

# Technical Report for the Fish Assemblage Study

Lowell Hydroelectric Project (FERC No. 2790)

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February 25, 2021

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## 1 Introduction

A survey of the resident fish community was conducted in support of the relicensing for the Lowell Hydroelectric Project (Lowell or Project), Federal Energy Regulatory Commission (FERC) No. 2790, as identified in the Revised Study Plan (RSP) submitted by Boott Hydropower, LLC (Boott) on January 28, 2019. The approach and methodology described in the RSP for the fish community study was approved by FERC in its Study Plan Determination letter dated March 13, 2019.

In accordance with 18 C.F.R. § 5.15(c), Boott filed their Initial Study Report (ISR) with FERC on February 25, 2020. As described in the ISR, data analyses were in progress and scheduled for completion during 2020. On June 12, 2020 FERC issued a Revised Process Plan and Schedule and Determination on Requests for Study Modifications for the Lowell Hydroelectric Project (Revised PPS). In accordance with the Revised PPS, Boott filed their Revised ISR with FERC on September 30, 2020, which contained a full report for the Fish Assemblage Study. Boott held a revised ISR meeting on October 15, 2020 and a summary of the study results was presented to representatives from FERC, U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Massachusetts Division of Fisheries and Wildlife (MADFW), Massachusetts Division of Marine Fisheries (MDMF), and the New Hampshire Fish and Game Department (NHFGD). No significant comments on the Fish Assemblage Study were received.

This final technical report provides a description of the objectives, methodologies and results of the 2019 field sampling intended to describe the fish community within the Lowell Project area.

## 2 Objectives

The goal of this study was to characterize the fish assemblage in areas affected by the Lowell Project, specifically the impoundment and bypassed reach.

Specific objectives included:

- Field sampling to describe the fish assemblage structure, distribution, and abundance within the Project affected area along spatial and temporal gradients; and
- A comparison of historical records of fish species occurrence in the Project area to results of this study.

## 3 Project Description and Study Area

The Lowell Project is located at River Mile (RM) 41 on the Merrimack River in the City of Lowell in Middlesex County, Massachusetts, with an impoundment extending approximately 23 miles upstream into Hillsborough County, New Hampshire. The existing Lowell Project consists of: (1) a 1,093-foot-long, 15-foot-high masonry gravity dam (Pawtucket dam) that includes a 982.5-foot-long spillway with a crest elevation of 87.2 feet National Geodetic Vertical Datum 1929 (NGVD 29) topped by 5-foot-high pneumatically-operated crest gates deployed in five independently-operable zones; (2) a 720-acre impoundment with a normal maximum water

surface elevation of 92.2 feet NGVD 29; (3) a 5.5-mile-long canal system which includes several small dams and gatehouses; (4) a powerhouse (E.L. Field) which uses water from the Northern Canal and contains two turbine-generator units with a total installed capacity of 15.0 megawatts (MW); (5) a 440-foot-long tailrace channel; (6) four powerhouses (Assets, Bridge Street, Hamilton, and John Street) housed in nineteenth century mill buildings along the Northern and Pawtucket Canal System containing 15 turbine-generator units with a total installed capacity of approximately 5.1 MW; (7) a 4.5-mile long, 13.8-kilovolt transmission line connecting the powerhouses to the regional distribution grid; (8) upstream and downstream fish passage facilities including a fish elevator and downstream fish bypass at the E.L. Field powerhouse, and a vertical-slot fish ladder at the Pawtucket dam; and (9) appurtenant facilities. At the normal pond elevation of 92.2 feet NGVD 1929 (crest of the pneumatic flashboards), the surface area of the impoundment encompasses an area of approximately 720 acres. The gross storage capacity between the normal surface elevation of 92.2 feet and the minimum pond level of 87.2 feet is approximately 3,600 acre-feet. The Project operates essentially in a run-of-river (ROR) mode using automatic pond level control, and has no usable storage capacity.

The study area for this fish community survey included the mainstem Merrimack River from the Pawtucket Dam to the upper extent of the Project's impoundment located approximately 23 river miles upstream, and the Project's 0.7-mile-long bypassed reach.

## 4 Methods

### 4.1 Lowell Impoundment

The 23-mile-long (37 kilometer) impoundment was stratified based on mesohabitat characteristics. Each stratum was delineated in 547-yard (500-meter) segments using Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS). Sampling locations were randomly selected and weighted proportional to mesohabitat type frequency (e.g., if 50 percent of a particular geographic reach was shallow, riffle habitat, then 50 percent of the total number of sampling locations for that geographic reach were randomly placed within that habitat type). As long as habitat was accessible, efforts were made to ensure that a minimum of three sampling locations were placed within each strata (i.e., habitat type). A total of twelve, 547-yard (500-meter) segments were randomly selected within the reach so that approximately 16% of the impoundment was sampled. The stratified-random site selection process was repeated for each of three seasonal surveys (spring, summer, and fall).

