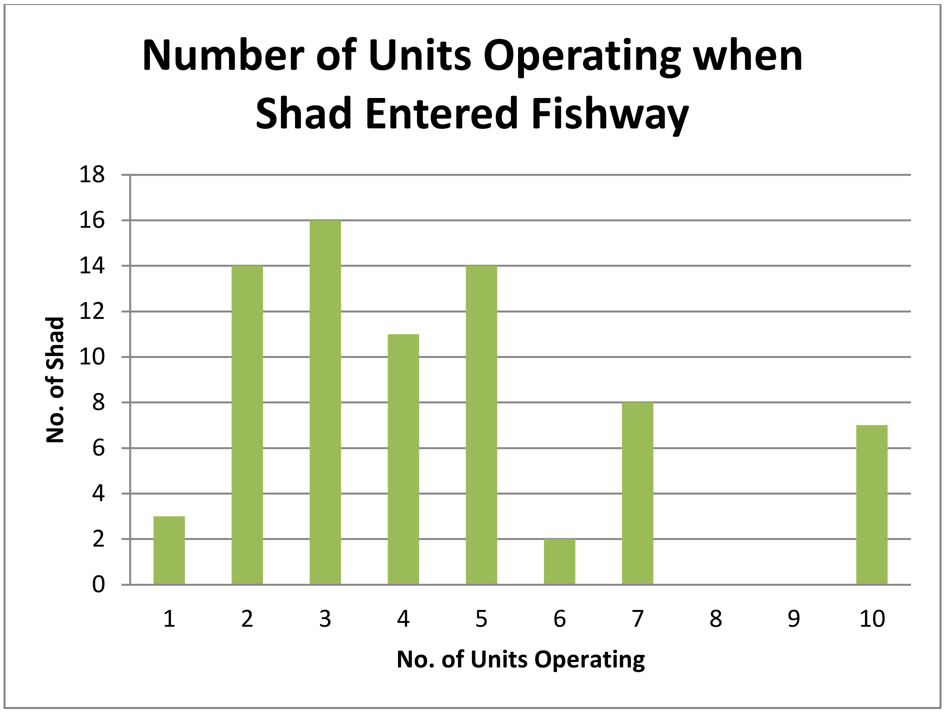

Figure 5.3-6. Number of turbine units operating when tagged shad entered the Vernon fishway, spring 2015.

The most common turbine combination for fish entering the fishway was with three units running (21.3%) and included a combination of either Units 7, 8 and 10; 8, 9 and 10; or 4, 8, and 10. The second most common turbine combination was with five units operating (20.0%) and included combinations of Units 5-8 and 10; Units 6-9 and 10; and Units 4, 5, 7, 8, and 10 (Table 5.3-5).

Table 5.3-5. Turbine operation when tagged shad entered the Vernon fishway.

Number of Units	Generating Scheme (Unit Combinations)	Average Operating cfs During Entry	Number of Shad	% by Generating Scheme	% by Number of Units
1	10	1,443	3	4%	4.0%
2	8,10	2,343	13	17%	18.7%
	9,10	2,751	1	1%	
3	4,8,10	3,198	2	3%	21.3%
	8,9,10	3,293	4	5%	
	7,8,10	3,920	10	13%	
4	6,7,8,10	6,162	8	11%	14.7%
	4,8,9,10	4,610	3	4%	
5	4,5,7,8,10	3,272	1	12%	20.0%
	5,6,7,8,10	7,187	9	7%	
	6,7,8,9,10	7,514	5	4%	
6	4,5,6,7,8,10	7,404	1	7%	1.3%
7	4,5,6,7,8,9,10	5,844	1	1%	10.7%
	3,4,5,6,7,8,10	9,403	7	9%	
10	1,2,3,4,5,6,7,8,9,10	13,375	7	9%	9.3%

5.4 Upstream Movement Assessment

For the upstream migration and spawning study, sixty-five radio-tagged shad were monitored upstream of Vernon dam. Of these, 54 had been collected at the Vernon fishway trapping facility, tagged and released in the forebay. The remaining 11 had passed upstream through the fishway with their radio-tag intact (one of the 12 dual-tag fish that passed the fishway lost its radio tag). All fish were detected upstream on at least one occasion beyond detections within the vicinity of Vernon forebay. Figure 5.4-1 identifies all manual tracking detections throughout the study period and illustrates the broad geographic range of shad movement throughout the study area, including in the reach downstream of Vernon (both fish that later passed downstream and fish that never passed upstream through the fishway). Appendix E (filed separately in ARC and kmz formats) provides a geodatabase of tracking locations.

Eighteen (32.1%) of the 65 shad monitored for the upstream assessment migrated to the Bellows Falls tailrace. Travel time to Bellows Falls ranged from 20 hours, 23 minutes to over 23 days; with a median travel time of 5 days, 16 hours, 29 minutes. Three of the shad that reached Bellows Falls had been collected at Vernon and fifteen had been collected at Holyoke. All but four of the shad reaching Bellows Falls eventually passed downstream of Vernon dam.

Overall, 54 of the 65 (83.1%) shad monitored for upstream migration were later re-located in the Vernon forebay. The time from release in the impoundment or upstream passage through the Vernon fishway to the subsequent initial detection in the forebay ranged from 4 minutes (for a fish that moved into the forebay and immediately moved upstream) to more than 29 days; with a median time of 11 days, 22 hours, 32 minutes; and includes time spent upstream prior to subsequent downstream migration.

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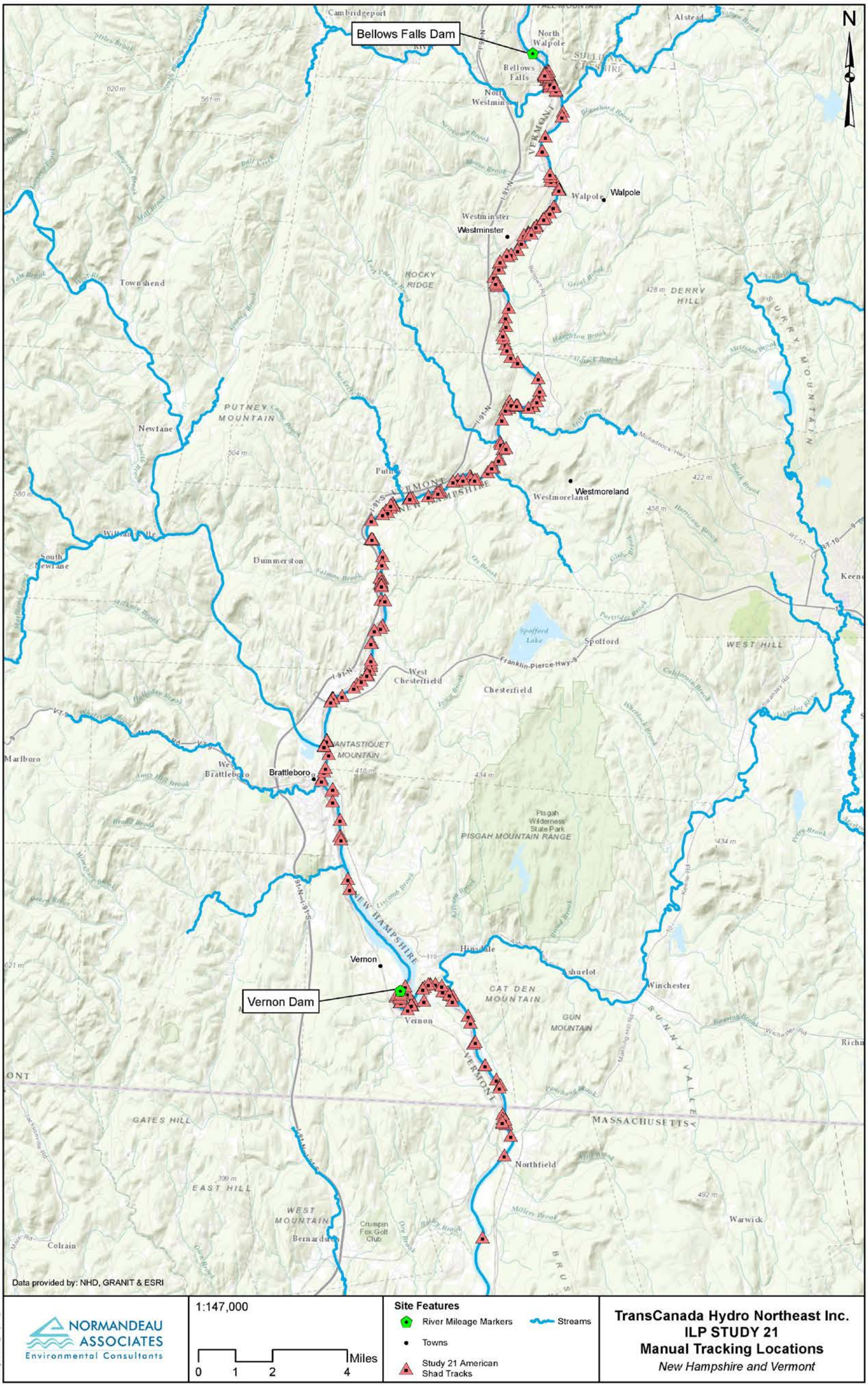

Figure 5.4-1. Adult shad manual tracking locations, 2015.

