Relicensing Study 3.3.18

IMPACTS OF THE TURNERS FALLS CANAL DRAWDOWN ON FISH MIGRATION AND AQUATIC ORGANISMS

Study Report

Task 1

Northfield Mountain Pumped Storage Project (No. 2485)

and Turners Falls Hydroelectric Project (No. 1889)

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MARCH 2015

EXECUTIVE SUMMARY

FirstLight Hydro Generating Company (FirstLight), a subsidiary of GDF SUEZ North America, Inc., is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for the Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018. This report documents the results of Task 1 of Study No. 3.3.18 *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms*.

Annually, during late September or early October, FirstLight draws down the Turners Falls Canal (canal) to conduct inspections of the civil works as recommended in the 5th Safety Inspection Report. The draining of the canal results in a series of pools, of which a majority were hydrologically connected, located in the lower portion of the canal.

A survey was performed in the lower portion of the canal during the 2014 drawdown to gain an understanding of potential effects of canal drawdowns on aquatic species. Annual drawdowns typically span about one week. Electrofishing and seining techniques were employed to survey fish species in pools (greater than 0.5 feet in depth) remaining in the lower portion of the canal both on the initial sampling event and on the day prior to rewatering. A concurrent survey for mussels, young sea lamprey, and mudpuppies was conducted utilizing 1-m^2 quadrats and hand-searching methods in appropriate soft sediment areas of the canal. Water quality parameters (temperature, dissolved oxygen, turbidity, conductivity and pH) were measured in the pools of the lower canal, as well as at two stations further upstream in the portion of the canal that remains watered during the drawdowns.

Fourteen pools greater than 0.5 feet in depth were identified and sampled on September 29-30[1] (Day 1) and October 3, 2014 (Day 2). The aggregated mean turbidity, water temperature, and conductivity decreased on Day 2 as compared to Day 1. With the exception of three stations, dissolved oxygen levels increased on Day 2. Average pH remained relatively stable.

Over the course of the two sampling events, 22 fish and 1 amphibian species representing 11 families were observed in the pools. Total catch per unit effort (CPUE) of all species combined was comparable between sampling events, indicating that relative abundance of fish restricted to pools in the lower canal was similar over the duration of the drawdown. Species identified are common in the Connecticut River and no endangered, rare, threatened, or special concern species were observed. Spottail Shiner, Tessellated Darter, and juvenile American Shad were the most abundant species observed. As all fishes captured in the pools were alive at the time of collection on both sampling events of Day 1 and Day 2, observed mortalities at the time of sample processing were assumed to be due to handling and temporary holding associated with sampling. Observed sampling mortality for the majority of the species was higher on Day 2 than Day 1.

Quadrat sampling identified two species of mussels, Eastern Elliptio and Alewife Floater, as well as a few individual Sea Lamprey ammocoetes/transformers and mudpuppies. Eastern Elliptio (n=534) dominated mussel observations, as only one Alewife Floater was observed. Of the 32 quadrats sampled, 20 of the

[1] For the purposes of reporting, the sampling event spanning September 29 and 30, 2014, is referred to as Day 1 or the initial survey, and the sampling event of October 3, 2014 is referred to as Day 2 or the prior-to-rewatering survey.

sites contained no mussels, while the CPUE for the remaining sites ranged from 1-133. Mussels tended to be concentrated at sites proximally located to the canal's thalweg. All mussels and young sea lamprey observed during quadrat sampling on both Day 1 and Day 2 were alive, and 2 of the 3 mudpuppies observed were dead.

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canal	Turners Falls Canal
cfs	cubic feet per second
CPUE	catch per unit effort
°F	degrees Fahrenheit
DO	dissolved oxygen
FERC	Federal Energy Regulatory Commission
FirstLight	FirstLight Hydro Generating Company
ft	foot/feet
ILP	Integrated Licensing Process
ISO-NE	Independent System Operator-New England
H	horizontal
hrs	hours
m	meter
MADFW	Massachusetts Division of Fisheries and Wildlife
mg/L	milligrams per liter
NMFS	National Marine Fisheries Service
No.	number
NTU	Nephelometric Turbidity Units
PAD	Pre-Application Document
PSP	Proposed Study Plan
RSP	Revised Study Plan
s	seconds
SD1	Scoping Document 1
SD2	Scoping Document 2
SPDL	Study Plan Determination Letter
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VY	Vermont Yankee Nuclear Power Plant
V	vertical
µS/cm	microSiemens per centimeter

1 INTRODUCTION

FirstLight Hydro Generating Company (FirstLight), a subsidiary of GDF SUEZ North America, Inc., is the current licensee of the Northfield Mountain Pumped Storage Project (Northfield Mountain Project, FERC No. 2485) and the Turners Falls Hydroelectric Project (Turners Falls Project, FERC No. 1889). FirstLight has initiated with the Federal Energy Regulatory Commission (FERC, the Commission) the process of relicensing the Northfield Mountain and Turners Falls Projects using the FERC's Integrated Licensing Process (ILP). The current licenses for Northfield Mountain and Turners Falls Projects were issued on May 14, 1968 and May 5, 1980, respectively, with both set to expire on April 30, 2018.

As part of the ILP, FERC conducted a public scoping process during which various resource issues were identified. On October 31, 2012, FirstLight filed its Pre-Application Document (PAD) and Notice of Intent with the FERC. The PAD included FirstLight's preliminary list of proposed studies. On December 21, 2012, FERC issued Scoping Document 1 (SD1) and preliminarily identified resource issues and concerns. On January 30 and 31, 2013, FERC held scoping meetings for the Northfield Mountain and Turners Falls Projects. FERC issued Scoping Document 2 (SD2) on April 15, 2013.

FirstLight filed its Proposed Study Plan (PSP) on April 15, 2013 and, per the Commission regulations, held a PSP meeting at the Northfield Visitors Center on May 14, 2013. Thereafter, FirstLight held ten resource-specific study plan meetings to allow for more detailed discussions on each PSP and on studies not being proposed. On June 28, 2013, FirstLight filed with the Commission an Updated PSP to reflect further changes to the PSP based on comments received at the meetings. On or before July 15, 2013, stakeholders filed written comments on the Updated PSP. FirstLight filed a Revised Study Plan (RSP) on August 14, 2013 with FERC addressing stakeholder comments.

On August 27, 2013 Entergy Corp. announced that the Vermont Yankee Nuclear Power Plant (VY), located on the downstream end of the Vernon Impoundment on the Connecticut River and upstream of the two Projects, will be closing no later than December 29, 2014. With the closure of VY, certain environmental baseline conditions will change during the relicensing study period. On September 13, 2013, FERC issued its first Study Plan Determination Letter (SPDL) in which many of the studies were approved or approved with FERC modification. However, due to the impending closure of VY, FERC did not act on 19 proposed or requested studies pertaining to aquatic resources. RSP No. 3.3.18 *Impacts of the Turners Falls Canal Drawdown on Fish Migration and Aquatic Organisms*, was one of the studies that FERC did not act upon in the first SPDL. The SPDL for these 19 studies was deferred until after FERC held a technical meeting with stakeholders on November 25, 2013 regarding any necessary adjustments to the proposed and requested study designs and/or schedules due to the impending VY closure. FERC issued its second SPDL on the remaining 19 studies on February 21, 2014, approving the RSP with certain modifications.

The modifications included:

- FERC recommended that FirstLight repeat the survey detailed in Task 1 (Conduct Aquatic Organism Survey of the Canal During 2014 Drawdown) the day prior to canal re-watering and include a comparison of the two survey results in the study report. FirstLight agreed to conduct a second survey on the day prior to scheduled rewatering of the canal and to provide a comparison of the results from the two surveys in the study report.
- FERC recommended FirstLight consult with the United States Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and Massachusetts Division of Fish and Wildlife (MADFW) on two appropriate locations for measuring dissolved oxygen (DO) within the Zone 7 pool. FERC specified that DO measurements at these locations should be conducted in conjunction with each of the two canal drawdown surveys for aquatic organisms. FirstLight

agreed to collect DO concentrations as well as water temperature measurements at two locations in the upper portion of the canal both during the initial and prior to re-watering surveys.

As required by FERC, on June 3, 2014 FirstLight met with the FERC, USFWS, NMFS, MADFW, the Connecticut River Watershed Council, The Nature Conservancy, Don Pugh and Karl Meyer to review Study No. 3.3.18, as well as other studies. At the meeting, an aerial image of the Zone 7 portion of the power canal was provided showing proposed DO sampling locations at the 5th and 11th Street bridges. All parties were in agreement with the proposed sampling locations.

Subsequent to June 3, 2014 meeting, FirstLight had further consultation with resource agencies and the United States Geological Survey's (USGS) Conte Lab relating to the proposed locations and number of quadrats. It was agreed that a total of 30 sites distributed between the banks and channel of Zones 2-6 was appropriate. Further, it was agreed that following the 2014 drawdown survey and review of the results, FirstLight would seek input from agencies on potential mitigation options if determined necessary for implementation during future drawdown events.

1.1 Existing Information

FirstLight annually dewaters the canal to allow for inspection and maintenance of the power canal and appurtenant facilities. The annual canal drawdown typically spans a one-week period and was formerly conducted in July. In response to ISO-NE's peak electrical demand period in the June-mid-September period FirstLight rescheduled the annual drawdowns to occur during a lower demand period in the latter half of September or early October, which coincides with the part of the migration period for some diadromous species. In 2015, the canal drawdown is scheduled for October 5 – 11. Under normal operating conditions (when the canal is watered), downstream migrants are able to utilize the Cabot bypass facility; however, as the canal water level is drawn down, the bypass is no longer available, and available routes of egress (until re-filling occurs) are through the turbine bays at Cabot Station and Station No. 1, as well as various gates within the canal. Although much of the canal bed still has a well-defined channel with water flowing during the drawdowns, some isolated shallow pools and exposed substrate areas remain in the lower portion of the canal. During this period, fish (including lamprey ammocoetes), amphibians (e.g., mudpuppies), mussels, and benthic invertebrates may be prone to desiccation, predation or other sources of mortality.

Juvenile American Shad and American Eel are known to migrate through the project area, including during the canal drawdown period, and Sea Lamprey ammocoetes that burrow in soft substrates until emergence as transformed juveniles have been documented in the lower portion of the canal during previous drawdown events. During the 2011 drawdown, FirstLight, with assistance from Conte Lab staff, delineated the canal into seven distinct zones (Figure 1.1-1) and conducted a visual survey primarily to document the location of pools and estimate the number of stranded juvenile American Shad, although data on other species observed were recorded as well. A significant flood event just prior to the onset of the drawdown most likely contributed to no observations of stranded shad during the 2011 drawdown, although a variety of other species were documented, including Centrarchid and Cyprinid species, Sea Lamprey, Common Carp, Perches, Chain Pickerel, American Eel, and mussels. Numbers observed varied by zone and by species; however, abundance of stranded individuals was greatest in Zones 1-4.