Following selection of the twelve, 500-meter sample units, boat electrofish sampling took place during the nighttime hours (as defined by daily sunset/sunrise times). A single bank (east or west) was randomly selected for each sample unit. Prior to the start of sampling, settings on the electrofishing unit were adjusted by a trained crew member to ensure that approximately 4.0 amps of pulsed DC current was being generated. After recording the start time, boat electrofish sampling consisted of a single shoreline pass starting at the upstream end of each 500m transect and proceeded downstream. Effort was made by the boat driver to follow the shoreline contour and probe the sampling anodes into habitat areas (i.e., overhanging vegetation, submerged aquatic vegetation, woody debris, etc.). The boat driver maintained the

boat in near-shore littoral habitat (< 10-feet deep) where the sampling field would be most effective. A pair of netters stood on the bow of the sampling vessel and placed all stunned fish into an onboard live well for processing. Once the sample transect was finished, the driver recorded the completion time and duration of the sampling effort.

An experimental gill net was set concurrent with boat electrofishing in each 500-m sample unit. Gill nets were fished within all sample units containing adequate water depths and flow conditions to allow for proper performance of the nets, specifically deep and mid-channel microhabitats. Experimental gillnets were eight feet deep and were constructed of four 25-ft panels of increasing mesh size (1.0, 2.0, 3.0, and 4.0-inch stretch mesh). Gillnets were set during nighttime hours (as defined by daily sunset/sunrise times) when fish species are most susceptible to the gear due to the reduced visual avoidance. Gillnets were deployed perpendicular to the shoreline in areas where water depths were greater than the net height and capture area was maximized. Nets were set and fished for an approximate four-hour period prior to retrieval to minimize netting mortality. Net set coordinates and the date and time of each set and pull were recorded.

To supplement experimental gill net sampling in deeper habitats (> 10 ft) where electrofishing is not effective and small fish and eels are not susceptible to gillnets, a pair of standard minnow traps were deployed. The traps were 2.5 feet long galvanized wire mesh (0.25 square inch) cylinders with two entry fykes. Traps were baited and anchored to remain on station for the duration of their soak time. For each sample unit, two traps were fished simultaneously with gillnets for an approximate four-hour period. Trap set coordinates and the date and time of each set and pull were recorded.

All fish collected from the impoundment were identified to the lowest possible taxonomic classification (preferably to species), enumerated, measured to total length (to the nearest mm), and weighed (to the nearest g). If large numbers of small fish (i.e., YOY or small cyprinid species) were captured, length and weight information was collected from the first 25 individuals within the sample and the remaining individuals were grouped, enumerated, and batch weighed.

For each 500-m sample unit, the sampling crews visually evaluated habitat within the reach. The dominant substrate (organics, sand/silt/clay, cobble/gravel, boulder, or ledge), proportion of transect with submerged aquatic vegetation (i.e., 0-25%, 5-50%, 50-75%, or 75-100%), and the proportion of transect with overhanging vegetative cover (i.e., 0-25%, 5-50%, 50-75%, or 75-100%) was recorded. To get a sense of relative water depth for the Merrimack River at each sampling transect, a series of nine measurements were collected. River depths were recorded at the quarter points (i.e., 25, 50, and 75%) of three cross sections placed at the upstream extent, downstream extent, and midpoint of each sample unit. A representative water velocity (ft/s) was recorded at the midpoint of the middle cross-section of each habitat unit. Following documentation of sample unit habitat and characteristics, a representative water quality measurement was collected at approximately one meter of depth. Water temperature (°C), dissolved oxygen (mg/L) conductivity (µs/cm), pH, and turbidity (ntu) were recorded.



## 4.2 Lowell Bypassed Reach

Delineation of sample units was scaled for the shorter, less accessible bypassed reach. Each stratum was delineated in 55-yard (50-meter) segments using ArcGIS. Sampling locations were randomly selected and weighted proportional to mesohabitat type frequency. As long as habitat was available, effort was made to ensure that at least one sampling location was placed within each strata (i.e., habitat type) within the bypassed reach. A total of three segments were randomly selected within the bypassed reach during each of three seasonal surveys (spring, summer, fall). Due to safety and gear limitations, sampling was not conducted in (1) the reach from the Pawtucket Dam downstream to the School Street Bridge, and (2) the lowermost section of the bypass channel downstream of the Northern Canal surge gate. Sampling was limited to periods of minimum flow in the bypassed reach.

Backpack electrofish sampling was conducted within the Lowell bypassed reach. Halltech Aquatic Research Model HT2000B/MK5, battery-powered backpack electrofishers with ring probes and rattail cathodes were used to sample within the bypassed reach. Sampling was conducted by anchoring a fine mesh seine at the downstream end of a 50-m sample unit. A pair of backpack electrofishing units and four technicians moved in a downstream direction towards the seine while actively netting stunned individuals and kicking the substrate to drive additional stunned individuals towards the collection net. Backpack electrofish sampling was conducted during daylight hours. The backpack units were set at 550 volts at 100 Hertz (Hz). The start time, end time and duration of sampling were recorded for each sample unit. Specifics related to habitat and effort were the same as described above for impoundment sampling.