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5.5 Downstream Passage

Downstream passage was established for 44 of the 54 shad subsequently located in the Vernon forebay after their upstream migration. Of these, 11 (25%) passed through the fish pipe, nine (20%) passed through turbine Units 5 through 8, three (6.8%) passed through turbine Units 9 and 10, seven (15.9%) passed through turbine Units 1 through 4, five (11.1%) passed via an unknown route, and nine (20.5%) used the spillway. None used the smaller fish tube at the Vermont end of the powerhouse (Table 5.5-1, Appendix B).

The status of the remaining ten shad that were located in the forebay but did not successfully pass includes nine that died and became lodged on the trash racks and one with an unknown passage route for which the radio signal became stationary in the tailrace. It is unclear when these fish died as they may have died upstream and drifted into the forebay after spawning; and the one that became stationary may have died either before or during passage.

Most shad passed downstream from May 19 to June 25, with one not passing until July 7. Water temperatures in the Vernon forebay ranged from 14.7°C to 20.9°C (Louis Berger Group and Normandeau, 2016). A slight majority (51.3%, N=20) of fish passed at water temperatures between 18.0°C and 19.9°C (Figure 5.5-1).

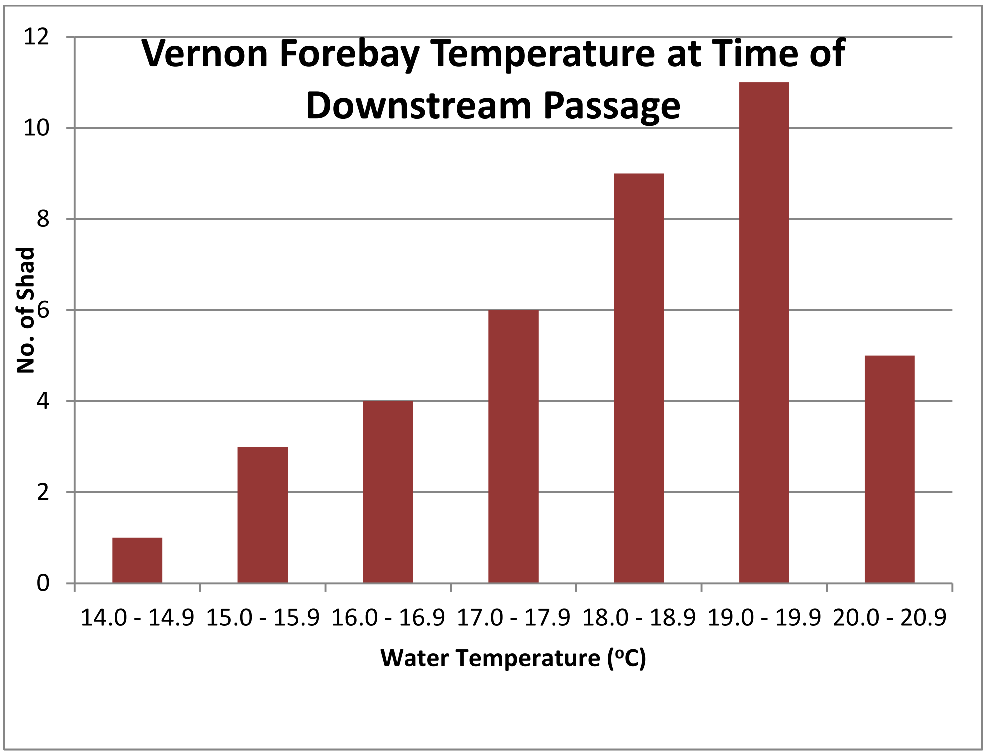

Figure 5.5-1. Forebay water temperature (°C) at the time of downstream passage of adult shad at Vernon, 2015.

Comparable numbers passed during the day and at night. Residency time in the forebay prior to passage ranged from less than one minute to 21 days, 7 hours, 6 minutes; with median residency of 9 hours, 43 minutes.

Total project discharge during downstream passage for the 39 shad with known passage routes ranged from just under 2,000 cfs to over 30,000 cfs with no apparent preferential flow volume (Table 5.1-1, Figure 5.5-2). Turbine combinations during downstream passage ranged from two to ten units operating and most fish (61.5%) passed when all ten units were operating followed by 12.8% when nine units were operating (Table 5.5-1, Figure 5.5-3).

Table 5.5-1. Downstream passage routes of adult American Shad at Vernon dam, 2015.

Route	Number Passed	% Passed	Range of Discharge at Passage (cfs)	No. of Units Operating[a]
Fish pipe	11	25.0	6,154 - 24,615	7, 9 or 10
Turbine Units 5-8	9	20.5	1,965 - 29,907	2, 5, 6, 9 or 10
Turbine Units 1-4	7	15.9	7,002 - 22,667	6, 9 or 10
Turbine Units 9-10	3	6.8	8,267 - 22,667	5, 7 or 10
Spillway	9	20.5	8,798 - 30,690	5 or 10
Unknown	5	11.4	n/a	n/a
Fish tube	0	0	n/a	n/a
Total	**44**	**100.0**		

a. Does not indicate turbine Unit ID numbers.

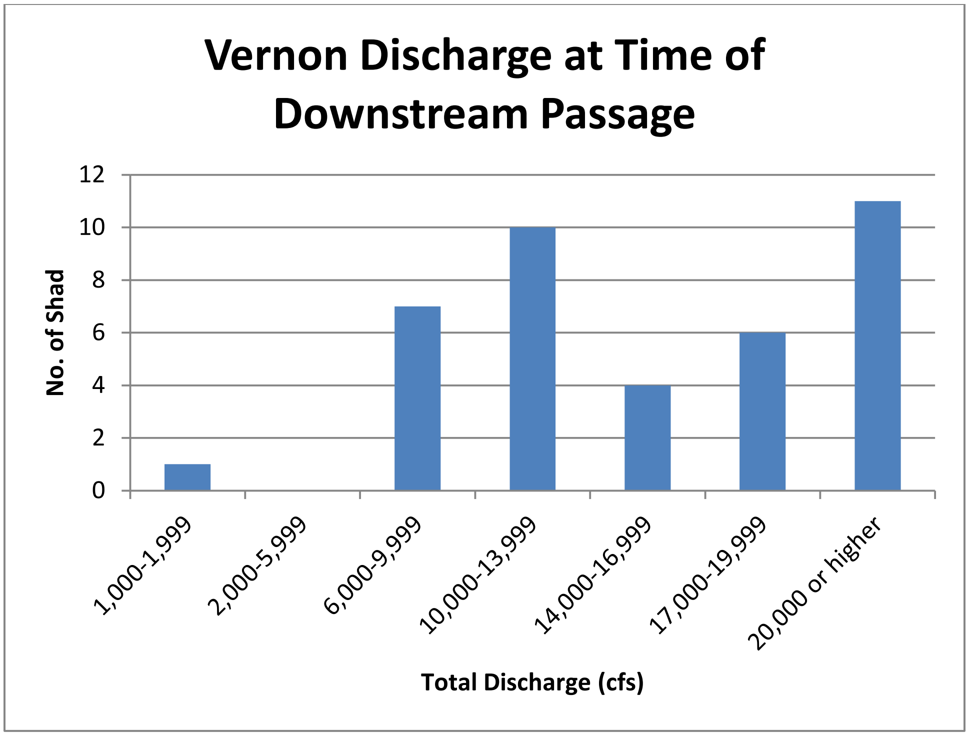

Figure 5.5-2. Project discharge at time of downstream passage of adult shad at Vernon, 2015.