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0 250 500 1,000 Feet

1.1-1 Delineated Segments of Turners Falls Power Canal

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A freshwater mussel survey was also conducted during the September 2011 drawdown of the canal (Biodrawversity, 2012). Ten sites in the canal were surveyed (timed searches), with three of the sites located in the lower, pond-like segment of the canal within the thalweg. The survey targeted habitats most suitable for mussels, which was predominantly finer substrates (silt and sand) in the canal. Only two species of mussels were observed in the lower portion of the canal: Eastern Elliptio (*Elliptio complanata*) overwhelmingly dominated abundance with hundreds to thousands of individuals reported for the three sites; and one individual Alewife Floater (*Anodonta implicata*) was observed at the site just downstream of where the canal begins to widen. Two individuals of a third species, Eastern Floater (*Pyganodon cataracta*), were observed in the upper reach of the canal (Zone 7), which remains wetted during drawdown periods.

1.2 Study Goal and Objectives

The study goal was to identify and evaluate potential measures to reduce adverse effects due to dewatering of the canal for the annual drawdown events. The objectives were to:

1. Assess whether juvenile American Shad and American Eel abundance in the canal increases leading up to the time of its closure, due to delays in downstream passage (e.g., is fish accumulation occurring).
2. Evaluate the level of mortality for juvenile Sea Lamprey from exposure of burrow habitats in the canal.
3. Conduct a survey of fish and aquatic organisms (e.g., freshwater mussels and mudpuppies) during the 2014 canal drawdown to document species presence, estimate relative densities, determine status (stranded, alive, dead), and map wetted areas.
4. Evaluate measures to minimize aquatic organism population impacts of the canal drawdown.

As indicated in the RSP, Relicensing Study Nos. 3.3.3 (*Evaluate Downstream Passage of Juvenile American Shad*) and 3.3.5 (*Evaluate Downstream Passage of American Eel*) will provide information to address Objective No. 1 above. The study described herein addresses Objective Nos. 2 and 3, and as indicated previously, FirstLight will work with the agencies following review of the 2014 drawdown survey results to address Objective No. 4.

2 STUDY AREA AND SURVEY SITE SELECTION

2.1 Description of Turners Falls Canal

The Turners Falls Canal is an approximately 11,500 ft (2.2 miles) long canal leading from the Turners Falls Impoundment to Cabot Station. The original upstream portion of the canal was constructed around 1866, and the canal was subsequently widened, extended, and heightened around 1915. The canal supplies water to two hydroelectric power stations and to other commercial and industrial users downstream. The first 3,900-ft reach of the canal downstream of the gatehouse is rectangular with canal walls varying from masonry to concrete to cut-rock faces. The bottom width ranges from 170 ft at the gatehouse to 123 ft at the end of this 3,900-ft reach. The next 3,300-ft reach has been excavated to a trapezoidal shape with 1.5H:1V slopes on both sides; the canal walls are generally similar to the preceding segment. The remaining segment (about 4,300 ft upstream of the Cabot Station) is essentially a pond covering about 50 acres, which was excavated to provide fill for the canal dikes. The width of the pond is approximately 783 ft at its widest point. The bottom of the pond was not originally excavated. It was a field having an average surface elevation of 159 ft at the upstream end, with a few trees that were removed. The average depth of the pond was about 14 ft when the canal level was raised in 1915.

The last 600 ft of the canal, extending from the "pond" to the Cabot Station, was excavated from rock and has earth and concrete walls. It is generally trapezoidal in shape and riprap was added to the earth portions of the channel slopes for slope protection.

Also associated with the canal are two drainage tunnels (Keith and Copley); a branch canal to FirstLight's Station No. 1 powerhouse; fish passage structures; and, an emergency spillway structure adjacent to Cabot Station. The concrete-lined Keith Tunnel is located in the upper quarter of the canal and serves as the primary means of dewatering the upper portion of the canal (see Figure 1.1-1). The Keith Tunnel typically remains open for the duration of the canal outage period. Copley Tunnel is located in the canal just upstream of where the canal widens out into the pond and has not been used since it was constructed in 1913 due to seepage issues.

During a recent engineering inspection of the canal under de-watered conditions, it was reported that bottom elevations of the pond have changed dramatically since construction in 1915. Areas of higher flow velocities have scoured the bottom and areas of low velocity, particularly where the canal beings to widen, have large silt deposits. The topography of the lower portion of the canal now ranges from large areas of silt deposits, to areas of exposed bedrock, and areas with coarse and fine grain sediments. Appendix A contains photographs taken during the 2014 drawdown showing various substrates types in the lower portion of the canal.

2.2 Study Area

The study area for the fish and aquatic species (freshwater mussels, mudpuppies, and Sea Lamprey ammocoetes) survey encompassed the lower, pond-like portion of the canal. This lower portion of the canal was segmented into six approximately equal zones with the upper, narrower portion of the canal referred to as Zone 7 (Figure 1.1-1). Observations during previous drawdown events indicated that, with the exception of the higher elevation areas of the manmade banks, Zone 7 remains sufficiently wetted to prevent organism stranding during drawdown events; therefore, no biological sampling was performed in Zone 7 (although water quality monitoring was performed as described in Section 3.4 herein).

3 METHODS

The aquatic surveys commenced as soon as FirstLight safety protocols permitted entrance into the dewatered canal following the drawdown process, which occurred at approximately 1300 (Eastern Daylight Time) on Monday, September 29, 2014. Sampling continued until about 1800, just before diminishing daylight prevented accurate observations and jeopardized crew safety. The field crews returned the following morning (September 30) at approximately 0800, completing the initial survey by 1430. As FirstLight had scheduled to rewater the canal on Saturday, October 4, 2014, the second survey was performed (entirely) from approximately 0800-1430 hrs on Friday, October 3, 2014. For the purposes of reporting, the sampling event spanning September 29 and 30, 2014, is referred to as Day 1 or the initial survey, and the sampling event of October 3, 2014 is referred to as Day 2 or the prior-to-rewatering survey.

The study employed standard backpack electrofishing or seining protocols to sample fish in pools (greater than 0.5 ft deep) remaining in Zones 1-6 following the drawdown (see Section 3.1). The locations of pools deeper than 0.5 ft that remained following canal dewatering were approximated by recording GPS coordinates of the upstream and downstream extents, as well as notes regarding the general size, extent and depth of each pool. Quadrat sampling was also performed in Zones 2-6 to identify and enumerate any mussels, mudpuppies, and sea lamprey ammocoetes observed (see Section 3.2 below). Between sampling pools and quadrats crews also took observations of any stranding, noting species and estimating abundance.

3.1 Pool Sampling

3.1.1 Electrofishing

Backpack electrofishing was used to sample shallow areas of pools (generally 0.5 – 3 ft in depth). A single backpack operator with a dip net was accompanied by two additional netters. Each sampling event was standardized by time, such that electrofishing continued for approximately 500 s, or until pool depletion (all fish sampled), whichever occurred first. Collected fish were held in aerated coolers until sampling was completed at a given pool, after which they were identified to species, counted, assessed for condition (alive or dead), and released to the pool of collection. The same pools were sampled during both Day 1 and Day 2 sampling events. Water temperature (°C), dissolved oxygen (DO), pH (standard units), conductivity (µS/cm), and turbidity (NTU) were measured and recorded at each sampling location prior to or during fish collection. In addition, any stranded fish observed in proximity to the wetted perimeters were identified and enumerated. All data were recorded on field data sheets and entered into an Excel spreadsheet for later analysis.

3.1.2 Seining

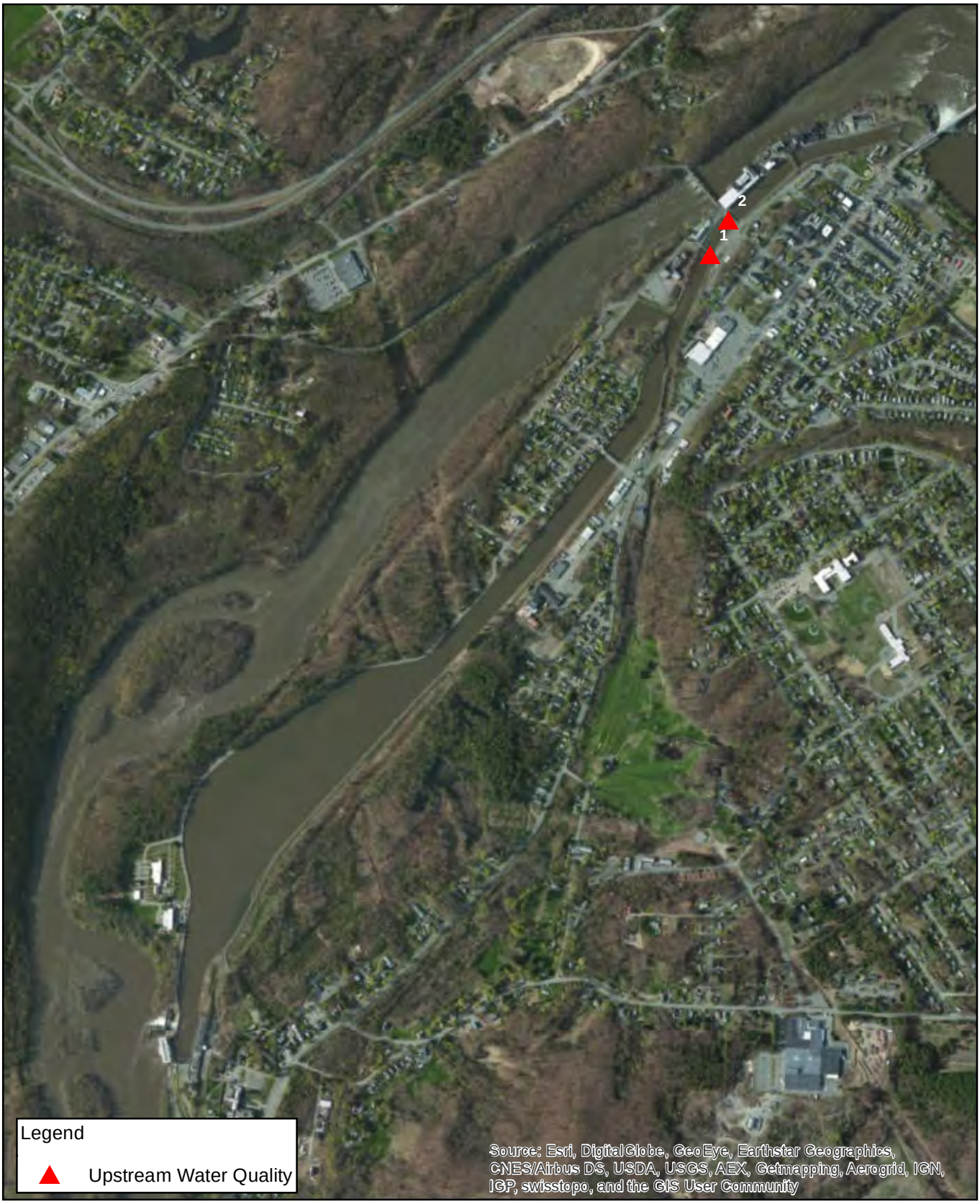
A 25-ft long by 3-ft high beach seine (0.25" mesh) was used in pools conducive to seining (i.e., relatively smooth bottom and no major obstructions) and where backpack electrofishing would not be effective. Beach seines were deployed by two people, each holding a pole at the end of the wing and towing the net through the wetted area. At the conclusion of the seine sampling event, the wings of the net were brought together and the bag was hauled to an appropriate area where the net content was sorted for fish identification and enumeration. Similar to processing of electrofishing samples, each fish was identified to species, counted, assessed for condition (alive or dead), and released to the pool of collection. Water temperature (°C), dissolved oxygen (DO), pH (standard units), conductivity (µS/cm), and turbidity (NTU) were also measured and recorded at each sampling location.