## 5 Results

### 5.1 Lowell Impoundment

#### *5.1.1 Habitat Evaluation and Sample Unit Selection*

A pair of biologists boated the stretch of the Merrimack River from the Pawtucket Dam upstream 23.0 miles to the uppermost extent of the Project area on May 18, 2019. Changes in mesohabitat type were visually identified and their locations recorded. Following importation of those habitat break points into ArcGIS, the 23.0 miles of the Merrimack River upstream of Lowell impoundment was subdivided into a total of 74 547-yard (500-meter) segments. The majority of those (78%) were classified as impoundment habitat. Lesser amounts of the overall reach were classified as run (7%) and pool (15%). The spatial distribution of mesohabitat types and 500-m segments for the 23.0 miles upstream of Lowell is provided in Appendix A.

Table 5-1 provides a listing of the habitat units upstream of the Pawtucket Dam that were randomly selected for sampling during the spring, summer, and fall periods of 2019. A total of twelve, 500-m segments were selected per season. During the spring season, a total of six impoundment, three run and three pool habitat units were sampled. River conditions (i.e., water depth) prevented effective sampling within some of the run habitat at the uppermost end of the Project area during the summer and fall sampling periods. As a result, seven impoundment, two run, and three pool habitat units were sampled during those seasons.

### 5.1.2 *Sampling Effort*

Fish community data were collected from a total of 36, 500-m sample units during the spring, summer, and fall of 2019 (12 sites per season). Effort expended at a sample unit during each of the three seasons consisted of (1) a 500-m shoreline boat electrofish sample, (2) a four hour experimental gill net set, and (3) a four hour baited minnow trap set. Fish community sampling in the Lowell impoundment occurred on June 24-26 (spring), August 19-21 (summer) and October 28-30 (fall). Tables 5-2 through 5-4 provide a summary of boat electrofish, gill net and minnow trap sampling in the Lowell impoundment. Impoundment sample units selected by season are presented visually in Appendix A.

### 5.1.3 *Species Richness and Composition*

A total of 1,847 individuals representing twenty-two fish species were collected from the Lowell impoundment during 2019 when all sampling seasons and sample units are considered (Table 5-5). The total impoundment catch represents all individuals collected and identified during boat electrofish and gill net sampling. There were no fish collected via minnow trap during the 2019 survey. Table 5-6 provides a summary of the impoundment community composition by season (electrofish and gill net). Spottail shiner (23.0%), redbreast sunfish (20.5%) and smallmouth bass (12.3%) were the three most numerically abundant species within the Lowell impoundment during the 2019 sampling. When examined by species, spottail shiner were most abundant during the spring (27.6% of seasonal catch) and fall (33.9% of seasonal catch) whereas redbreast sunfish were most abundant during the summer period (27.1% of seasonal catch).

Total catch and community composition from sampling units upstream of Pawtucket Dam and classified as impoundment, pool and run mesohabitat types are presented in Table 5-7. Centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2%), pumpkinseed (14.2%), and smallmouth bass (12.5%) representing the three most abundantly sampled species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4%) and run (46.3%) habitat areas.

The majority of catch in the impoundment was observed during boat electrofishing efforts (Table 5-8). A total of 1,792 individuals representing 20 fish species were collected. Spottail shiner, redbreast sunfish, and smallmouth bass were the most frequently observed species within the impoundment electrofish catch. Total boat electrofish catch within the impoundment was fairly even across seasons (high of 677 individuals during the summer to a low of 543 individuals during the fall). A total of 55 individuals representing 15 species were recorded during gill net sampling in the Lowell impoundment. Yellow bullhead was the most frequently encountered species during gill net sampling and the majority of catch was recorded during the summer season.

### 5.1.4 *Relative Abundance*

Relative abundance, the number of fish captured with known sampling effort and indexed as catch per unit of effort (CPUE), was calculated on a species-specific basis. CPUE values were standardized to a fixed unit of time or distance using the following equations:

For time (i.e., fish per hour): CPUE for taxon j in sample i = (catch ji / duration i) \* 60 min

Where: duration is expressed in minutes

For distance (i.e., fish per 100 m): CPUE for taxon j in sample i = (catch ji / length i) \* 100m

Where: length is expressed in meters

Prior to the calculation of any CPUE values the data set was “zero filled” for each fish species, such that each species collected in the study was represented in every sample. CPUE values were calculated for each fish species by season and gear.

Catch rates were highest for spottail shiner, redbreast sunfish and smallmouth bass captured by boat electrofish sampling in the 23.0 mile reach upstream of Pawtucket Dam during the 2019 sampling (Table 5-9). Values for fish per unit of effort were highest for spottail shiner and smallmouth bass during the spring sampling event, redbreast sunfish and spottail shiner during the summer sampling event and fallfish and alewife during the fall sampling event. Table 5-10 provides CPUE rates for fish collected during gill net sampling in the upstream reach during 2019. The CPUE rate for yellow bullhead was the highest for fish collected in the experimental gill nets. A listing of CPUE rates for all species by season and mesohabitat type is provided in Appendix B.

#### *5.1.5 Biocharacteristics*

Length frequency distributions for fish species where 25 or more individuals were collected and measured during the impoundment sampling are presented in Appendix E. The observed range for fish sizes recorded for species observed in both the boat electrofish and gill net catch from the Lowell impoundment fall within the expected bounds for those species in the northeastern U.S. (Table 5-11). A full listing of catch data is provided in Appendix F.