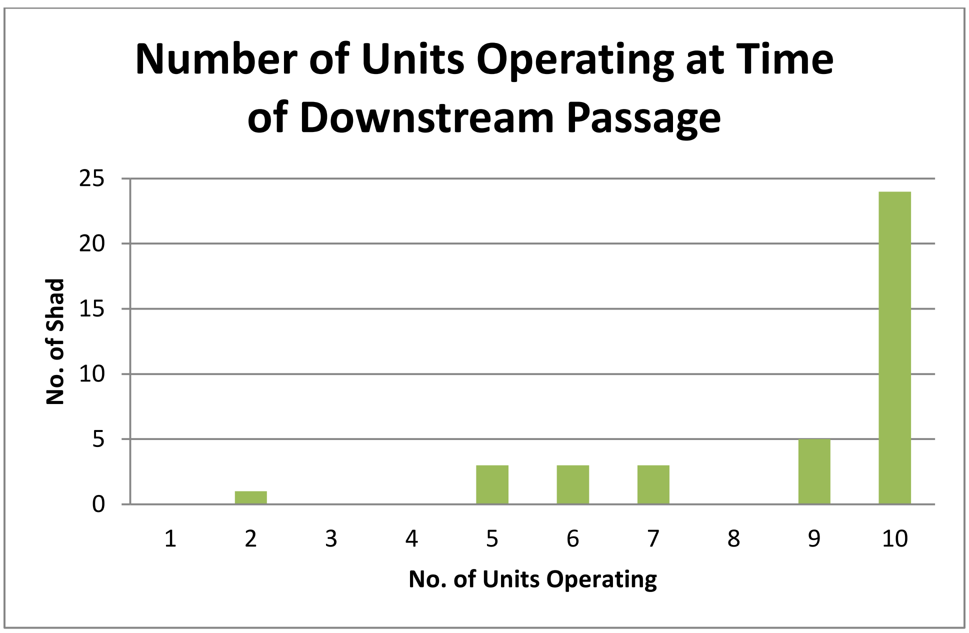

Figure 5.5-3. Number of units in operation at the time of downstream passage of adult shad at Vernon, 2015.

Fish passed by a variety of routes within each discharge range (Table 5.5-1, Table 5.5-2). At flows less than 14,000 cfs most fish passed via the turbines. Between 14,000 and 20,000 cfs half of all passed fish used either the fish pipe or the spillway; and not surprisingly at flows 20,000 cfs or higher most used the spillway. Overall 42.9% of fish that passed during spill used the spillway; five (23.8%) used the fish pipe, three (14.3%) used Units 5-8, another three (14.3%) used Units 1-4, and one (4.7%) used Units 9-10.

Table 5.5-2. Distribution of downstream passage route by project discharge at Vernon dam, 2015.

Route	Number of Shad Passed				
	<10,000 cfs	10,000–13,999 cfs	14,000-16,999 cfs	17,000-19,999 cfs	≥ 20,000 cfs
Fish pipe	1	4	2	2	2
Turbine Units 5-8	4	2	1	1	1
Turbine Units 1-4	1	3	0	2	1
Turbine Units 9-10	1	1	0	0	1
Spillway	1	0	1	1	6
Total	**8**	**10**	**4**	**6**	**11**

Proportional to total project discharge, the fish pipe provides the smallest overall flow (about 350 cfs or 2.7% average during passage) and most fish used that route indicating its effectiveness for that purpose (Table 5.5-3).

From April 15 – July 15 (during normal seasonal upstream passage fishway operations) operating preference is generally given first to Unit 10, followed by Unit 8 or 7, then Unit 9, Unit 5 or 6, and lastly, Units 1-4. On average, Units 9 and 10 accounted for 26.2% of total flow during passage through them, although they were never the only units operating when fish passed via that route. Turbine Units 5-8 are generally operated more frequently (after Unit 10) than other units, due to their higher efficiency and during passage through them accounted for an average of 43.7% of total flow. Units 1-4 operate the least and accounted for 16.3% of total flow when fish passed this route. The spillway accounted for over 42% of total flow on average when that route was used.

Table 5.5-3. Downstream passage routes of adult American Shad at Vernon dam, 2015.

Route	Number Passed	% Passed with Known Route	Average of Proportional Flow at Passage
Fish pipe	11	28.2%	2.7%
Turbine Units 5-8	9	23.1%	43.7%
Turbine Units 1-4	7	17.9%	16.3%
Turbine Units 9-10	3	7.7%	26.2%
Spillway	9	23.1%	42.2%

5.6 Spawning Surveys

Sixty trawl sampling events occurred on 30 nights between May 26 and July 2, 2015. The sampling frequency generally involved sampling for two nights above Vernon and one night below Vernon. This cycle was then repeated. A total of 120 individual ichthyoplankton net samples were collected (Table 5.6-1; Appendix C; and Appendix E).

Sampling sites were located using radio-tagged shad. Once a fish was located via radio telemetry the boat was anchored and the ichthyoplankton nets were fished off the stern. For each event at a given site, two nets were fished simultaneously. Sample effort at each site was 30 minutes to one hour. The number of samples collected ranged from two to six per night (typically four samples per night). During each sampling event flow meters were fixed to the mouth of each ichthyoplankton net. These flow meters provided the distance and volume of water filtered to give velocity at the time the sample was taken. The velocity (ft/sec) during each sample ranged from 0 to 3.2 ft/sec. The average velocity during the course of the study was approximately 1.1 ft/sec and the median velocity was approximately 0.9 ft/sec. Before and during a sampling event an attempt to count splashes from spawning shad was made. Much of the time few to no splashes were noted. When splashes were documented the average count was low at 2-3 splashes per one minute of observation.

Eggs and/or larvae were collected in 46 net samples at 31 of the 60 trawl locations. A total 792 American shad eggs and larvae were collected from May 29 through July 2, 2015. Of these, 774 (98%) were eggs, nine (1%) were yolk sack larvae (YSL), and nine (1%) were post yolk sack larvae (PYSL) (Table 5.6-1). Figures 5.6-1 – 5.6-7 illustrate that egg and/or larvae collections occurred throughout the study area and also in proximity both temporally and spatially to trawls that yielded no egg/larvae collections.

Table 5.6-1. Summary of American Shad eggs and larvae collections, 2015.

Date	Sample Location[a]	Life Stage[b]	Number Collected
5/29/2015	21-013	egg	2
		YSL	2
5/31/2015	21-017	egg	39
		YSL	1
5/31/2015	21-018	egg	20
6/1/2015	21-019	egg	65
		PYSL	1
		YSL	1
6/1/2015	21-020	egg	39
		PYSL	3
		YSL	3
6/3/2015	21-025	egg	3
6/3/2015	21-026	egg	1
6/3/2015	21-027	egg	1
6/5/2015	21-033	egg	20
6/5/2015	21-034	egg	3
6/5/2015	21-035	egg	19
6/5/2015	21-036	egg	25
6/9/2015	21-043	egg	2
6/10/2015	21-045	egg	2
6/10/2015	21-046	egg	1
6/10/2015	21-047	egg	3
6/11/2015	21-049	egg	1
6/11/2015	21-051	egg	25
6/11/2015	21-052	egg	20
		YSL	1
6/13/2015	21-054	egg	109
6/14/2015	21-059	egg	2
6/15/2015	21-062	egg	1
6/15/2015	21-063	egg	15
6/15/2015	21-064	egg	19
6/17/2015	21-070	egg	1
6/17/2015	21-071	egg	2
6/17/2015	21-072	egg	4
6/19/2015	21-074	egg	1
6/19/2015	21-075	egg	39
6/19/2015	21-076	egg	2

Date	Sample Location[a]	Life Stage[b]	Number Collected
6/20/2015	21-078	egg	1
6/20/2015	21-080	egg	1
6/22/2015	21-084	egg	3
6/23/2015	21-086	PYSL	2
6/23/2015	21-087	PYSL	2
6/23/2015	21-088	YSL	1
6/24/2015	21-090	PYSL	1
6/26/2015	21-097	egg	119
6/26/2015	21-098	egg	117
6/26/2015	21-099	egg	2
6/26/2015	21-100	egg	14
6/30/2015	21-110	egg	1
6/30/2015	21-111	egg	11
6/30/2015	21-112	egg	10
7/2/2015	21-117	egg	1
7/2/2015	21-118	egg	8

a. Sample locations are geo-referenced in Appendix C.

b. YSL = yolk sack larvae, PYSL = post yolk sack larvae

For each sampling event, water quality parameters including water temperature, pH, turbidity, conductivity and dissolved oxygen (DO) were measured (Appendix D). Temperature among all sites ranged from 11.7°C to 21°C over the course of the study. Temperatures were lowest in the first week of June and highest in the third week of June. All pH measurements taken over the course of the study were within the New Hampshire and Vermont state standards, between 6.5 and 8.0 standard units (su) (8.5 su for Vermont) for Class B waters. Turbidity ranged from less than 1 NTU to 37.9 NTU with 78% of all measurements less than 10 NTU and another 16% less than 20 NTU. Conductivity measurements across all sites and sampling rounds ranged from 10 to 170 µS/cm. Fifty-one percent of conductivity measurements were less than 100 µS/cm; 49% were between 100 and 170 µS/cm. DO ranged from 5.8 to 13.8 mg/l with one measurement at Site 21-002 (in the Vernon impoundment near Dummerston, VT) on May 26 lower than Vermont's 6.0 mg/l standard, but within New Hampshire's 5.0 mg/l instantaneous standard.