3.2 Quadrat Sampling

In Zones 2-6, soft substrates suitable for mussel and/or lamprey ammocoete habitat were surveyed utilizing a 1-m^2 quadrat within each of the five zones, for a total target of 30 quadrat samples (2 additional quadrats were surveyed for a total of 32 quadrat samples). As requested by stakeholders at least 10 quadrats were located along the each side of the canal and 10 were located in the thalweg. The quadrats were stratified by bank and channel, with two quadrats located at each of the banks and two in the center channel/thalweg area of each zone. On Day 1, each quadrat was geo-located with a handheld GPS unit and photographed. Once a quadrat location was selected, a 3-biologist team systematically searched the substrate within the boundaries of the quadrat for mussels, lamprey ammocoetes, and mudpuppies using hands and small hand tools (rake, hoe, and shovel). Organisms observed were identified to species, assessed for physical condition (alive or dead), enumerated, and released to adequately wetted areas. For sea lamprey, lifestage (ammocoete versus transformer) was also recorded, with juveniles distinguished from ammocoetes based on eye development (NYSDEC, 2015). As sampling disturbed the substrate within each quadrat and animals were relocated following identification, Day 2 quadrats were placed adjacent to the Day 1 quadrat locations. Organism counts and condition assessments were recorded on standardized, waterproof field sheets, as well as information to characterize the predominant substrate types within each quadrat.

3.3 Upper Canal Water Quality Monitoring

Water temperature, dissolved oxygen, and pH were measured at two locations (Figure 3.3-1) in the upper portion of the canal (Zone 7) during both the initial survey (Day 1) and the prior-to-rewatering (Day 2) survey. Instantaneous readings were collected by lowering the probe of a handheld water quality instrument (YSI Model 550) from a bridge to approximately mid-depth in the water column. Readings were recorded on standardized field sheets and entered into a Microsoft Excel database for later analysis.



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Feet

3.3-1 Upper canal water quality monitoring locations

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3.4 Data Analyses

Catch per unit effort (CPUE) was determined for both pool sampling techniques, with effort at electrofishing sites expressed in units of time (seconds) and at seine sites expressed as area swept (width of seine X length of pool swept). Standard error of CPUE for electrofishing was calculated using ratio estimation to account for varying sampling effort among pools (Hansen et al. 2007). CPUE and standard error were calculated using the formulas:

$$\hat{R} = \frac{\sum y}{\sum x} \qquad SE(\hat{R}) = \frac{1}{\sqrt{n}\,\bar{x}}\sqrt{\frac{\sum(y-\hat{R}x)^2}{n-1}}$$

Where y is the catch (count of fish), x is effort (seconds), and n is the number of sample sites (Hansen et al. 2007).

CPUE for quadrat sampling was calculated as the number of organisms (mussels, mudpuppies, or lamprey ammocoetes) per area sampled (m^2). CPUE and sampling mortalities between sampling events (Day 1 and Day 2) was compared. A logistic regression was performed on sampling mortalities with CPUE and sampling day as factors. Further, a binomial test assessed sampling mortalities between days, while a contingency table analysis evaluated sampling mortalities among species families and day, and among hydrologically connected/ hydrologically isolated pools and day using a chi-square test of independence.

4 RESULTS

Results for pool and quadrat sampling are summarized in the following sections. Although the initial survey spanned two calendar dates, the entire initial survey was completed within nearly a 24-hr period.

4.1 Pools

Overall, 14 pools greater than 0.5 ft in depth were identified and sampled for fish on both Day 1 and Day 2 (Figure 4.1-1; Table 4.1-1). Each of the ellipses depicted on Figure 4.1-1 represents the area in which each pool is contained rather than depicting the exact area/perimeter of the pool. The pools were concentrated in the thalweg of the canal, between Zones 1-4, and ranged from approximately 0.0-5.0 ft in depth. Additional wetted areas were observed along the bank adjacent to Migratory Way, in Zones 4 and 5 and partially into 6; however, these areas were generally void of stranded organisms and did not meet the 0.5 foot depth criteria for quantitative sampling. Large scale strandings were spatially isolated (photos 21 – 23), and typically found in depressions within the canal region east of the hydrologically connected pools. As seen in photos 21-23, species composition varied and no one species was dominant. Strandings were highly spatially correlated and generally consisted of multiple species indicating that the fish were aggregated before water drained. It was noted that the pools at Stations 1, 2, 3, 6, 7, 8, 10, 11, 12, 13 and 14 were hydrologically connected with flow directed downstream toward Station 1 in Zone 1. The remaining Stations (4, 5, 9) were isolated pools that were not hydraulically connected to the other Stations. Flow between pools, seepage patterns and/or evaporation may have contributed to the discrepancies in pool depths between sampling events. Further upstream, in Zone 6, riprap generally composed of 2-10 inch diameter stones spans the canal bed and acts as a weir, such that flow in a large pool at the upstream end of Zone 6 was directed upstream towards Zone 7. Although slightly diminished, the flow remained apparent on the day prior to rewatering (Day 2). As fish would be able to access Zone 7 through the weir, no quantitative sampling was performed in that pool.

On Day 1, turbidity ranged from 0.1 to 55.2 NTU; water temperature ranged from 17.1 to 23.5 °C; conductivity ranged from 168.0 to 477.0 µS/cm; DO ranged from 3.7 to 8.3 mg/L; and pH ranged from 7.0 to 7.9. On Day 2, turbidity ranged from 0.9 to 20.0 NTU; water temperature ranged from 12.3 to 18.9 °C; conductivity ranged from 99.0 to 129.0 µS/cm; DO ranged from 4.1 to 9.7 mg/L; and pH ranged from 7.1 to 7.6. The aggregated mean turbidity, water temperature, and conductivity decreased on Day 2 as compared to Day 1. With the exception of Stations 9, 11, and 12, DO increased on Day 2. Average pH remained relatively stable. Table 4.1-1 includes the detailed water chemistry findings.

Table 4.1-2 includes the species observed during the canal drawdown.

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0 250 500 1,000 Feet

4.1-1 Locations of pools greater than 0.5 ft depth identified during 2014 drawdown event of Turners Falls Canal.

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Table 4.1-1. Sample collection and water quality information for pools sampled in the Turners Falls Canal.

Site ID	Date	Time	Method[1]	Turbidity (NTU)	Temperature (°C)	Conductivity (µS/cm)	DO (mg/L)	pH	Depth (inch)
1	9/29/14	13:30	E	55.2	22.6	185	7.2	7.2	10.0
2	9/29/14	15:13	E	40.1	22.1	193	7.9	7.3	14.0
3	9/29/14	16:15	E	40.1	22.1	187	7.4	7.2	32.0
4	9/29/14	17:20	E	5.7	23.5	271	6.1	7.5	7.0
5	9/30/14	11:30	E	2.5	17.1	225	6.9	7.6	11.0
6	9/30/14	12:25	E	4.3	18.3	168	n/r[2]	7.5	7.0
7	9/30/14	13:07	E,S	26.8	18.6	171	8.3	7.9	48.0
8	9/30/14	13:50	E	0.1	19.3	477	7.9	7.4	48.0
9	9/30/14	14:40	E	n/r	18.4	175	8.3	7.9	10.0
10	9/30/14	15:10	E	4.7	19.6	168	n/r	7.6	11.0
11	9/30/14	15:50	E	n/r	19.4	212	4.4	7.6	14.0
12	9/30/14	16:40	E	0.5	19.2	221	5.8	7.4	14.0
13	9/30/14	17:05	E	0.4	19.0	172	3.7	7.0	n/r
14	9/30/14	17:15	E	0.8	18.9	176	5.6	7.1	15.0
1	10/3/14	8:34	E	17.9	14.6	126	8.7	7.6	13.0
2	10/3/14	8:35	E	15.2	14.6	118	9.7	7.6	12.0
3	10/3/14	9:10	E	20.0	12.3	107	9.6	7.6	20.5
4	10/3/14	10:15	E	20.0	12.3	107	9.6	7.6	4.8
5	10/3/14	10:10	E	6.5	13.0	129	7.8	7.5	9.0
6	10/3/14	11:00	E	3.4	15.5	120	9.1	7.5	7.0
7	10/3/14	11:18	E,S	1.8	15.0	116	8.7	7.6	25.0
8	10/3/14	11:50	E	0.9	15.7	117	8.0	7.5	60.0
9	10/3/14	11:50	E	6.4	15.1	99	7.6	7.4	5.5
10	10/3/14	12:10	E	6.8	18.7	127	6.2	7.6	12.0
11	10/3/14	13:10	E	2.1	18.9	121	4.1	7.1	19.0
12	10/3/14	12:55	E	2.7	18.5	125	4.4	7.4	13.0
13	10/3/14	13:24	E	5.6	18.0	129	7.1	7.4	9.5
14	10/3/14	14:00	E	3.3	16.8	126	7.6	7.2	14.0

Notes
[1] E = electrofishing, S = seining
[2] n/r = not reported

Over the two sampling events, field crews identified a total of 23 species encompassing 11 families (Table 4.1-2) in the pools. All species are common to the Connecticut River and no endangered, threatened, or special concern species were observed.