#### *5.1.6 Habitat and Water Quality Characteristics*

Tables 5-12 and 5-13 provide summaries of habitat and water quality information recorded for each of the 36, 500-m sample units surveyed during the spring, summer and fall seasons. Dominant substrate, presence of submerged aquatic vegetation (SAV), and presence of general cover were consistent among all sample units regardless of mesohabitat classification (i.e., pool, run or impoundment). Sampled areas upstream of Pawtucket Dam were characterized by sand-silt-clay sediments, presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth (as sampled at quarter points of the river channel at the upper, middle, and lower points of each transect) trended towards shallower at the upper end of the reach upstream of Pawtucket Dam in areas classified as pool and run and deeper at the lower end in areas classified as impoundment.

Water temperature was relatively consistent among sample units with a  $\pm 1-2^{\circ}\text{C}$  range in values within each season. The average Merrimack River water temperature was  $21.5^{\circ}\text{C}$  during the spring sampling,  $25.6^{\circ}\text{C}$  during the summer sampling, and  $10.8^{\circ}\text{C}$  during the fall sampling. Dissolved oxygen was measured at 8.1 mg/L or greater at all stations upstream of Pawtucket

Dam regardless of season. Conductivity averaged 114  $\mu\text{s}/\text{cm}$  during the spring sampling, 181  $\mu\text{s}/\text{cm}$  during the summer sampling, and 117  $\mu\text{s}/\text{cm}$  during the fall sampling. In general, conductivity increased with proximity to the Pawtucket Dam. River pH was consistent across seasons ranging from 6.5-7.5. The average turbidity reading was higher during the spring sampling (2.6 NTU) than was observed during the summer or fall periods (1.8 and 1.6 NTUs, respectively).

**Table 5–1. Sample unit habitat type and location for the spring, summer and fall Lowell impoundment fish community survey**

Season	Sample Unit	Mesohabitat Type	Upstream		Downstream		Efish Bank
			Latitude	Longitude	Latitude	Longitude	
Spring	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	W
	LIMP_004	Run	42.87414	-71.47563	42.87073	-71.47963	E
	LIMP_005	Pool	42.87073	-71.47963	42.86747	-71.48384	W
	LIMP_012	Pool	42.84162	-71.48371	42.83729	-71.48473	E
	LIMP_015	Pool	42.82889	-71.48038	42.82455	-71.47880	E
	LIMP_016	Run	42.82455	-71.47880	42.82055	-71.47999	W
	LIMP_017	Impoundment	42.82055	-71.47999	42.81789	-71.47512	W
	LIMP_021	Impoundment	42.80479	-71.47225	42.80101	-71.46898	W
	LIMP_027	Impoundment	42.78203	-71.45706	42.77753	-71.45706	W
	LIMP_049	Impoundment	42.69368	-71.42215	42.69125	-71.41704	W
	LIMP_050	Impoundment	42.69125	-71.41704	42.68765	-71.41352	W
	LIMP_069	Impoundment	42.63767	-71.36403	42.63851	-71.35805	W
Summer	LIMP_001	Run	42.88500	-71.46616	42.88173	-71.47036	W
	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	W
	LIMP_006	Pool	42.86747	-71.48384	42.86341	-71.48632	E
	LIMP_011	Pool	42.84596	-71.48228	42.84162	-71.48371	E
	LIMP_014	Pool	42.83315	-71.48236	42.82889	-71.48038	W
	LIMP_020	Impoundment	42.80909	-71.47339	42.80479	-71.47225	E
	LIMP_021	Impoundment	42.80479	-71.47225	42.80101	-71.46898	E
	LIMP_042	Impoundment	42.72045	-71.43789	42.71597	-71.43723	W
	LIMP_045	Impoundment	42.70703	-71.43625	42.70288	-71.43394	W
	LIMP_056	Impoundment	42.67057	-71.41675	42.66851	-71.41135	E
	LIMP_065	Impoundment	42.64835	-71.37998	42.64423	-71.37771	E
	LIMP_068	Impoundment	42.63777	-71.37011	42.63767	-71.36403	E
Fall	LIMP_002	Run	42.88173	-71.47036	42.87818	-71.47409	E
	LIMP_003	Run	42.87818	-71.47409	42.87414	-71.47563	W
	LIMP_005	Pool	42.87073	-71.47963	42.86747	-71.48384	W
	LIMP_011	Pool	42.84596	-71.48228	42.84162	-71.48371	E
	LIMP_015	Pool	42.82889	-71.48038	42.82455	-71.47880	W
	LIMP_023	Impoundment	42.79761	-71.46500	42.79481	-71.46027	W
	LIMP_037	Impoundment	42.74124	-71.43966	42.73705	-71.43771	E
	LIMP_044	Impoundment	42.71149	-71.43696	42.70703	-71.43625	W
	LIMP_058	Impoundment	42.66630	-71.40605	42.66252	-71.40286	W
	LIMP_060	Impoundment	42.65840	-71.40047	42.65406	-71.39903	W
	LIMP_061	Impoundment	42.65406	-71.39903	42.64990	-71.39711	E
	LIMP_067	Impoundment	42.64024	-71.37510	42.63777	-71.37011	E