Benthic habitat in each area sampled was generally homogeneous and consisted of sand/silt/clay, gravel/cobble, or occasionally, boulder. Figures 5.6-1 through 5.6-7 illustrate trawling locations (trawl start location), locations where egg and/or larvae were and were not collected, substrate type in impoundment locations, and meso-habitat type in riverine locations. In many cases substrate was not visible so information was based on ILP Study 7 (Normandeau, 2015).

Shad eggs or larvae were collected in all habitat types sampled with the exception of woody debris where only two samples were taken (Table 5.6-2). The distribution of sampling effort by either impoundment substrate habitat type or riverine meso-habitat type ranged from 1.7% over woody debris to 31.7% in pool habitats. Additionally, the proportion of eggs or larvae collected followed a similar trend with no eggs collected over woody debris and the highest proportion (39.1%) were collected in pool habitat. An additional 28.3% of the egg-containing samples were collected in run habitat.

Table 5.6-2. Summary of American Shad egg and larvae collection by substrate/habitat type, 2015.

			Total No. of Samples	**Eggs or larvae present**	**Eggs or larvae not present**
Impoundment Substrate Type	Gravel Cobble	No.	17	3	14
		%		17.6%	82.4%
	Ledge	No.	3	1	2
		%		33.3%	66.7%
	Sand, Silt, Clay	No.	12	4	8
		%		33.3%	66.7%
	Woody Debris	No.	2	0	2
		%		0.0%	100.0%
Total impoundment Samples		No.	34	8	26
		%		23.5%	76.5%
Riverine Meso-Habitat Type	Pool	No.	38	18	20
		%		47.4%	52.6%
	Glide	No.	24	7	17
		%		29.2%	70.8%
	Run	No.	24	13	11
		%		54.2%	45.8%
Total Riverine Samples		No.	86	38	48
		%		44.2%	55.8%
All Samples		No.	120	46	74
		%		38.3%	61.7%

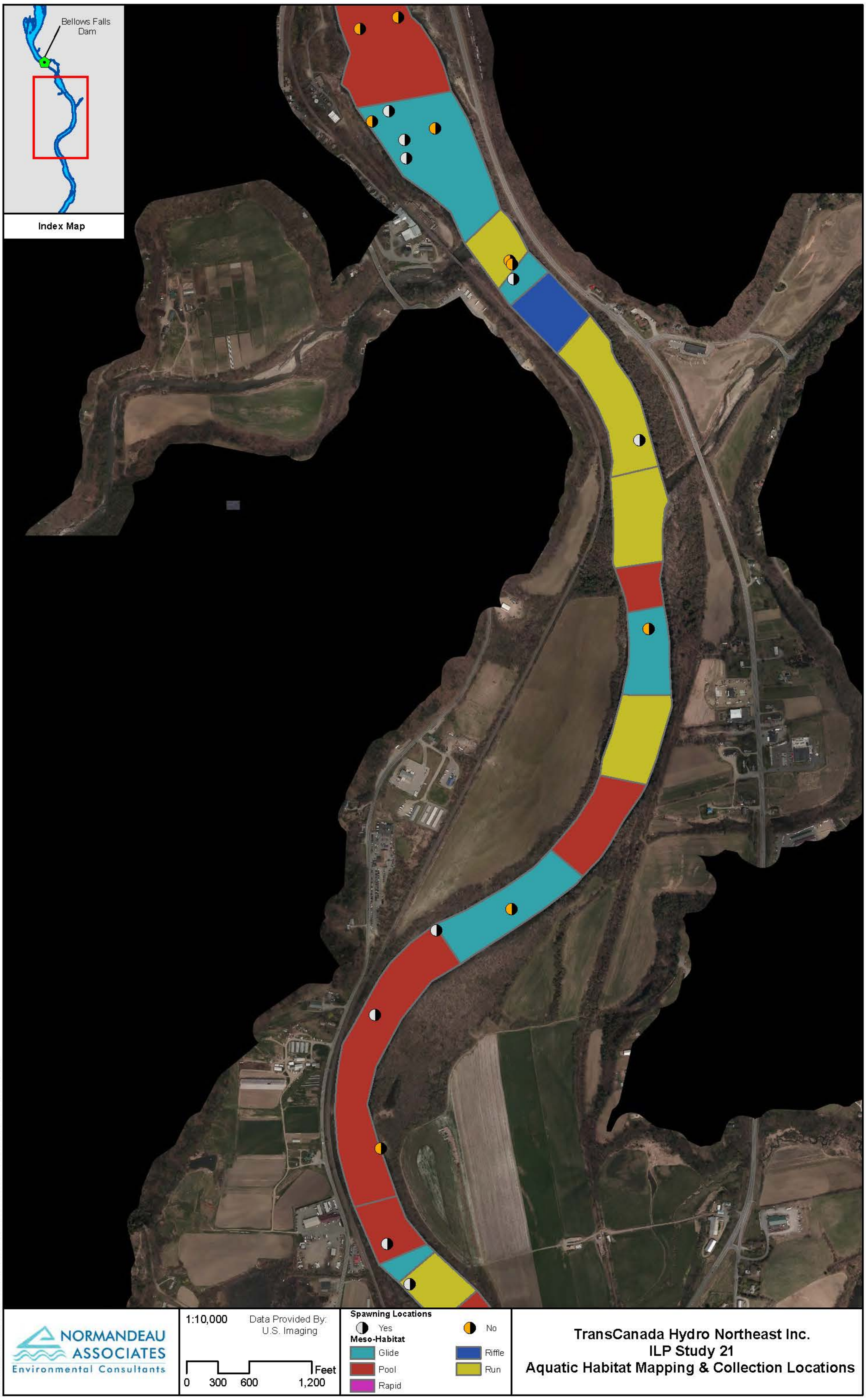

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Figure 5.6-1. Trawl and egg collections, upper Bellows Falls riverine reach.

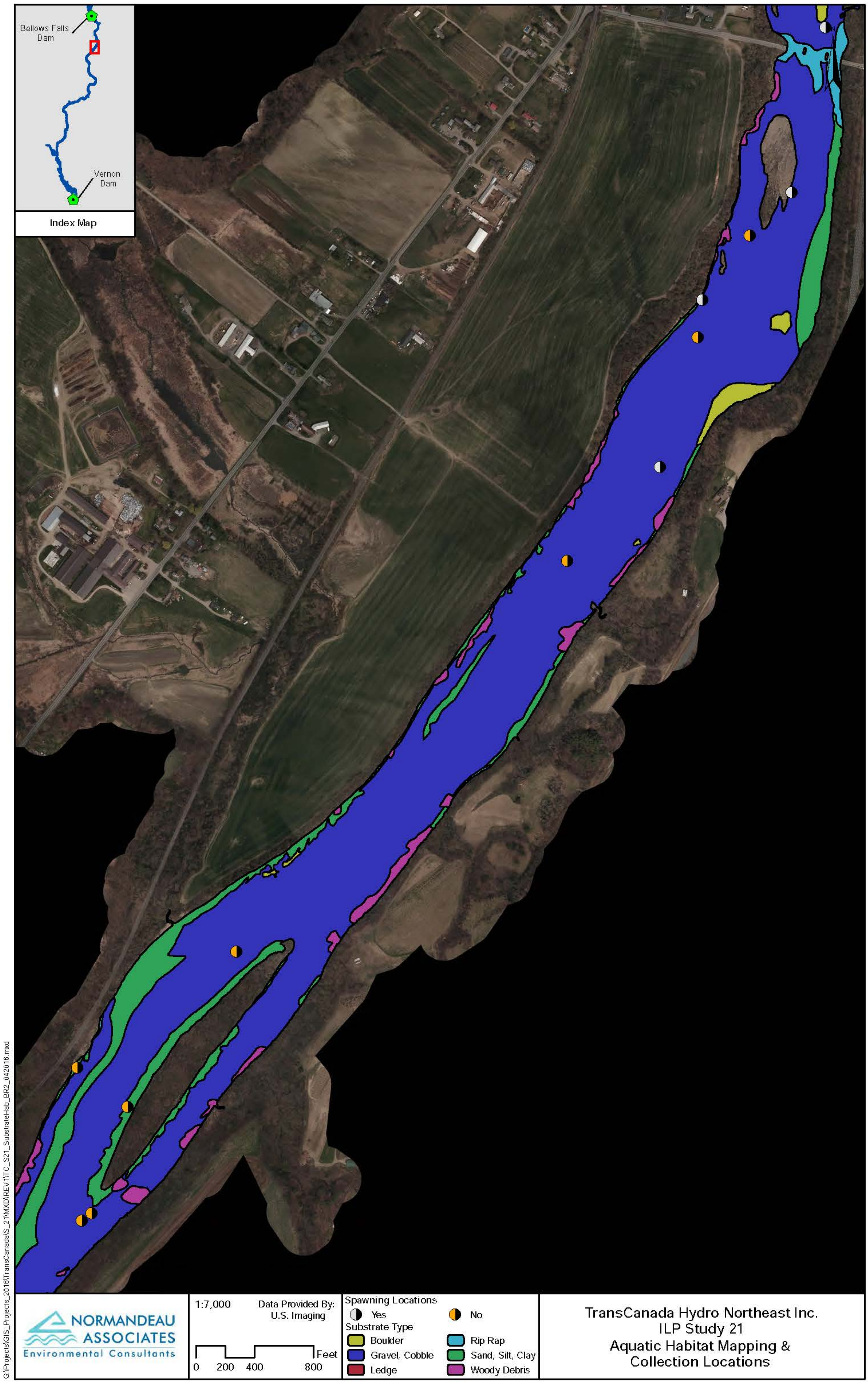

Figure 5.6-2. Trawl and egg collections, lower Bellows Falls riverine reach.