Table 4.1-2. Common, scientific, and family names of organisms observed in pools during the 2014 drawdown of Turners Falls Canal.

Common Name	Scientific Name	Family
American Eel	*Anguilla rostrata*	Anguillidae
American Shad	*Alosa sapidissima*	Clupeidae
Banded Killifish	*Fundulus diaphanus*	Fundulidae
Black Crappie	*Pomoxis nigromaculatus*	Centrarchidae
Bluegill	*Lepomis macrochirus*	Centrarchidae
Brown Bullhead	*Ameiurus nebulosus*	Ictaluridae
Channel Catfish	*Ictalurus punctatus*	Ictaluridae
Common Carp	*Cyprinus carpio*	Cyprinidae
Common Shiner	*Luxilus cornutus*	Cyprinidae
Fallfish	*Semotilus corporalis*	Cyprinidae
Golden Shiner	*Notemigonus crysoleucas*	Cyprinidae
Largemouth Bass	*Micropterus salmoides*	Centrarchidae
Mudpuppy	*Necturus maculosus*	Proteidae
Pumpkinseed	*Lepomis gibbosus*	Centrarchidae
Rock Bass	*Ambloplites rupestris*	Centrarchidae
Sea Lamprey	*Petromyzon marinus*	Petromyzontidae
Smallmouth Bass	*Micropterus dolomieu*	Centrarchidae
Spottail Shiner	*Notropis hudsonius*	Cyprinidae
Tessellated Darter	*Etheostoma olmstedi*	Percidae
Walleye	*Sander vitreus*	Percidae
White Perch	*Morone americana*	Moronidae
White Sucker	*Catostomus commersonii*	Catostomidae
Yellow Perch	*Perca flavescens*	Percidae

4.1.1 Catch Per Unit Effort (CPUE)

Site 7, which ranged in depth from 2 to 4 ft, was sampled via both electrofishing and seining techniques, while the remaining pools were sampled via electrofishing only[2]. Compared to electrofishing, relatively few fish were captured by seining (Table 4.1.1-1); no species were captured in seine samples that were not also captured by electrofishing. Electrofishing effort over both Day 1 and Day 2 sampling averaged 485.5 seconds, and varied between 199 and 893 seconds (Table 4.1.1-1). Electrofishing CPUE for all fish was 0.3843 fish/second on Day 1 and 0.5026 fish/second on Day 2, though standard error calculations suggest that CPUE was similar between sampling events (Figure 4.1.1-1). CPUE was highest at Station 2 on both sampling days despite being the smallest pool sampled (22 ft long and estimated maximum width of 6 ft). During electrofishing, one mudpuppy was observed on Day 1, and three were observed on Day 2, all of which were alive before and after sampling.

Table 4.1.1-2 provides aggregated CPUE by species across sampling events. With the exception of Common Shiner, which was only observed on Day 1 (n=1), all species were observed during both sampling events. Higher CPUE was observed for the majority of species on Day 2. Spottail Shiner was the most common species observed on both sample days.

[2] Although Site 8 was greater than 3 ft in depth, the presence of boulders and debris did not lend seining to be an effective sampling technique.

Table 4.1.1-1. Summary of sampling effort at pools remaining in lower portion of Turners Falls Canal during 2014 drawdown.

Site ID	Method	Effort		No. Organisms		Aggregated CPUE	
		Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
1	E	511 s	568 s	203	38	0.40	0.07
2	E	500 s	508 s	694	1270	1.39	2.50
3	E	507 s	500 s*	53	305	0.10	0.61
4	E	542 s	199 s	94	219	0.17	1.10
5	E	508 s	500 s*	460	586	0.91	1.17
6	E	567 s	515 s	114	148	0.20	0.29
7	S	1100 ft^2	1100 ft^2	34	7	0.03	0.01
7	E	529 s	500 s	59	15	0.11	0.03
8	E	524 s	508 s	166	174	0.32	0.34
9	E	284 s	360 s	3	11	0.01	0.03
10	E	513 s	503 s	87	33	0.17	0.07
11	E	893 s	546 s	417	241	0.47	0.44
12	E	294 s	500 s	87	85	0.30	0.17
13	E	255 s	384 s	2	5	0.01	0.01
14	E	500 s	662 s	224	267	0.45	0.40
	Mean	495	482	180	227	0.36	0.52
	Min	255	199	2	5	0.01	0.01
	Max	893	662	694	1270	1.39	2.50

* Estimated

Table 4.1.1-2. CPUE by species across sampling events.

Species	Day 1	Day 2	Change*
All Fish	0.3843	0.5026	+
American Eel	0.0022	0.0013	-
American Shad	0.0680	0.0900	+
Banded Killifish	0.0022	0.0012	-
Black Crappie	0.0012	0.0003	-
Bluegill	0.0240	0.0413	+
Brown Bullhead	0.0102	0.0155	+
Channel Catfish	0.0006	0.0004	-
Common Carp	0.0003	0.0003	nc
Common Shiner	0.0001	0.0000	-
Fallfish	0.0017	0.0015	-
Golden Shiner	0.0017	0.0027	+
Lamprey	0.0108	0.0166	+
Largemouth Bass	0.0051	0.0041	-
Mud puppy	0.0001	0.0004	+
Pumpkinseed	0.0013	0.0003	-
Rock Bass	0.0032	0.0120	+
Smallmouth Bass	0.0173	0.0107	-
Spottail Shiner	0.1501	0.1188	-
Tessellated Darter	0.0404	0.1032	+
Walleye	0.0003	0.0015	+
White Perch	0.0003	0.0009	+
White Sucker	0.0361	0.0609	+
Yellow Perch	0.0121	0.0201	+

*(-) = species aggregate CPUE decreased, (+) = species aggregate CPUE increased, (nc) = no change in aggregate species CPUE

Figure 4.1.1-1. Total electrofishing CPUE ± 1SE for sampling during the Turners Falls Canal drawdown

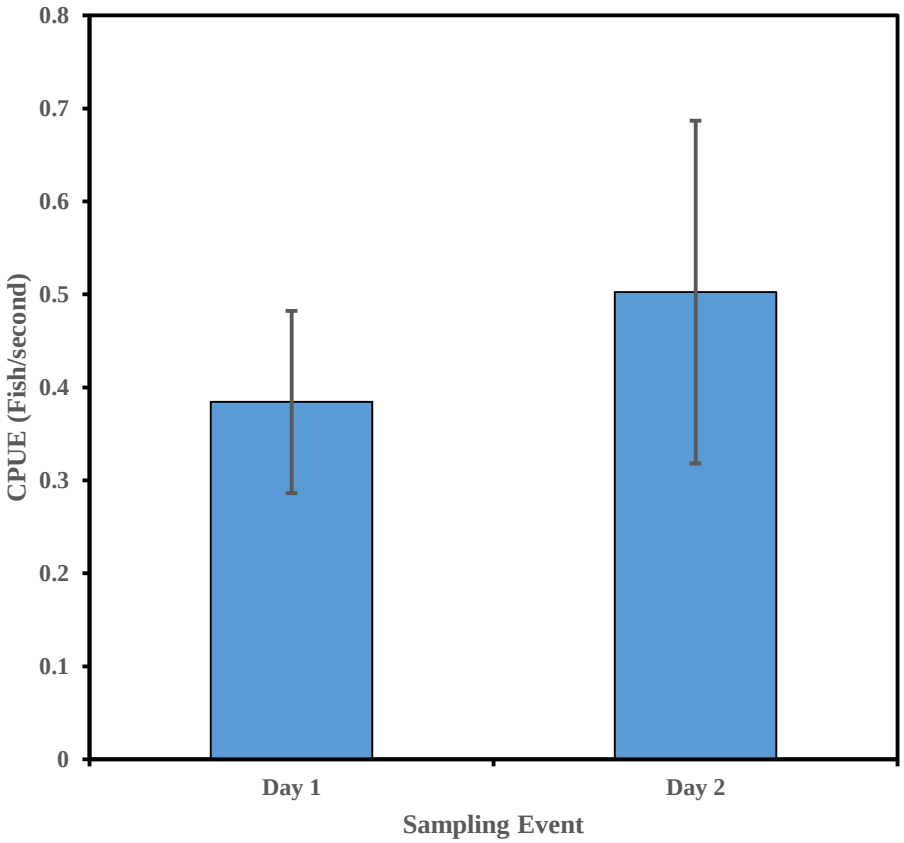
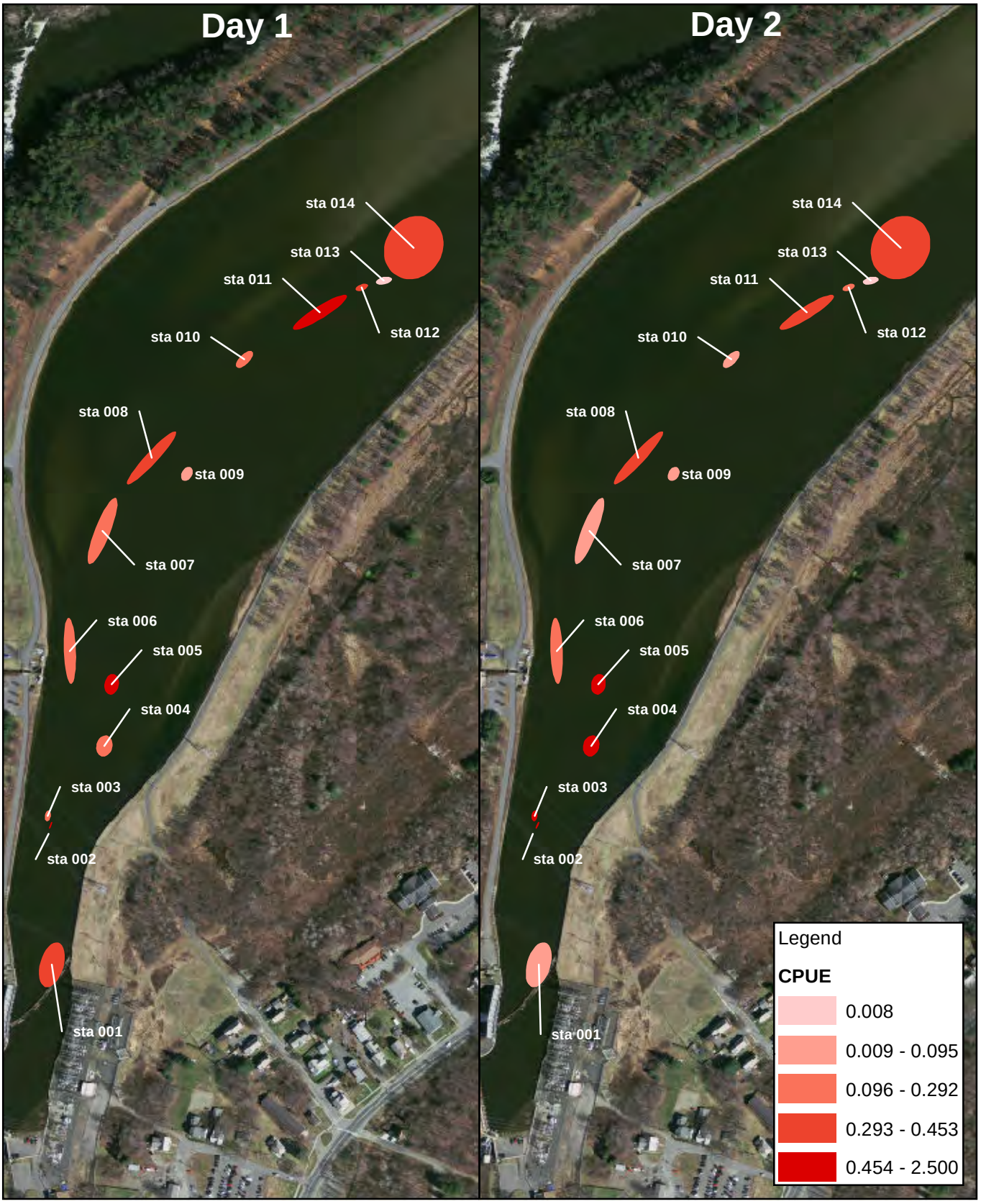