**Table 5–2. Impoundment boat electrofish effort for the spring, summer and fall Lowell impoundment fish community survey**

Season	Sample Unit	Sample			No. Amps	No. Netters	No. Runs
		Date	Time	Duration (Sec)			
Spring	LIMP_002	6/24/2019	21:01	753	4	2	1
	LIMP_004	6/24/2019	22:04	956	4	2	1
	LIMP_005	6/24/2019	23:29	741	4	2	1
	LIMP_012	6/25/2019	0:37	782	4	2	1
	LIMP_015	6/26/2019	22:31	907	4	2	1
	LIMP_016	6/26/2019	21:49	968	4	2	1
	LIMP_017	6/26/2019	21:01	1001	4	2	1
	LIMP_021	6/26/2019	23:30	833	4	2	1
	LIMP_027	6/26/2019	1:25	888	4	2	1
	LIMP_049	6/25/2019	23:56	909	4	2	1
	LIMP_050	6/25/2019	22:42	842	4	2	1
	LIMP_069	6/25/2019	21:26	837	4	2	1
Summer	LIMP_001	8/19/2019	20:38	851	4	2	1
	LIMP_002	8/19/2019	21:44	722	4	2	1
	LIMP_006	8/19/2019	22:54	775	4	2	1
	LIMP_011	8/20/2019	0:02	959	4	2	1
	LIMP_014	8/21/2019	22:02	837	4	2	1
	LIMP_020	8/21/2019	20:56	841	4	2	1
	LIMP_021	8/21/2019	20:20	729	4	2	1
	LIMP_042	8/21/2019	0:17	903	4	2	1
	LIMP_045	8/20/2019	23:32	852	4	2	1
	LIMP_056	8/20/2019	22:22	815	4	2	1
	LIMP_065	8/20/2019	21:35	881	4	2	1
	LIMP_068	8/20/2019	20:21	812	4	2	1
Fall	LIMP_002	10/29/2019	16:54	839	4	2	1
	LIMP_003	10/29/2019	18:02	834	4	2	1
	LIMP_005	10/29/2019	20:02	814	4	2	1
	LIMP_011	10/29/2019	21:11	939	4	2	1
	LIMP_015	10/29/2019	21:48	842	4	2	1
	LIMP_023	10/29/2019	22:45	946	4	2	1
	LIMP_037	10/30/2019	18:39	835	4	2	1
	LIMP_044	10/30/2019	17:45	942	4	2	1
	LIMP_058	10/28/2019	17:54	900	4	2	1
	LIMP_060	10/28/2019	18:24	1140	4	2	1
	LIMP_061	10/28/2019	19:00	1080	4	2	1
	LIMP_067	10/28/2019	20:00	1140	4	2	1

**Table 5–3. Impoundment experimental gill net effort for the spring, summer and fall Lowell impoundment fish community survey**

Season	Sample Unit	Sample			Set Location	
		Date	Time	Duration (hr)	Latitude	Longitude
Spring	LIMP_002	6/24/2019	20:49	4.3	42.87818	71.47409
	LIMP_004	6/24/2019	21:02	4.3	42.87054	71.47924
	LIMP_005	6/24/2019	21:09	4.6	42.86747	71.48384
	LIMP_012	6/24/2019	21:30	4.7	42.83729	71.48472
	LIMP_015	6/26/2019	21:02	4.1	42.82588	71.47865
	LIMP_016	6/26/2019	21:14	4.2	42.82069	71.47828
	LIMP_017	6/26/2019	21:24	4.3	42.81857	71.47600
	LIMP_021	6/26/2019	21:35	4.4	42.80157	71.46944
	LIMP_027	6/25/2019	22:22	4.2	42.77752	71.45763
	LIMP_049	6/25/2019	21:55	4.1	42.69118	71.41750
	LIMP_050	6/25/2019	21:47	4.0	42.68747	71.41373
	LIMP_069	6/25/2019	21:18	4.1	42.63792	71.35815
Summer	LIMP_001	8/19/2019	20:33	4.7	42.88173	71.47036
	LIMP_002	8/19/2019	21:04	4.5	42.87818	71.47409
	LIMP_006	8/19/2019	21:30	4.4	42.86341	71.48632
	LIMP_011	8/19/2019	21:54	4.5	42.84162	71.48371
	LIMP_014	8/21/2019	20:20	4.1	42.82890	71.48038
	LIMP_020	8/21/2019	19:52	5.2	42.80479	71.47225
	LIMP_021	8/21/2019	19:44	5.6	42.80101	71.46984
	LIMP_042	8/20/2019	21:58	5.7	42.71597	71.43723
	LIMP_045	8/20/2019	21:42	5.6	42.70288	71.43394
	LIMP_056	8/20/2019	21:10	5.6	42.66851	71.41135
	LIMP_065	8/20/2019	20:39	5.7	42.64423	71.37771
LIMP_068	8/20/2019	20:18	5.4	42.63767	71.36403	
Fall	LIMP_002	10/29/2019	17:50	4.2	42.87818	71.47409
	LIMP_003	10/29/2019	18:06	4.3	42.87414	71.47563
	LIMP_005	10/29/2019	18:15	4.7	42.86747	71.48384
	LIMP_011	10/29/2019	18:35	5.0	42.84162	71.48371
	LIMP_015	10/29/2019	18:50	5.3	42.82455	71.47880
	LIMP_023	10/30/2019	17:41	4.0	42.79481	71.46027
	LIMP_037	10/30/2019	18:01	4.2	42.73705	71.43771
	LIMP_044	10/30/2019	18:16	4.5	42.70703	71.43625
	LIMP_058	10/28/2019	17:48	4.0	42.66252	71.40286
	LIMP_060	10/28/2019	18:06	4.1	42.65406	71.39903
	LIMP_061	10/28/2019	18:13	4.2	42.64990	71.39711
	LIMP_067	10/28/2019	18:29	4.3	42.63777	71.37011