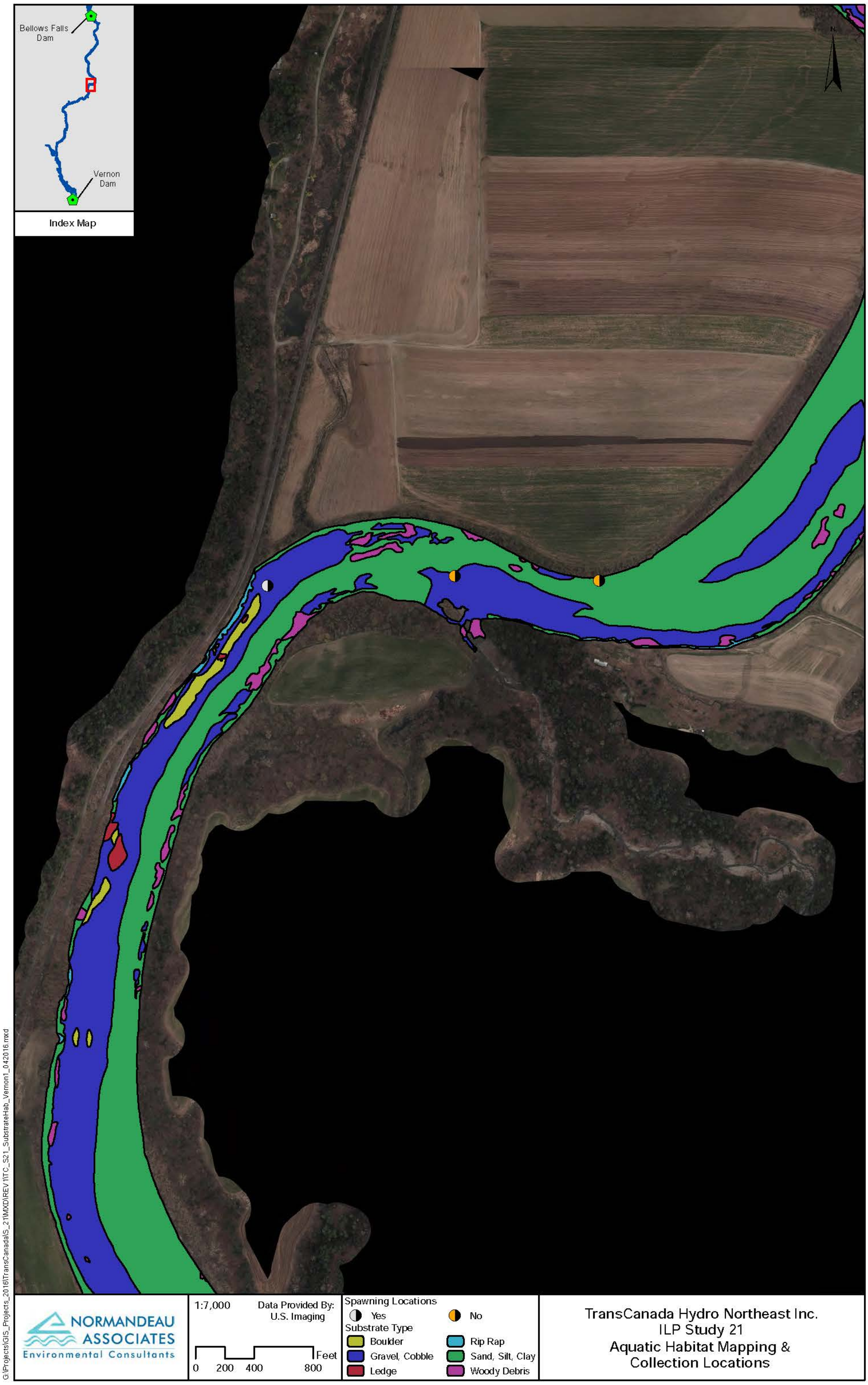

Figure 5.6-3. Trawl and egg collections, upper Vernon impoundment.

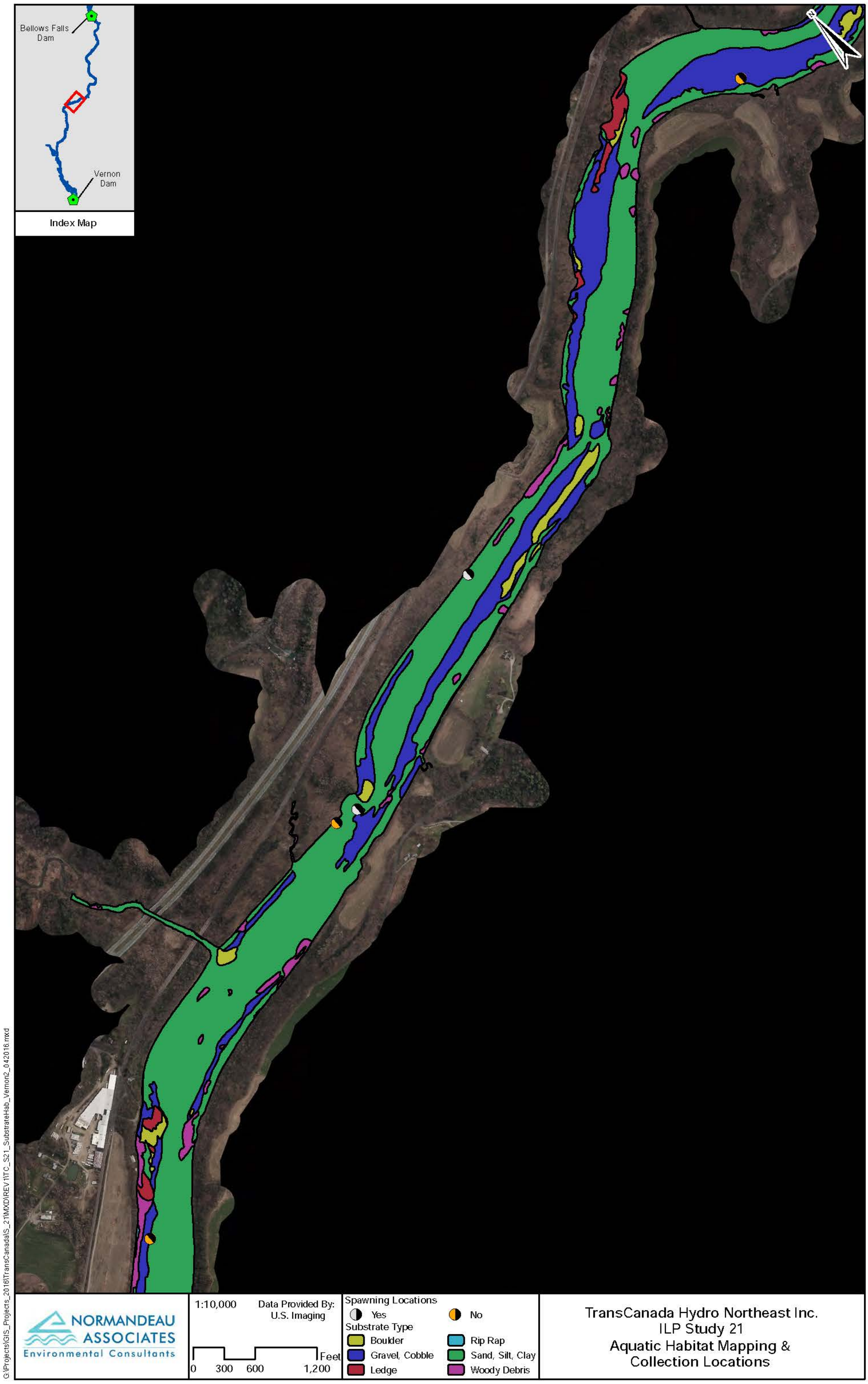

Figure 5.6-4. Trawl and egg collections, upper-middle Vernon impoundment.