Figure 4.1.1-2. Distribution of logarithmic CPUE for each species on both sampling days

Electrofishing effort was skewed with a small number of stations sampled for much longer durations than others; therefore, units of CPUE were logarithmically transformed and measures of central tendency expressed with the median (summary statistics included in Appendix B). Figure 4.1.1-2 presents a histogram of $log_{10}(CPUE)$ per species by sample day. Note $log_{10}(CPUE)$ values pertain to orders of magnitude (i.e. $log_{10}(1000) = 3$ and$log_{10}(0.001) = -3$).

Given the large levels of effort in comparison to the number of individuals observed, a majority of the species exhibited $log_{10}(CPUE)$ of less than 0, with the exception of American Shad and Spottail Shiner, indicating relatively large abundances for each species in at least one of the pools sampled. Tables B-1 and B-2 (Appendix B) describe $log_{10}(CPUE)$ by species on Day 1 and Day 2 respectively.

Figure 4.1.1-3 shows the aggregate CPUE among sites by sample day. On Day 1, abundance in the upstream canal sites, particularly among Stations 11, 13 and 14, tended to be higher as compared to Day 2. Conversely, abundance in some of the downstream pools, for example Stations 2 and 3, increased on Day 2 as compared to Day 1.



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N

0 250 500 1,000 Feet

4.1.1-3 CPUE by pool for Day 1 and Day 2 sampling events during 2014 drawdown of Turners Falls Canal.

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4.1.2 Sampling Mortality

Sampling mortality by family across sampling events varied, with some families demonstrating higher post-sampling mortality on Day 2 (Table 4.1.2-1). Most notable were Clupeidae with an increase in sampling mortality from 44% to 67%, Cyprinidae with an increase from 40% to 64%, and Percidae with an increase in sampling mortality from 5% to 58%. The low number of individuals for some families prohibited the use of the chi-square test of independence. However, given that some families had sampling mortality probabilities of 0% on both days while others demonstrated greater sampling mortality (67%), it appears that sampling mortality is influenced by family and sampling event. Overall, aggregated sampling mortality on Day 1 was relatively low at 30%, while sampling mortality increased on Day 2 to 53%.

Sampling mortality among hydrologically connected and hydrologically isolated pools varied as well (Table 4.1.2-2). The survivability among fish in hydrologically connected and isolated pools declined over time, but isolated pools decreased from 77% to 38%, while connected pools only decreased from 74% to 58%. A chi-square test of independence was significant (X^2 = 443.3, df = 4, $p < 0.001$), indicating sampling mortality is dependent upon day and whether or not the fishes reside in a hydrologically connected pool.

A two sample test for equality of proportions resulted in a significant difference in sampling mortality between sampling events (X^2 = 308.09, df = 1, $p < 0.001$).

Table 4.1.2-1. Counts and ratios of alive and dead organisms (by family) observed in pools for Day 1 and Day 2 sampling events during the 2014 drawdown of Turners Falls Canal.

Family	Status	Count		Sample Ratio	
		Day 1	Day 2	Day 1	Day 2
Anguillidae	Alive	15	9	1	1
	Dead	0	0	0	0
Catostomidae	Alive	242	367	0.97	0.89
	Dead	8	44	0.03	0.11
Centrarchidae	Alive	347	350	0.93	0.75
	Dead	25	114	0.07	0.25
Clupeidae	Alive	262	198	0.56	0.33
	Dead	209	410	0.44	0.67
Cyprinidae	Alive	644	299	0.60	0.36
	Dead	423	533	0.40	0.64
Fundulidae	Alive	13	8	0.87	1
	Dead	2	0	0.13	0
Ictaluridae	Alive	72	106	0.96	0.98
	Dead	3	2	0.04	0.02
Moronidae	Alive	2	6	1	1
	Dead	0	0	0	0
Percidae	Alive	348	371	0.95	0.44
	Dead	18	472	0.05	0.56
Petromyzontidae	Alive	74	99	0.83	0.87
	Dead	15	15	0.17	0.13
Proteidae	Alive	1	3	1	1
	Dead	0	0	0	0

Table 4.1.2-2. Summary of aggregated sampling mortality between hydrologically connected and isolated pools.

Hydrologically Connected	Status	Count		Ratio	
		Day 1	Day 2	Day 1	Day 2
Isolated	Survival	430	308	0.77	0.38
	Mortality	128	510	0.23	0.62
Connected	Survival	1,590	1,508	0.73	0.58
	Mortality	575	1,080	0.27	0.42

The results of the logistic regression performed to determine if overall CPUE (total per pool) or sampling day influences sampling mortality were not significant (Figure 4.1.2-1; Table 4.1.2-3). Although the decreasing slope suggests a trend, there was no statistical significance to indicate that sampling mortality increases with increasing CPUE or sampling event.

Figure 4.1.2-1. Results of logistic regression on aggregated sampling survival with log_{10}(CPUE) and sample day as factors (shaded area represents standard error)

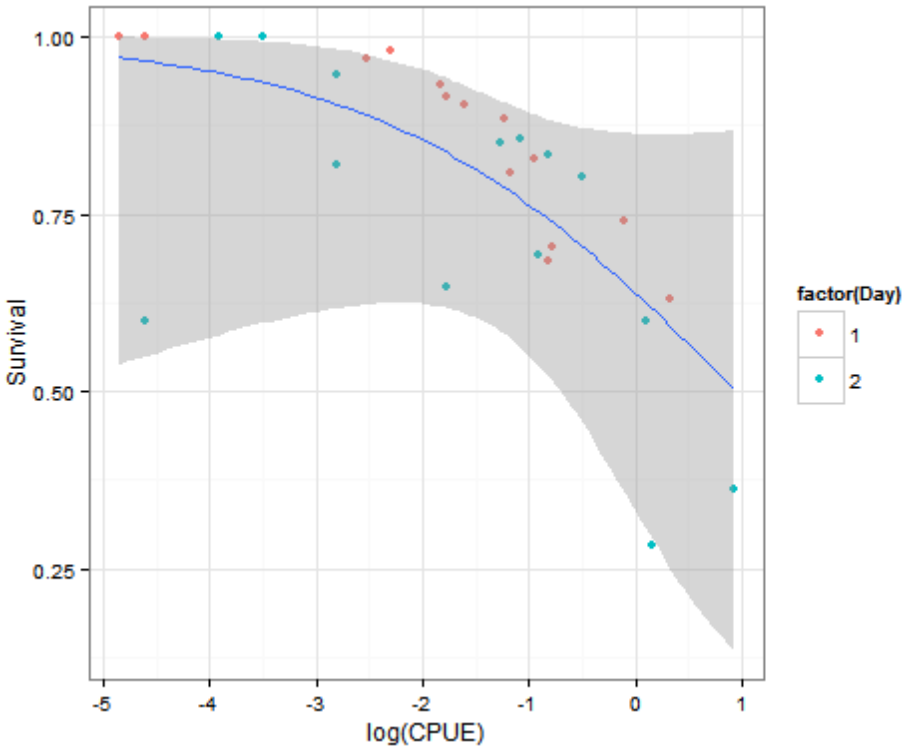
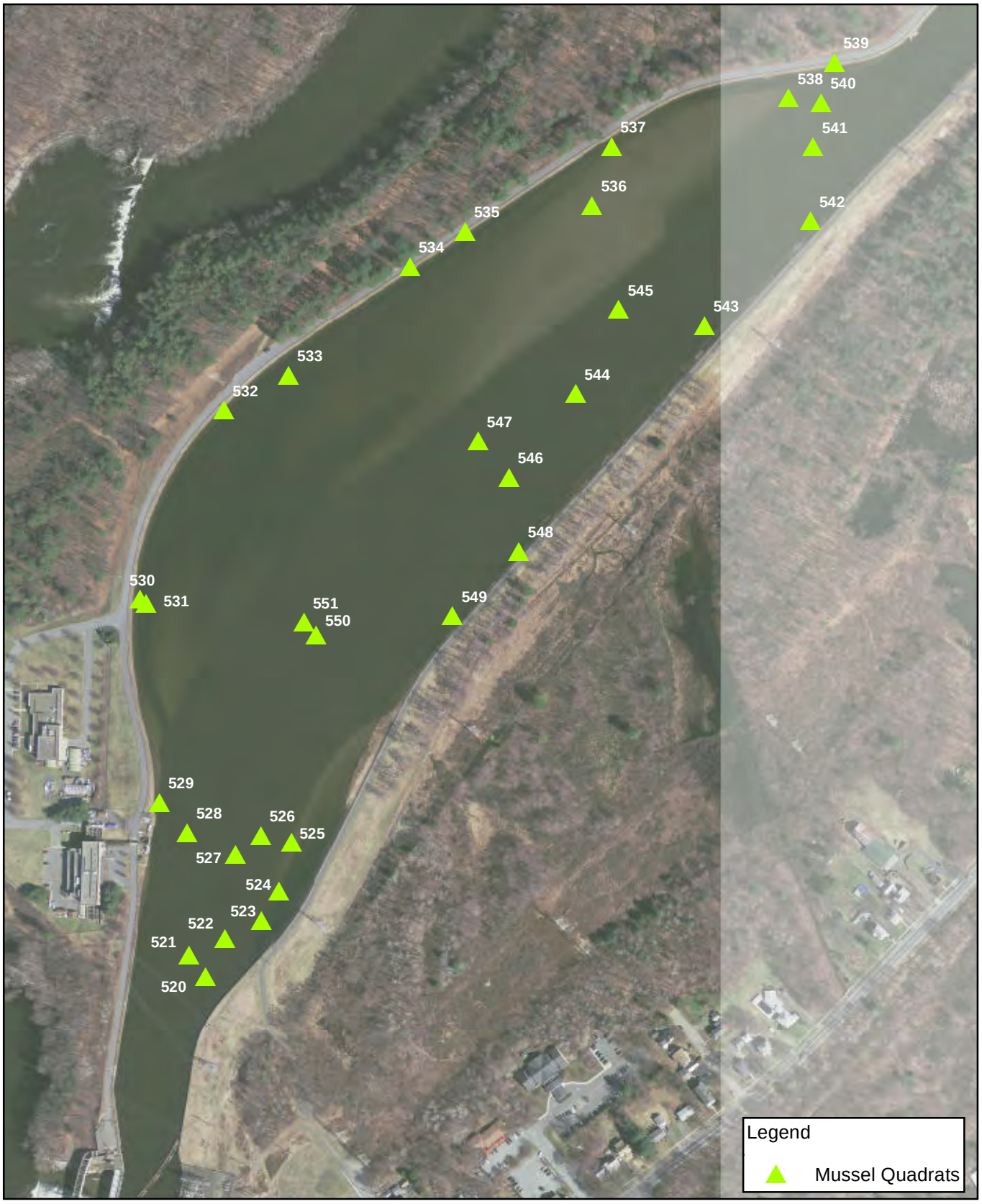