**Table 5–4. Impoundment minnow trap effort for the spring, summer and fall Lowell impoundment fish community survey**

Season	Sample Unit	Sample			Set Location	
		Date	Time	Duration (hr)	Latitude	Longitude
Spring	LIMP_002	6/24/2019	23:05	1.9	42.87818	71.47409
	LIMP_004	6/24/2019	22:29	3.1	42.87073	71.47963
	LIMP_005	6/24/2019	22:11	3.6	42.86747	71.48384
	LIMP_012	6/24/2019	21:30	4.8	42.83729	71.48472
	LIMP_015	6/25/2019	22:23	4.0	42.77731	71.45747
	LIMP_016	6/25/2019	21:56	4.1	42.69115	71.41727
	LIMP_017	6/25/2019	21:48	4.0	42.68721	71.41364
	LIMP_021	6/25/2019	21:22	4.0	42.63770	71.35809
	LIMP_027	6/26/2019	21:02	4.1	42.82511	71.47849
	LIMP_049	6/26/2019	21:15	4.2	42.82085	71.47791
	LIMP_050	6/26/2019	21:26	4.1	42.81836	71.47588
	LIMP_069	6/26/2019	21:36	4.2	42.80159	71.46933
Summer	LIMP_001	8/19/2019	22:42	2.8	42.88173	71.47036
	LIMP_002	8/19/2019	22:36	3.0	42.87818	71.47409
	LIMP_006	8/19/2019	22:20	3.7	42.86341	71.48632
	LIMP_011	8/19/2019	21:59	4.4	42.84162	71.48371
	LIMP_014	8/21/2019	20:22	4.0	42.82890	71.48038
	LIMP_020	8/21/2019	19:53	5.1	42.80479	71.47225
	LIMP_021	8/21/2019	19:46	5.5	42.80101	71.46984
	LIMP_042	8/20/2019	22:04	5.5	42.71597	71.43723
	LIMP_045	8/20/2019	21:45	5.5	42.70288	71.43394
	LIMP_056	8/20/2019	21:13	5.6	42.66851	71.41135
	LIMP_065	8/20/2019	22:48	3.5	42.64423	71.37771
LIMP_068	8/20/2019	20:22	2.3	42.63767	71.36403	
Fall	LIMP_002	10/29/2019	17:52	4.1	42.87818	71.47409
	LIMP_003	10/29/2019	18:07	4.2	42.87414	71.47563
	LIMP_005	10/29/2019	18:17	4.7	42.86747	71.48384
	LIMP_011	10/29/2019	18:37	5.0	42.84162	71.48371
	LIMP_015	10/29/2019	18:52	5.2	42.82455	71.47880
	LIMP_023	10/30/2019	17:42	4.0	42.79481	71.46027
	LIMP_037	10/30/2019	18:02	4.2	42.73705	71.43771
	LIMP_044	10/30/2019	18:18	4.4	42.70703	71.43625
	LIMP_058	10/28/2019	17:50	4.2	42.66252	71.40286
	LIMP_060	10/28/2019	18:04	4.2	42.65406	71.39903
	LIMP_061	10/28/2019	18:15	4.1	42.64990	71.39711
	LIMP_067	10/28/2019	18:31	4.2	42.63777	71.37011



**Table 5–5. Number of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling, 2019**

Common Name	Spring	Summer	Fall	2019
	N	N	N	N
Alewife	0	21	92	113
American Eel	6	10	1	17
Black Crappie	2	2	1	5
Bluegill	24	77	21	122
Channel Catfish	0	1	0	1
Common Carp	1	3	1	5
Fallfish	34	34	75	143
Golden Shiner	1	5	7	13
Largemouth Bass	2	32	7	41
Lepomis spp.	1	3	0	4
Margined Madtom	3	5	1	9
Pumpkinseed	10	126	19	155
Redbreast Sunfish	137	196	45	378
Rock Bass	3	2	2	7
Sea Lamprey	7	6	8	21
Smallmouth Bass	127	50	50	227
Spottail Shiner	160	79	185	424
Tessellated Darter	14	14	3	31
Walleye	0	1	0	1
White Perch	0	1	0	1
White Sucker	24	9	22	55
Yellow Bullhead	7	42	5	54
Yellow Perch	16	3	1	20
<b>Total</b>	<b>579</b>	<b>722</b>	<b>546</b>	<b>1847</b>