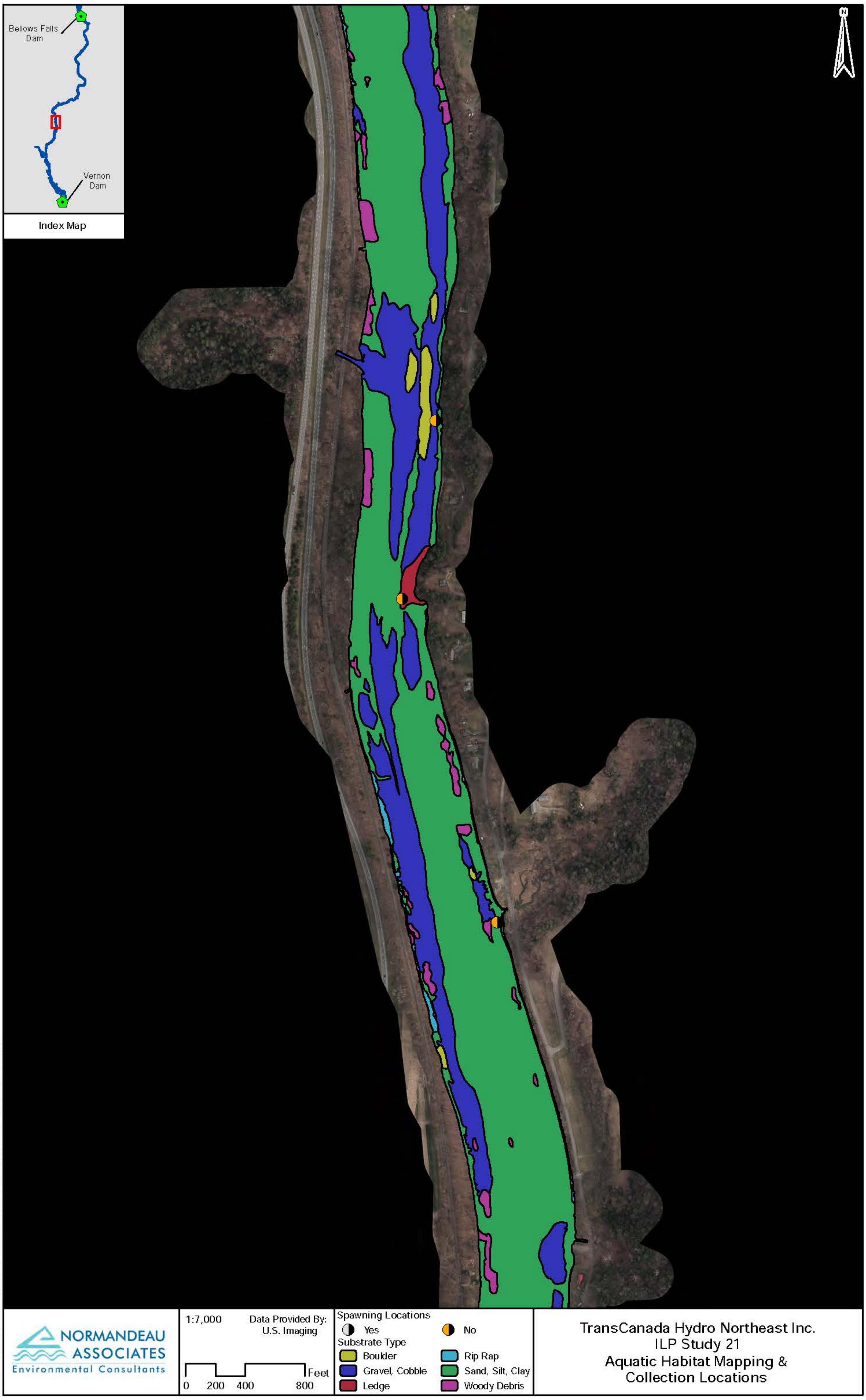

Figure 5.6-5. Trawl and egg collections, lower-middle Vernon impoundment.

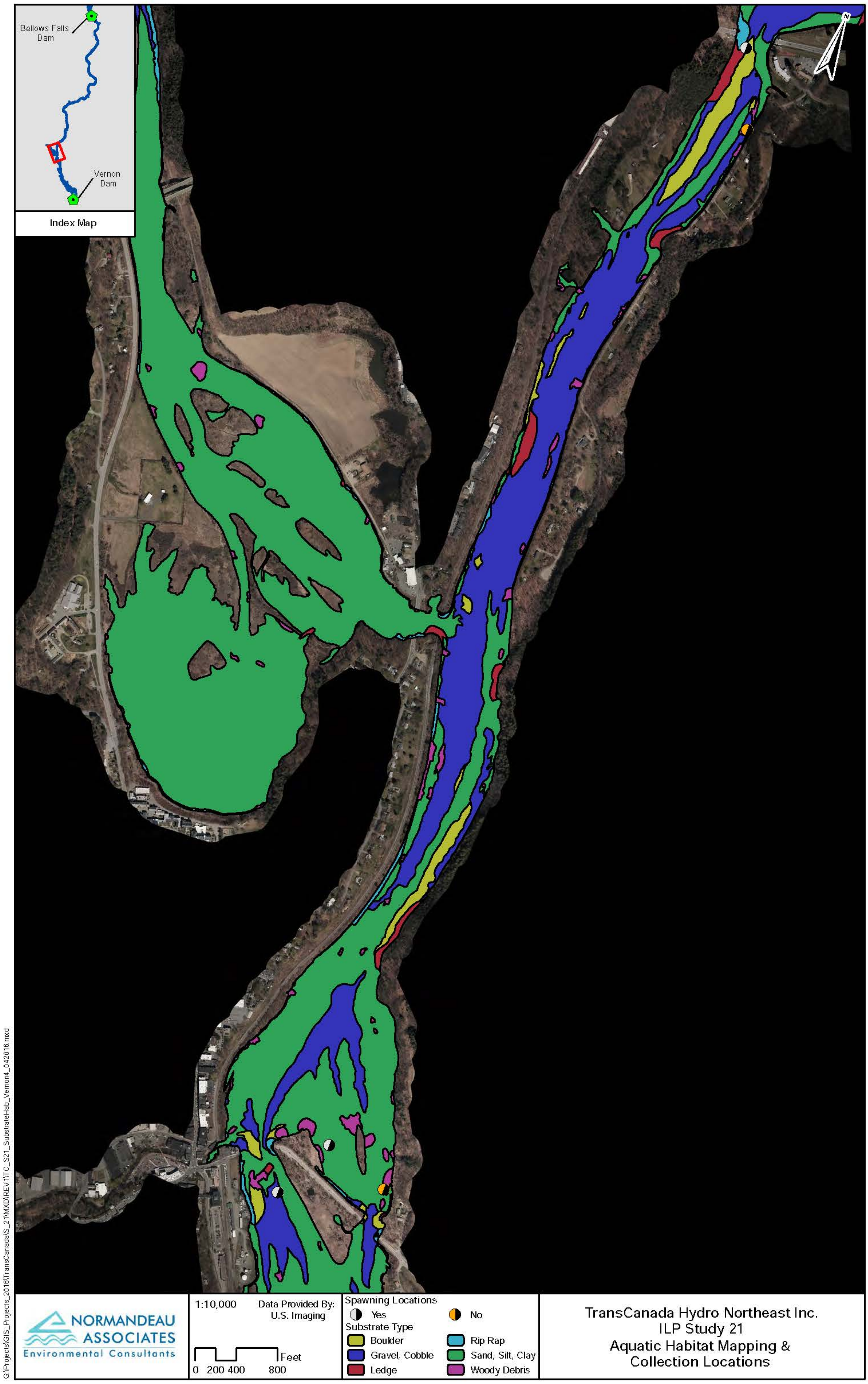

Figure 5.6-6. Trawl and egg collections, lower Vernon impoundment.