Table 4.1.2-3. Logistic regression analysis summary table.

	Estimate	**Standard Error**	**z value**	**p**
Intercept	0.9819	0.9008	1.090	0.276
log(CPUE)	-0.5790	0.4138	-1.399	0.162
Day	-0.7102	1.0127	-0.701	0.483
AIC = 19.611				

4.2 Quadrat Sampling

Thirty-two quadrats spanning Zones 2-6 were sampled for lamprey ammocoetes/transformers, mudpuppies, and freshwater mussel species during both the initial survey and prior-to-rewatering surveys (Figure 4.2-1). In total, only two mussel species were identified, Eastern Elliptio and Alewife Floater, the former dominating abundance as 534 individual Eastern Elliptios were observed and only one Alewife Floater over the course of the two sampling events. Distribution of mussels was skewed as only 12 of the 32 sites contained mussels (i.e., 20 sites had zero mussels). Very few individual mudpuppies (n=3) and young lampreys (n=12) were observed during the two sampling events (Tables 4.2-1 and 4.2-2).



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0 250 500 1,000 Feet

4.2-1 Locations of quadrat sampling in lower portion of Turners Falls Canal during 2014 drawdown

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Table 4.2-1. Summary of quadrat sampling on Day 1

Site ID	Substrate	Date	Time	Ammocoetes		Transformers		Eastern Elliptio		Alewife Floater		Mudpuppies		Combined CPUE
				Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive	Dead	
520	sand, silt, organics	9/29/14	15:53	0	0	0	0	0	0	0	0	0	0	0
521	sand, cobble	9/29/14	16:00	0	0	0	0	0	0	0	0	0	0	0
522	silt, sand	9/29/14	16:07	0	0	0	0	2	0	0	0	0	0	2
523	silt, clay, vegetation	9/29/14	16:17	0	0	0	0	0	0	0	0	0	0	0
524	silt, clay	9/29/14	16:30	1	0	0	0	0	0	0	0	0	0	1
525	silt, clay	9/29/14	16:44	1	0	0	0	0	0	0	0	0	0	1
526	sand	9/29/14	16:53	0	0	0	0	3	0	0	0	0	0	3
527	silt, sand	9/29/14	17:07	0	0	0	0	7	0	0	0	0	0	7
528	silt, cobble	9/29/14	17:25	0	0	0	0	28	0	0	0	0	0	28
529	silt, gravel	9/29/14	17:43	0	0	0	0	0	0	0	0	0	0	0
530	silt	9/30/14	9:20	0	0	0	0	0	0	0	0	0	0	0
531	silt, clay	9/30/14	9:23	0	0	0	0	0	0	0	0	0	0	0
532	silt, clay, vegetation	9/30/14	9:45	0	0	0	0	0	0	0	0	0	0	0
533	silt	9/30/14	9:50	0	0	0	0	0	0	0	0	0	0	0
534	silt, vegetation	9/30/14	10:00	0	0	0	0	0	0	0	0	0	0	0
535	silt, vegetation	9/30/14	10:17	1	0	0	0	0	0	0	0	0	0	1
536	silt, clay	9/30/14	10:28	0	0	0	0	0	0	0	0	0	0	0
537	silt, clay	9/30/14	10:32	0	0	0	0	0	0	0	0	0	0	0
538	silt, clay, sand	9/30/14	10:50	3	0	1	0	2	0	0	0	0	0	6
539	silt, sand	9/30/14	10:56	0	0	0	0	0	0	0	0	0	0	0
540	silt, sand	9/30/14	11:23	0	0	0	0	1	0	0	0	0	0	1
541	sand, cobble	9/30/14	11:27	0	0	0	0	9	0	0	0	0	0	9
542	silt, gravel, cobble	9/30/14	11:44	0	0	0	0	0	0	0	0	0	0	0
543	silt, vegetation	9/30/14	11:53	0	0	0	0	0	0	0	0	0	0	0
544	silt, clay	9/30/14	12:17	0	0	0	0	1	0	0	0	0	0	1
545	silt, sand	9/30/14	12:25	0	0	0	0	2	0	0	0	0	0	2
546	sand, gravel	9/30/14	12:45	0	0	0	0	0	0	0	0	0	0	0
547	sand, cobble	9/30/14	12:45	0	0	0	0	0	0	0	0	0	0	0
548	silt, clay, vegetation	9/30/14	13:00	0	0	0	0	0	0	0	0	0	0	0
549	silt, clay, cobble	9/30/14	13:03	0	0	0	0	3	0	0	0	0	2	5
550	sand, organics	9/30/14	13:28	0	0	0	0	133	0	0	0	0	0	133
551	sand, silt	9/30/14	13:30	0	0	0	0	46	0	0	0	0	0	46
			Total	6	0	1	0	237	0	0	0	0	2	246
			CPUE	0.2	0.0	0.0	0.0	7.4	0.0	0.0	0.0	0.0	0.1	7.7

Site ID	Substrate	Date	Time	Ammocoetes Alive	Ammocoetes Dead	Transformers Alive	Transformers Dead	Eastern Elliptio Alive	Eastern Elliptio Dead	Alewife Floater Alive	Alewife Floater Dead	Mudpuppies Alive	Mudpuppies Dead	Combined CPUE
		No. Site with Zero		28	32	31	32	20	32	32	32	32	31	17
		% Alive		100%		100%		100%		n/a		0		