**Table 5–6. Percent composition of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net during the spring, summer and fall sampling, 2019**

Common Name	Spring	Summer	Fall	2019
	Pct.	Pct.	Pct.	Pct.
Alewife	<0.1	2.9	16.8	6.1
American Eel	1.0	1.4	0.2	0.9
Black Crappie	0.3	0.3	0.2	0.3
Bluegill	4.1	10.7	3.8	6.6
Channel Catfish	<0.1	0.1	<0.1	0.1
Common Carp	0.2	0.4	0.2	0.3
Fallfish	5.9	4.7	13.7	7.7
Golden Shiner	0.2	0.7	1.3	0.7
Largemouth Bass	0.3	4.4	1.3	2.2
Lepomis spp.	0.2	0.4	<0.1	0.2
Margined Madtom	0.5	0.7	0.2	0.5
Pumpkinseed	1.7	17.5	3.5	8.4
Redbreast Sunfish	23.7	27.1	8.2	20.5
Rock Bass	0.5	0.3	0.4	0.4
Sea Lamprey	1.2	0.8	1.5	1.1
Smallmouth Bass	21.9	6.9	9.2	12.3
Spottail Shiner	27.6	10.9	33.9	23.0
Tessellated Darter	2.4	1.9	0.5	1.7
Walleye	<0.1	0.1	<0.1	0.1
White Perch	<0.1	0.1	<0.1	0.1
White Sucker	4.1	1.2	4.0	3.0
Yellow Bullhead	1.2	5.8	0.9	2.9
Yellow Perch	2.8	0.4	0.2	1.1

**Table 5–7. Number and percent composition of fish captured upstream of Pawtucket Dam by boat electrofishing and experimental gill net within impoundment, pool and run mesohabitat areas, 2019**

Common Name	Impoundment		Pool		Run	
	N	Pct.	N	Pct.	N	Pct.
Alewife	104	9.9	4	1.3	5	1.0
American Eel	11	1.0	1	0.3	5	1.0
Black Crappie	1	0.1	3	1.0	1	0.2
Bluegill	87	8.2	28	9.0	7	1.5
Channel Catfish	1	0.1	0	0.0	0	0.0
Common Carp	4	0.4	0	0.0	1	0.2
Fallfish	66	6.3	37	11.9	40	8.3
Golden Shiner	3	0.3	6	1.9	4	0.8
Largemouth Bass	22	2.1	15	4.8	4	0.8
Lepomis spp.	2	0.2	1	0.3	1	0.2
Margined Madtom	6	0.6	2	0.6	1	0.2
Pumpkinseed	150	14.2	3	1.0	2	0.4
Redbreast Sunfish	255	24.2	39	12.6	84	17.4
Rock Bass	3	0.3	2	0.6	2	0.4
Sea Lamprey	11	1.0	5	1.6	5	1.0
Smallmouth Bass	132	12.5	35	11.3	60	12.4
Spottail Shiner	113	10.7	88	28.4	223	46.3
Tessellated Darter	14	1.3	11	3.5	6	1.2
Walleye	1	0.1	0	0.0	0	0.0
White Perch	1	0.1	0	0.0	0	0.0
White Sucker	21	2.0	12	3.9	22	4.6
Yellow Bullhead	42	4.0	6	1.9	6	1.2
Yellow Perch	5	0.5	12	3.9	3	0.6
<b>Total</b>	<b>1055</b>	<b>100.0</b>	<b>310</b>	<b>100.0</b>	<b>482</b>	<b>100.0</b>

**Table 5–8. Number of fish captured upstream of Pawtucket Dam by boat electrofishing or experimental gill net during spring, summer, and fall, 2019**

Common Name	Boat Efish				Gill Net			
	Spring	Summer	Fall	Total	Spring	Summer	Fall	Total
Alewife	0	19	92	111	0	2	0	2
American Eel	6	10	1	17	0	0	0	0
Black Crappie	2	2	1	5	0	0	0	0
Bluegill	23	77	21	121	1	0	0	1
Channel Catfish	0	0	0	0	0	1	0	1
Common Carp	1	2	1	4	0	1	0	1
Fallfish	33	32	75	140	1	2	0	3
Golden Shiner	1	4	7	12	0	1	0	1
Largemouth Bass	2	32	7	41	0	0	0	0
Lepomis spp.	1	3	0	4	0	0	0	0
Margined Madtom	2	5	1	8	1	0	0	1
Pumpkinseed	10	125	19	154	0	1	0	1
Redbreast Sunfish	137	191	45	373	0	5	0	5
Rock Bass	3	2	2	7	0	0	0	0
Sea Lamprey	7	6	8	21	0	0	0	0
Smallmouth Bass	126	46	50	222	1	4	0	5
Spottail Shiner	159	79	184	422	1	0	1	2
Tessellated Darter	14	14	3	31	0	0	0	0
Walleye	0	0	0	0	0	1	0	1
White Perch	0	1	0	1	0	0	0	0
White Sucker	22	7	22	51	2	2	0	4
Yellow Bullhead	7	19	3	29	0	23	2	25
Yellow Perch	16	1	1	18	0	2	0	2
<b>Total</b>	<b>572</b>	<b>677</b>	<b>543</b>	<b>1792</b>	<b>7</b>	<b>45</b>	<b>3</b>	<b>55</b>