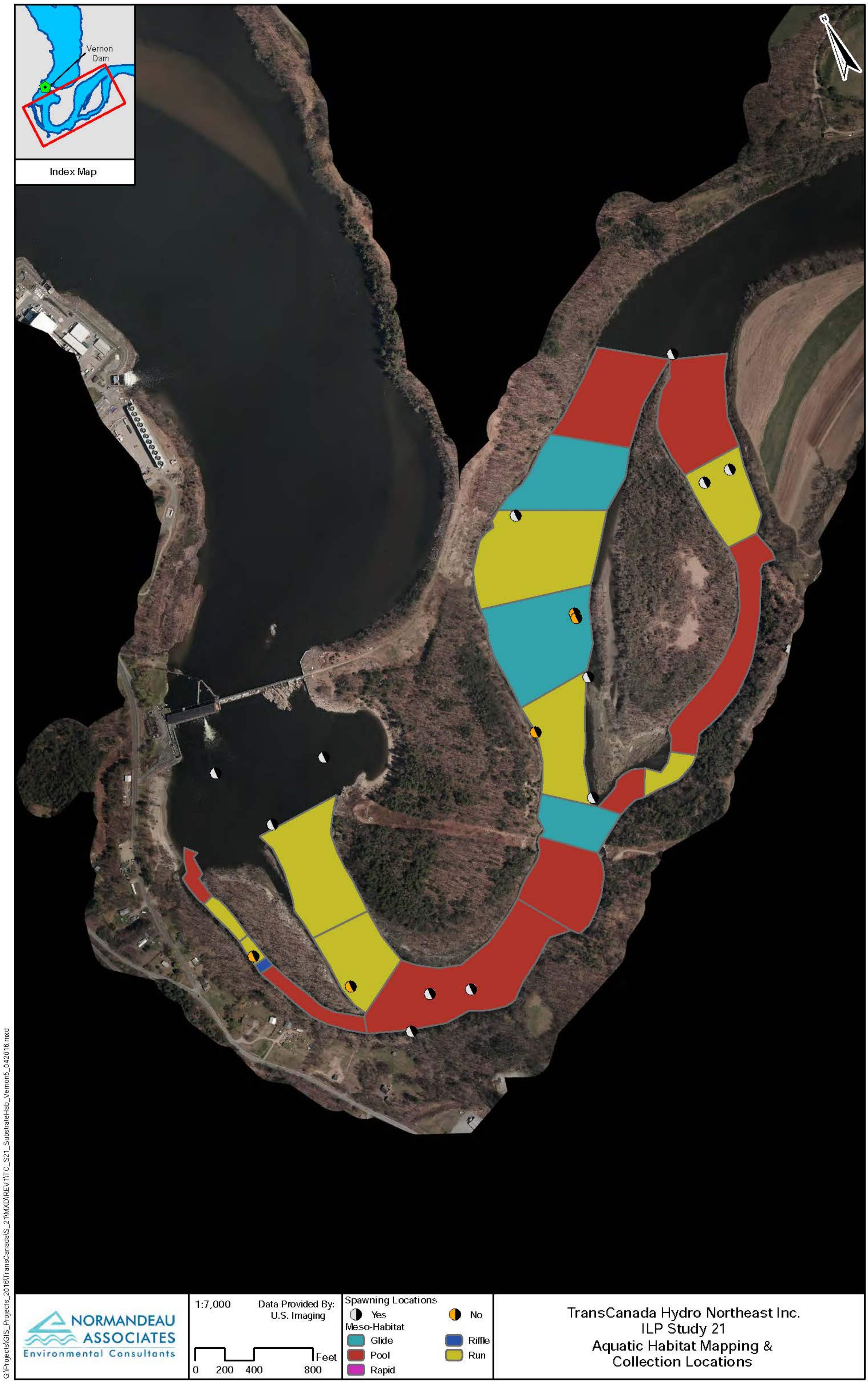

Figure 5.6-7. Trawl and egg collections, Vernon riverine reach.

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6.0 DISCUSSION AND STUDY CONCLUSIONS

6.1 Upstream Passage and Fishway Utilization

To evaluate upstream passage of shad, Fishway Attraction Effectiveness, Upstream Fish Passage Efficiency, and Upstream Fish Passage Effectiveness calculation results were examined.

Fishway Attraction Effectiveness was calculated to be 51.4%. This rate falls within the range of attraction effectiveness values (11.0% - 73.0%) observed at other facilities where similar studies were conducted with adult shad, although the size and configuration of other projects varied (e.g., Normandeau, 2008; Normandeau and Gomez and Sullivan, 2012). Average time from initial detection in the tailrace to entering the fishway was just over 2.5 days. Although not illustrated in Figure 4.3-2, receiver coverage areas overlapped to ensure complete coverage and this resulted in multiple detections at different receivers throughout the tailrace, which does not allow fish micro-movements within the tailrace to be discerned accurately.

For fish that entered the study area but did not enter or pass the fishway, nearly 65% were detected by manual tracking downstream of Vernon and spawning was also documented in that reach. It is likely that these shad lacked the predisposition to continue upstream beyond Vernon.

Upstream Fish Passage Efficiency (those fish that entered the fishway and were detected at the counting house window) was calculated to be 67.3% overall.

The counting house consists of a regulating pool provided with a constant water flow at a constant surface elevation. Fish are guided by flow and crowder screens through a narrow opening and past the counting window. The counting house forms the transition between the lower and longer ice harbor section of 26 overflow weir pools each 12 inches higher than the last, and the upper and shorter vertical slot section consisting of 25 pools each 6 inches higher than the last.

Average travel time was greater through the lower fishway section (11h, 21m) than through the upper section (2h, 50m) but median travel times were not as different: 2 hours, 28 minutes in the lower section compared to 1 hour, 19 minutes in the upper section.

Upstream Fish Passage Effectiveness was calculated to be 51.0% overall which falls within the range (40-60%) of the management objective in the Connecticut River Atlantic Salmon Commission (CRASC) management plan for shad in the Connecticut River (CRASC, 1992). CRASC also reports American Shad upstream passage numbers based on fish ladder/lift counts through projects from Holyoke upstream to Vernon. For 2015, CRASC reported 68.5% of shad that passed Turners Falls also entered the Vernon fishway and passed the counting house window (Vernon data came from Study 17 – Upstream Passage of Riverine Fish Species Assessment, Normandeau, 2016). This rate is comparable to the 67.3% of tagged shad detected upstream of the counting house window in this study. For the three previous years (2012–2014), CRASC reported an average of 53.3% passage at Vernon, again based on counting house window results. Prior years showed lower passage rates at Vernon, due in part to structural and equipment issues that were resolved in 2012.

The difference in fishway effectiveness between tag types (33.3% dual, 60.3% PIT) cannot readily be explained except that additional handling of dual-tagged fish to insert the radio tag, or potentially the effect of the radio tag in addition to the PIT tag stressed or encumbered these fish more than the PIT-tagged fish. But once in the fishway median travel times for successful passage of dual-tagged and PIT-tagged fish to ascend the fishway were similar at 3 hours 31 minutes, and 3 hours 56 minutes, respectively.

6.2 Upstream Movement beyond Vernon and Subsequent Downstream Passage

Approximately 32% of shad released above Vernon dam or passed via the fishway continued upstream to the Bellows Falls tailrace. It is likely that the remaining 68% found suitable spawning habitat in the approximate 31-mile reach between Vernon and Bellows Falls as spawning was documented throughout this reach. All but four of the tagged shad that reached Bellows Falls eventually returned to Vernon dam.

For downstream passage, the fish pipe was the dominant route used, indicating it was the preferred route, followed closely by similar numbers of fish using turbine Units 5 - 8 and the spillway which was operated during several periods of high flows in June. When one or more spill gates including the trash sluice were operating, 42.9% of fish used the spillway; however, a majority of fish used either the fish pipe (23.8%) or the turbines (33.3%) with equal numbers using Units 5-8 and Units 1-4. It is not known which spill gates fish used to pass, but tainter gate No. 2 was operated most frequently alone or in combination with tainter gate No. 1; both are located on the eastern end of the spillway, on the opposite side of the spillway from the powerhouse. Tainter gate No. 3 is located about one-third of the distance from the powerhouse to the eastern end of the spillway and the trash/ice sluice is located directly next to the powerhouse. Both of these gates operated less often and only in combination with gate No. 2. When spill gates were not open, an equal number used the fish pipe and Units 5 – 8 with fewer fish using Units 1-4 and 9-10.

There were no specific patterns to route selection based on time of day or project discharge flows; although most passage (51.3% of those with known passage routes) occurred at spill flows with all ten units operating. One fish passed via the spillway when only five units were operating but a spillway gate was open. Only one fish passed during approximate minimum flow. Since residence time within the Vernon forebay prior to downstream passage was relatively short (median <10 hours) it can be concluded that the ability to locate downstream routes of passage through the Vernon project does not hinder the timing of the emigration.

6.3 Spawning – Assessment of Project Effects

Shad are broadcast spawners and eggs are swept downstream and lodge in the substrate. Shad develop quickly from egg to larval stage and it appears that spring river flows and water temperature are determining factors for survival (Savoy et al., 2004). Larvae drift downstream into areas of reduced velocity along shorelines and backwaters. Shad eggs and larvae were found throughout the study area in a variety of habitat conditions and flows which indicates that the entire study reach is suitable for spawning.

In this study, shad eggs or larvae that were collected in the riverine reaches were collected in three meso-habitat types including pool, glide, and run with pool and run being the dominant habitat types. Layzer (1974) noted that in the Connecticut River downstream of Vernon dam shad spawning locations were primarily in run habitat, and that shad selected discrete spawning sites where they remained for most of the season despite a large area available for spawning. However, Glebe and Leggett (1981) indicated that shad spawn repeatedly as they progressively move upriver. This is supported by Olney et al. (2001) who provided evidence of batch spawning over a period of days or weeks suggesting an increased chance of progeny finding ideal conditions.