Table 4.2-2. Summary of quadrat sampling on Day 2

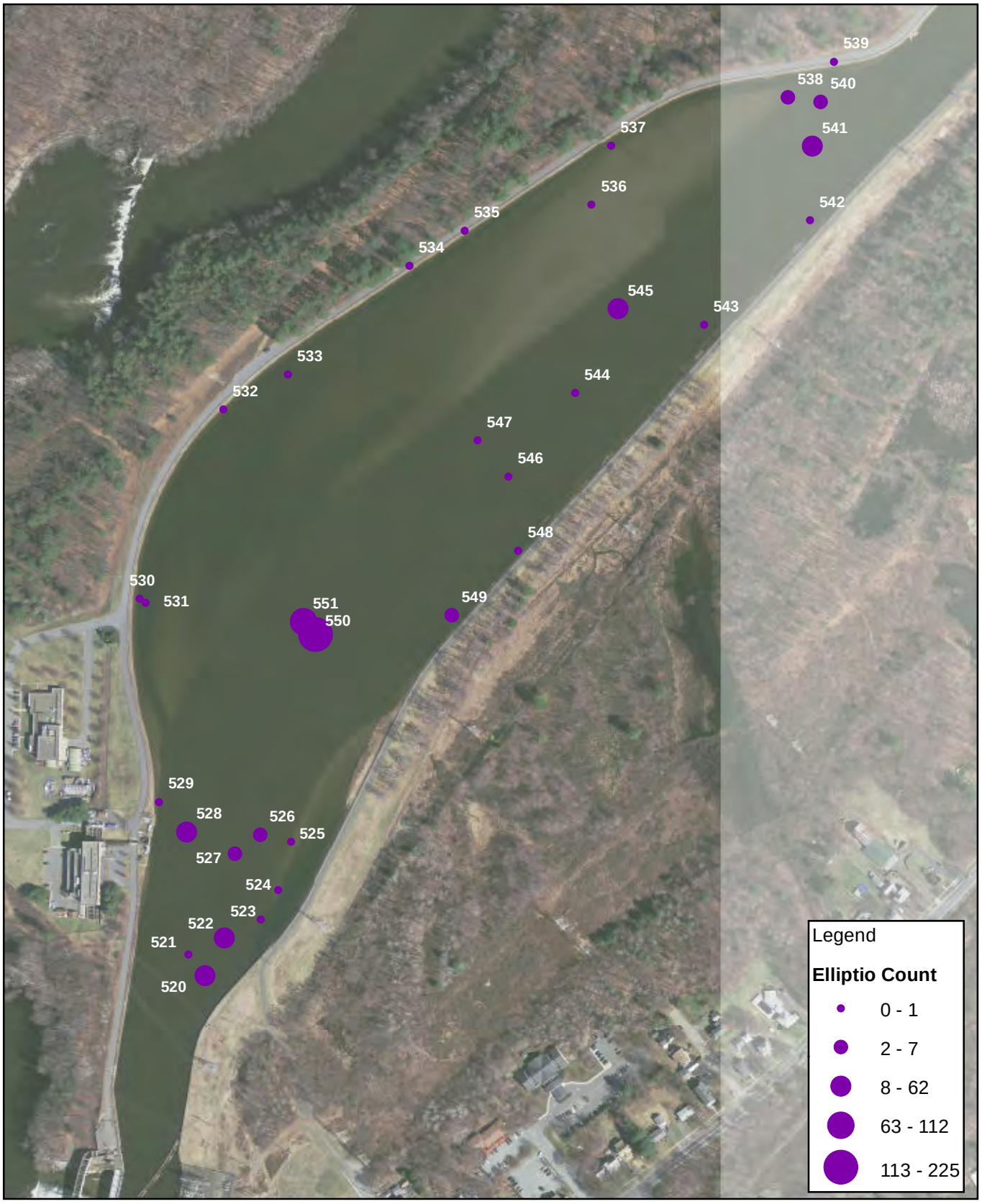
Site ID	Substrate	Date	Time	Ammocoetes Alive	Ammocoetes Dead	Transformers Alive	Transformers Dead	Eastern Elliptio Alive	Eastern Elliptio Dead	Alewife Floater Alive	Alewife Floater Dead	Mudpuppies Alive	Mudpuppies Dead	Combined CPUE
520	sand, silt, organics	10/3/14	13:15	0	0	0	0	30	0	0	0	0	0	30
521	sand, cobble	10/3/14	13:27	0	0	0	0	0	0	0	0	0	0	0
522	silt, sand	10/3/14	13:16	0	0	0	0	28	0	0	0	0	0	28
523	silt, clay, vegetation	10/3/14	13:07	0	0	0	0	0	0	0	0	0	0	0
524	silt, clay	10/3/14	12:54	0	0	0	0	0	0	0	0	0	0	0
525	silt, clay	10/3/14	12:43	0	0	0	0	0	0	0	0	0	0	0
526	sand	10/3/14	12:43	0	0	0	0	3	0	0	0	0	0	3
527	silt, sand	10/3/14	13:00	0	0	0	0	0	0	0	0	0	0	0
528	silt, cobble	10/3/14	13:50	0	0	0	0	34	0	0	0	0	0	34
529	silt, gravel	10/3/14	13:54	0	0	0	0	1	0	0	0	0	0	1
530	silt	10/3/14	8:28	0	0	0	0	0	0	0	0	0	0	0
531	silt, clay	10/3/14	8:28	0	0	0	0	0	0	0	0	0	0	0
532	silt, clay, vegetation	10/3/14	8:42	0	0	0	0	0	0	0	0	0	0	0
533	silt	10/3/14	8:44	0	0	0	0	0	0	0	0	0	0	0
534	silt, vegetation	10/3/14	8:55	0	0	0	0	0	0	0	0	1	0	1
535	silt, vegetation	10/3/14	8:59	0	0	0	0	0	0	0	0	0	0	0
536	silt, clay	10/3/14	9:12	0	0	0	0	0	0	0	0	0	0	0
537	silt, clay	10/3/14	9:13	0	0	0	0	0	0	0	0	0	0	0
538	silt, clay, sand	10/3/14	9:25	5	0	0	0	3	0	0	0	0	0	8
539	silt, sand	10/3/14	9:30	0	0	0	0	0	0	0	0	0	0	0
540	silt, sand	10/3/14	9:39	0	0	0	0	2	0	0	0	0	0	2
541	sand, cobble	10/3/14	9:48	0	0	0	0	12	0	0	0	0	0	12
542	silt, gravel, cobble	10/3/14	10:05	0	0	0	0	0	0	0	0	0	0	0
543	silt, vegetation	10/3/14	10:10	0	0	0	0	0	0	0	0	0	0	0
544	silt, clay	10/3/14	10:26	0	0	0	0	0	0	0	0	0	0	0
545	silt, sand	10/3/14	10:24	0	0	0	0	23	0	0	0	0	0	23
546	sand, gravel	10/3/14	10:53	0	0	0	0	0	0	0	0	0	0	0

Site				Ammocoetes		Transformers		Eastern Elliptio		Alewife Floater		Mudpuppies		Combined
ID	**Substrate**	**Date**	**Time**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**Alive**	**Dead**	**CPUE**
547	sand, cobble	10/3/14	10:53	0	0	0	0	0	0	0	0	0	0	0
548	silt, clay, vegetation	10/3/14	11:05	0	0	0	0	0	0	0	0	0	0	0
549	silt, clay, cobble	10/3/14	11:07	0	0	0	0	3	0	0	0	0	0	3
550	sand, organics	10/3/14	11:24	0	0	0	0	92	0	1	0	0	0	93
551	sand, silt	10/3/14	11:26	0	0	0	0	66	0	0	0	0	0	66
			Total	5	0	0	0	297	0	1	0	1	0	304
			CPUE	0.2	0.0	0.0	0.0	9.3	0.0	0.0	0.0	0.0	0.0	9.5
			No. Sites with Zero	31	32	32	32	20	32	31	32	31	32	19
			% Alive	100%		n/a		100%		100%		100%		

4.2.1 CPUE

CPUE was zero for a majority of sites across all target species (Figure 4.2.1-1; Tables 4.2-1 and 4.2-2); however, a small number of sites exhibited high CPUEs due to Eastern Elliptio observations (Sites 520, 522, 528, 541, 545, 550 and 551). Sites with greater densities of mussels were proximally located to the thalweg of the canal, which tended to remain wetted for the duration of the drawdown.

Nine of the 12 sea lamprey observed during quadrat sampling were located at Site 538, near the upstream end of Zone 6. Predominant substrate types at Site 538 were reported as silt, clay, and sand.



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FirstLight GDF SUEZ

N

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0 250 500 1,000 Feet

4.2.1-1 Combined (Day 1 and Day 2) CPUE by quadrat

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4.2.2 Sampling mortality

Over the course of both sampling events, all mussels and young lamprey observed in the quadrats were alive (Tables 4.2-1 and 4.2-2). Of the three mudpuppies observed in the quadrat samples, two dead individuals were observed on Day 1 and one live individual was observed on Day 2.

4.3 Upper Canal Water Quality Monitoring

Water quality data collected in the upper portion of the Turners Falls Canal, or Zone 7, on each day of sampling are summarized in Table 4.3-1 below.

Table 4.3-1. Summary of water quality parameters measured in upper portion of Turners Falls Canal

Location	Date	Time (hrs)	Temperature (°C)	DO (mg/L)	pH
Station 1	9/29/2014	13:30	19.08	8.83	7.15
	10/3/2014	07:20	16.07	6.36	7.03
Station 2	9/29/2014	13:40	19.15	8.75	7.14
	10/3/2014	07:32	15.97	6.45	7.05

5 DISCUSSION

The current study was undertaken to supplement information gained from the 2011 preliminary survey of aquatic species stranding in the canal during annual drawdown events and to inform a subsequent evaluation of potential measures to reduce adverse effects due to the drawdowns, if needed. The visual observations of bare substrate areas to estimate the types and numbers of species stranded in the lower canal during the 2011 survey revealed that a variety of aquatic organisms, including Centrarchid and Cyprinid species, Sea Lamprey, Carp, Perch, Chain Pickerel, American Eel and mussels are potentially stranded when the canal level is drawn down for annual maintenance activities. No American Shad were observed during the 2011 survey likely due to a flood event in the days preceding the drawdown that flushed outmigrating shad out of the canal and downriver.

Similar riverine and diadromous species documented during the 2011 survey were observed in the pools surveyed during the 2014 drawdown, as well as American Shad. Based on electrofishing results for the 2014 study, Spottail Shiner, American Shad, and Tessellated Darter were the most abundant species observed in pools. While sampling mortality for these species/families increased from Day 1 to Day 2, all specimens were alive until collection (i.e., no dead fish were observed on the surface of the pools prior to sampling) and it is likely these fish would have remained alive if no sampling occurred. These observations suggest that as water quality parameters in the pools change over time, the likelihood of sampling-induced mortality increases (in other words, fish collected from stressful conditions are more likely to die as a result of sampling than those that are collected from more suitable, less stressful conditions). Accumulated stress due to density dependence effects may also play a role; however, statistical analysis indicates no significant effects on sampling mortality due to sampling event (which day the sampling occurred) or abundance (CPUE).

Total electrofishing CPUE was comparable between sampling events. As some pools in the lower portion of the canal were hydrologically connected (Stations 1, 2, 3, 6, 7, 8, 10, 11, 12, 13 and 14), changes in abundance at sampling stations between Day 1 and Day 2 sampling events suggests that fish are capable of migrating between pools. Abundance at upstream Stations 12 and 14 decreased on Day 2 as compared to Day 1, while an increase in abundance was observed at Stations 3 and 4 further downstream. As DO measurements at Stations 12 and 14 decreased between Day 1 and 2, and DO increased at Stations 3 and 4, it may be possible that fish were moving downstream between pools in search of more suitable conditions in the lower portion of the canal.

Stranding events were observed (Appendix A, photos 21-24) consisting of a few hundred individuals each. Locations where stranding occurred were spatially correlated, typically found in depressions within the canal region east of the hydrologically connected pools. Species composition varied and no species was consistently dominant. Strandings were highly spatially correlated and generally consisted of multiple species indicating that the fish aggregated before the water had completely drained. The rate of drawdown during the 2014 study allowed for many individuals to seek refuge in pools, and the stranding events that did occur suggest fish were aggregated in shallow water depressions that dried out within the first few hours of the study. Large scale strandings of migratory species or isolated individual strandings were not found during sampling events.

With the upper gates closed, the canal geometry allows the upper portion of the canal to remain wetted such that bottom habitat is unaffected by the drawdown. Fish that remain in Zone 7 may temporarily be restricted to the confines of the upper canal for the duration of the outage, although smaller individuals may be able to exit to the river via the Keith Tunnel. Water quality monitoring during the 2014 outage indicated that temperature ranged from 19.2 (Day 1) to 16.0 (Day 2) °C and DO concentration ranged from 8.8 (Day 1) to 6.4 (Day 2) mg/L in Zone 7 over the course of the canal outage. These ranges are

within normal seasonal ranges and, therefore, are not expected to adversely impact survival of fish that remain within Zone 7 for the duration of the outage.

Although several thousand Sea Lamprey were estimated to be stranded during the 2011 survey, very few individuals were observed during the 2014 survey, both within and between quadrats. All individuals observed during quadrat sampling were alive, and lamprey sampling mortality based on electrofishing efforts in the pools was 13% on the day prior to rewatering of the canal. During substrate sampling, live specimens of transformers and ammocoetes were found buried below the substrate, which likely serves to prevent desiccation and promotes survival for the duration of the drawdown event until rewatering occurs. The majority of lamprey observed during quadrat sampling were located toward the upstream boundary of Zone 6, which is about where the canal begins to widen and water velocity decreases. Substrate in this area is primarily composed of silt, clay, and sand.