A more detailed assessment of habitat suitability needs for shad within the riverine reaches below the Bellows Falls and Vernon dams is being undertaken as part of Study 9 - Instream Flow Study (interim report filed March 1, 2016). The Study 9 habitat suitability selection report (Normandeau, 2014) indicated that the role of substrate in determining spawning locations varies, with research suggesting sizes can range between sand and boulder (Greene et al., 2009); that radio-tagged shad tended to remain in localized areas during the spawning season; and that they were generally found in velocities between 0.20 and 0.69 m/s (0.7-2.3 ft/s), depths between 1.0 and 2.9 meters (3.3–9.5 ft), and substrate that varied from sand and gravel to boulder or bedrock (Harris and Hightower, 2011). The predominant substrate where the majority of eggs and larvae were collected in the Vernon impoundment fell within the size range identified above and was predominantly gravel/cobble and sand/silt/clay.

Project operations during the study period ranged from normal operations to sustained periods of high flow. Figure 6.3-1 shows Bellows Falls average hourly discharge (red horizontal line is the project’s maximum nominal generating capacity) along with water temperature (from the mid-Vernon impoundment from Study 6) and dates of observed spawning. Figure 6.3-2 shows Vernon average hourly discharge (red horizontal line is the project’s maximum nominal generating capacity) along with water temperature (from the Vernon tailrace from Study 6) and dates of observed spawning.

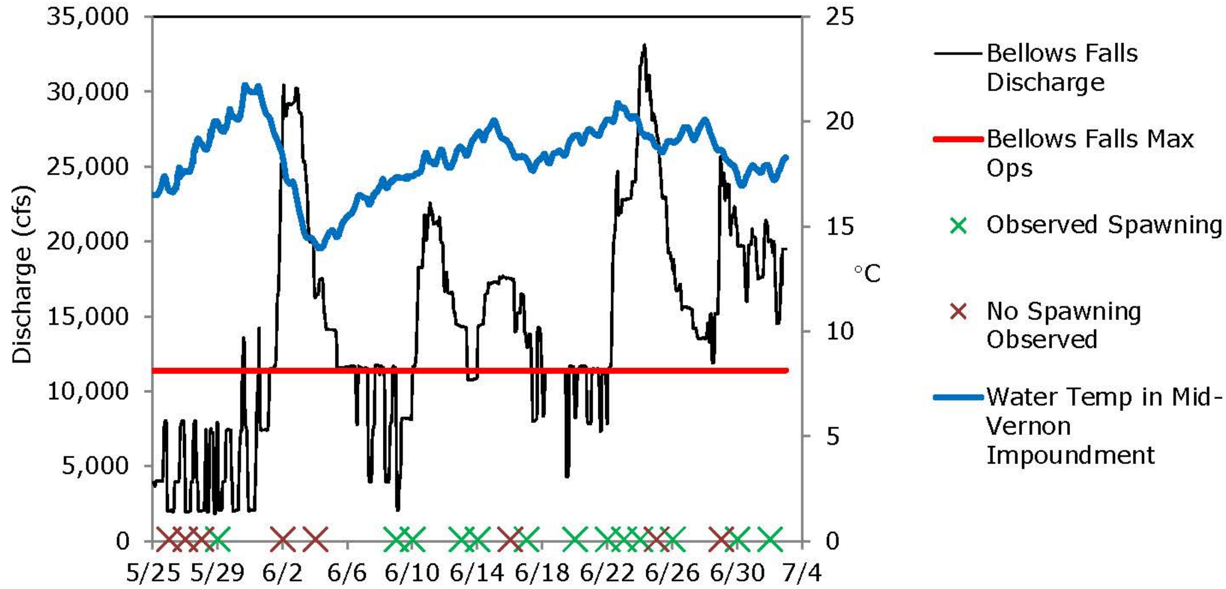

Figure 6.3-1. Bellows Falls discharge, water temperature, and spawning observations downstream of Bellows Falls dam, 2015.

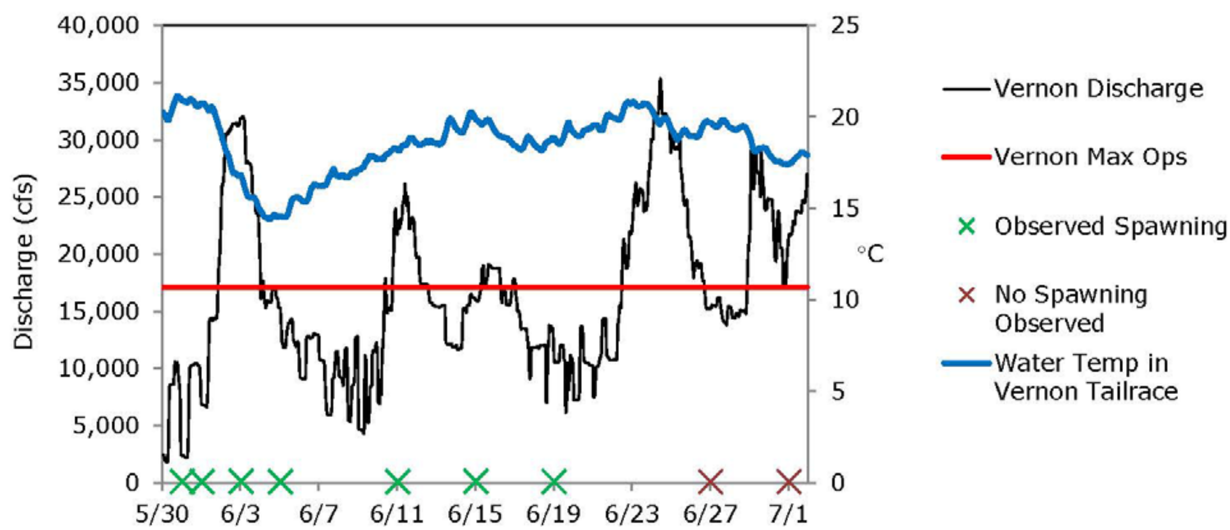

Figure 6.3-2. Vernon discharge, water temperature, and spawning observations downstream of Vernon dam, 2015.

As the figures illustrate, egg and/or larvae collections occurred during both periods of normal operation and during periods of spill above project maximum nominal generating capacity. Spawning was documented throughout the study area and throughout the study period; however, it was more concentrated in the Bellows Falls and Vernon riverine reaches as that is where telemetered shad were mainly concentrated during sampling events. Overall, spawning was documented on 20 of the 30 net sample dates and in locations proximate to net samples with no eggs or larvae collected during the same time periods (and hence during the same operational periods).

While spawning was not documented in the Bellows Falls riverine reach during early June, that period coincided with both high flows and cool temperatures (<15°C). Conversely spawning was documented later in June during a sustained period of high flow but when temperatures were warmer. Based on field-measured water temperatures at the time and location of egg collections, one site in the upper Vernon impoundment yielded two eggs at a local water temperature of 14.7°C.

Downstream of Vernon, spawning was documented at high flows and water temperatures less than 15°C in early June. Based on water temperatures at the time and location of egg collections at several locations at Stebbins Island yielded eggs and/or larvae at local water temperatures between 12.6°C and 12.9°C. No spawning was documented after June 19, however no sampling occurred in that reach between June 20 and June 26 due to sustained high flows throughout much of that period that prevented safe sampling. It is unknown what, if any, influence Turners Falls operations may have had on spawning downstream of Vernon.

The RSP specified that observed effects of project operations on spawning activity were to be classified per operational regime observed as:

1. no effect – no observable effect on spawning; viable eggs were collected;

2. moderate effect – observable possible effect on normal spawning activity; spawning may have been hindered but viable eggs were collected; and

3. adverse effect – project operations likely to have prevented successful spawning of shad; no viable eggs were collected.

Effects classified as 2 or 3 would be correlated to data in the HEC-RAS model in the Hydraulic Modeling Study (Study 4) specific to that location in an attempt to characterize the relative level of project effects that could contribute to potential adverse effects at the specific sites.

However, eggs and/or larvae were collected during a wide range of project discharge flows ranging from normal project operations to high water flows, and collections occurred throughout the study area in close proximity spatially and temporally to locations where they were not collected. Therefore, this effects classification could not be conducted as planned and the hydraulic model does not provide additional useful information to make such an assessment. Overall, based on the results of the spawning investigation it appears that project operations do not have an effect on spawning of American Shad.

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Appendices A – D filed separately as worksheets in a single workbook

Appendix A: Tag and Release Information

Appendix B: Downstream Passage Data

Appendix C: Trawl and Spawning Data

Appendix D: Water Quality Data

Appendix E: supporting geodata filed separately in KMZ and ARC (zipfile) formats