While many relic Eastern Elliptio shells were observed in the lower portion of the dewatered canal while mobilizing between sampling sites, these relic shells did not contain any tissue; therefore, death occurred well in advance of the drawdown. Within the quadrats sampled, all mussels observed were alive and appeared healthy. The absence of freshly dead mussels during quadrat sampling indicates no major impacts due to the annual drawdown events of the canal. Due to the higher CPUEs exhibited at Sites 550 and 551 and the evidence of mussel movement in the substrate (Appendix A, Photos 18 and 19), mussels likely migrate towards suitable habitat conditions when the canal is drawdown each year for maintenance. Other researchers studying the effects of drawdown events on freshwater mussel species reported that species burrowed deeper into sediments or laterally migrated toward watered areas (Newtown *et al.*, 2015).

Results of this study demonstrated little impact to organisms in the canal during the drawdown. This may have been the result of the canal drawdown being moved from the hottest period of the year, to the fall when water and air temperatures are similar and cool. Holding the drawdown during cooler periods not only favors adult mussel survival, but the survival of recently recruited juvenile mussels, which live in the top few millimeters of sediment and are greatly affected by conditions in the sediment/air interface. To further enhance aquatic organism survival, FirstLight has identified the following potential measures: conduct the rate of canal drawdown similar to what occurred in 2014 to allow time for fish to egress the canal, and for mussels and sea lamprey ammocoetes to burrow into sediment and placing cones in areas where heavy machinery travels and directing equipment operators to stay within these established boundaries.

6 LITERATURE CITED

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APPENDIX A – PHOTOGRAPHS

Photo 1. Overview of forebay area (Day 1). Area remains wetted for duration of drawdown and may serve a refuge area for fish.

Photo 2. Boundary of Zones 1 and 2 showing flow between pools and bedrock substrate (Day 1).

Photo 3. View towards right bank from Zone 1/2 boundary (Day 2). Note that although diminished, flow (center of photo) between pools remains on day prior to rewatering.

Photo 4. View from center of Zone 2 looking downstream towards powerhouse (Day 1).

Photo 5. View from left bank of Zone 2 looking upstream (Day 1).

Photo 6. View from Migratory Way (Zone 4/5) looking upstream.

Photo 7. View from Station 8 in Zone 4 looking downstream (Day 2). Note change in elevation from center channel area to upper bank area.

Photo 8. View from Conte Lab Intake (Zone 2) looking upstream (Day 2).

Photo 9. View from pool at Station 14 looking upstream. Flow from pool in background is directed upstream (Day 1).

Photo 10. Riprap "weir" spanning canal bed in Zone 6. Note upstream direction of flow (Day 2).

Photo 11. Typical condition of upper, narrow portion of canal during drawdown (Day 1).

Photo 12. Quadrat Site 520 after processing (Day 1).

Photo 13. Quadrat Site 528 where 28 Eastern Elliptio were identified on Day 1.

Photo 14. Alive mudpuppy (approximately 6-8" length) observed at Quadrat Site 534 on Day 2.

Photo 15. Quadrat Site 535 where an alive ammocoete was observed on Day 1.

Photo 16. Area near Quadrat Site 538 where young lamprey (n=4) and Eastern Elliptios were observed on Day 1.

Photo 17. Quadrat Site 538 on Day 2 where 5 alive young lamprey and 3 alive Eastern Elliptios observed. Note flag demarking location of Day 1 quadrat location.

Photo 18. Quadrat Site 550 where the highest density of Eastern Elliptios was observed (Day 1). Also where Alewife Floater was identified on Day 2.

Photo 19. Quadrat Site 551 where second highest abundance of Eastern Elliptios were observed (Day 2). Note evidence of mussel movement.

Photo 20. Typical condition of alive Eastern Elliptios observed. These three mussels were unburied for photo-documentation. Note mussels in sediment that remain buried.

Photo 21. Typical stranding event (Day 1).

Photo 22. Stranding event (Day 1)

Photo 23. Typical stranding event, discovered during the first sampling event, location is east of hydrologically connected pools

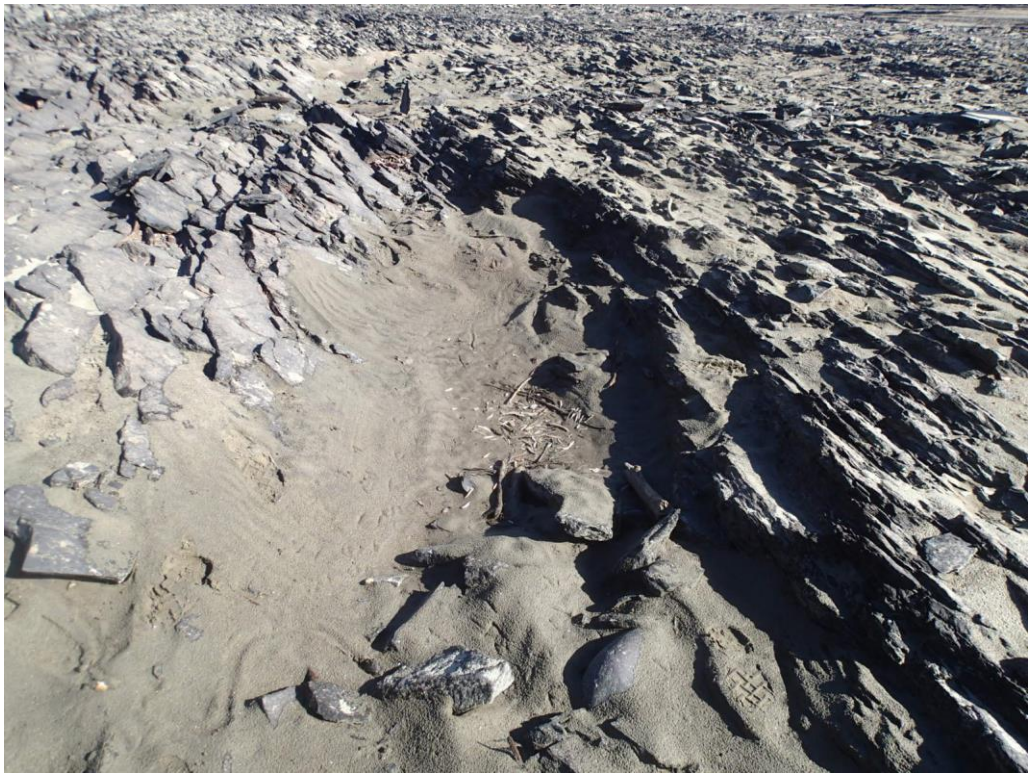

Photo 24. Stranding event discovered during second sampling event, located in bedrock just above pool 1, east of hydrologically connected pools.

APPENDIX B – CPUE SUMMARY STATISTICS

Table B-1. Log10 CPUE summary statistics by species for Day 1.

Species	Count	Min	1st Quartile	Median	3rd Quartile	Max
American Eel	15	-7.003	-6.254	-6.232	-5.415	-4.828
American Shad	471	-7.003	-5.889	-5.003	-3.492	-0.243
Banded Killifish	15	-6.240	-5.678	-5.116	-4.474	-3.833
Black Crappie	8	-6.229	-5.744	-5.259	-4.775	-4.290
Bluegill	166	-5.649	-4.626	-4.193	-3.560	-2.639
Brown Bullhead	71	-6.340	-5.734	-4.402	-3.993	-2.882
Channel Catfish*	4	-	-	-4.850	-	-
Common Carp*	2	-	-	-6.215	-	-
Common Shiner*	1	-	-	-6.236	-	-
Fallfish	12	-5.537	-5.136	-4.736	-4.335	-3.934
Golden Shiner	12	-7.003	-6.097	-5.573	-5.527	-4.844
Sea Lamprey	75	-5.684	-4.800	-4.369	-4.086	-3.251
Largemouth Bass	35	-7.003	-5.649	-5.142	-4.627	-3.912
Mudpuppy*	1	-	-	-6.215	-	-
Pumpkinseed	9	-4.854	-4.823	-4.792	-4.762	-4.731
Rock Bass	22	-7.003	-6.222	-6.215	-5.390	-3.370
Smallmouth Bass	120	-7.003	-6.229	-5.242	-4.844	-1.897
Spottail Shiner	1040	-4.8420	-3.8240	-1.867	-1.5090	-0.2903
Tessellated Darter	280	-6.215	-4.364	-3.817	-2.978	-2.218
Walleye*	2	-	-	-6.225	-	-
White Perch	2	-6.795	-6.653	-6.651	-6.370	-6.229
White Sucker	250	-6.6229	-5.197	-4.439	-3.045	-2.041
Yellow Perch	84	-7.003	-4.850	-4.283	-4.017	-3.270

* either only one specimen per species found or no variability in CPUE, summary statistics not required.

Table B-2. CPUE summary statistics by species for Day 2.

Species	Count	Min	1st Quartile	Median	3rd Quartile	Max
American Eel	9	-6.230	-6.111	-5.670	-5.525	-5.293
American Shad	608	-6.2440	-5.4070	-3.9120	-3.2000	0.0703
Banded Killifish	8	-5.293	-5.037	-4.781	-4.525	-4.269
Black Crappie*	2	-	-	-5.537	-	-
Bluegill	279	-7.003	-5.132	-4.135	-3.306	-1.275
Brown Bullhead	105	-6.342	-5.014	-4.486	-4.042	-1.996
Channel Catfish	3	-6.230	-5.823	-5.415	-5.008	-4.600
Common Carp	2	-6.495	-6.457	-6.419	-6.380	-6.342
Common Shiner	0	-	-	-	-	-
Fallfish	10	-6.230	-5.677	-5.124	-4.571	-4.017
Golden Shiner	18	-5.521	-5.132	-4.621	-4.600	-4.423
Sea Lamprey	112	-6.310	-5.217	-4.399	-3.868	-1.630
Largemouth Bass	28	-6.342	-6.221	-5.609	-4.844	-4.017
Mudpuppy*	3	-	-	-6.230	-	-
Pumpkinseed*	2	-	-	-5.802	-	-
Rock Bass	81	-6.342	-6.237	-5.868	-3.150	-1.961
Smallmouth Bass	72	-7.003	-5.932	-4.693	-3.644	-3.458
Spottail Shiner	802	-6.303	-3.932	-2.243	-2.019	0.0935
Tessellated Darter	697	-5.270	-4.115	-3.085	-2.066	-0.658
Walleye	10	-6.215	-5.669	-5.124	-4.579	-4.033
White Perch*	6	-	-	-4.439	-	-
White Sucker	411	-5.951	-4.626	-3.638	-2.234	-1.309
Yellow Perch	136	-4.033	-3.404	-3.170	-2.935	-2.223

* either only one specimen per species found or no variability in CPUE, summary statistics not required.