**Table 5–9. Catch per unit of effort for fish captured upstream of Pawtucket Dam by boat electrofishing during spring, summer, and fall, 2019**

Common Name	Spring		Summer		Fall		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	0.00	0.00	1.39	0.06	10.15	0.61	3.85	0.23
American Eel	0.53	0.03	2.17	0.09	<0.01	<0.01	0.90	0.04
Black Crappie	0.53	0.02	0.23	0.01	0.31	0.01	0.36	0.02
Bluegill	3.04	0.14	9.13	0.43	3.15	0.15	5.11	0.24
Common Carp	0.07	<0.01	0.76	0.03	0.13	0.01	0.32	0.01
Fallfish	7.27	0.34	6.43	0.28	14.09	0.65	9.26	0.43
Golden Shiner	0.06	<0.01	0.75	0.03	1.66	0.07	0.82	0.04
Largemouth Bass	0.34	0.02	4.28	0.20	1.43	0.06	2.02	0.09
Lepomis spp.	0.07	<0.01	0.92	0.04	0.00	0.00	0.33	0.01
Margined Madtom	0.37	0.02	1.06	0.05	0.12	0.01	0.52	0.02
Pumpkinseed	0.80	0.04	9.60	0.44	2.13	0.13	4.18	0.20
Redbreast Sunfish	22.79	1.05	35.24	1.55	5.52	0.29	21.18	0.96
Rock Bass	1.19	0.05	0.24	0.01	0.10	0.01	0.51	0.02
Sea Lamprey	1.63	0.08	0.42	0.02	1.20	0.06	1.08	0.06
Smallmouth Bass	25.51	1.16	9.26	0.42	5.58	0.29	13.45	0.62
Spottail Shiner	35.29	1.55	25.94	1.12	8.30	0.37	23.17	1.01
Tessellated Darter	3.02	0.14	1.56	0.07	0.12	0.01	1.57	0.07
White Perch	0.00	0.00	0.08	0.00	0.00	0.00	0.03	0.00
White Sucker	4.19	0.21	1.27	0.06	2.46	0.12	2.64	0.13
Yellow Bullhead	0.90	0.05	2.00	0.09	0.52	0.03	1.14	0.05
Yellow Perch	4.66	0.20	0.21	0.01	<0.01	<0.01	1.62	0.07

**Table 5–10. Catch per unit of effort for fish captured upstream of Pawtucket Dam by experimental gill net during spring, summer, and fall, 2019**

Common Name	Spring	Summer	Fall	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Alewife	<0.01	0.01	0.00	0.00
Bluegill	0.02	<0.01	<0.01	0.01
Channel Catfish	<0.01	0.00	<0.01	<0.01
Common Carp	<0.01	0.00	<0.01	<0.01
Fallfish	0.00	0.01	<0.01	0.01
Golden Shiner	<0.01	0.03	<0.01	0.01
Margined Madtom	0.00	<0.01	<0.01	<0.01
Pumpkinseed	<0.01	0.00	<0.01	<0.01
Redbreast Sunfish	<0.01	0.02	<0.01	0.01
Smallmouth Bass	0.00	0.01	<0.01	0.01
Spottail Shiner	0.03	<0.01	0.02	0.02
Walleye	<0.01	0.00	<0.01	<0.01
White Sucker	0.02	0.01	<0.01	0.01
Yellow Bullhead	<0.01	0.08	0.04	0.04
Yellow Perch	<0.01	0.01	<0.01	<0.01

**Table 5–11. Minimum, mean, and maximum total length (mm) and weight (g) for fish captured upstream of Pawtucket Dam by boat electrofish and experimental gill net sampling during spring, summer, and fall, 2019**

Sampling Gear	Common Name	No. Individuals	Total Length (mm)			Total Weight (g)		
			Min.	Mean	Max.	Min.	Mean	Max.
Boat Electrofish	Alewife	111	59	69	104	1	4	102
	American Eel	17	225	459	670	20	236	535
	Black Crappie	5	84	133	155	8	36	49
	Bluegill	121	47	110	220	1	38	255
	Common Carp	4	429	662	793	1350	4813	6500
	Fallfish	140	55	127	310	2	28	335
	Golden Shiner	12	80	120	208	6	23	73
	Largemouth Bass	41	57	141	382	2	108	900
	Margined Madtom	8	82	102	138	4	9	23
	Pumpkinseed	154	57	97	150	3	27	685
	Redbreast Sunfish	373	38	113	190	1	35	160
	Rock Bass	7	121	157	189	41	86	140
	Sea Lamprey	21	90	127	174	1	4	8
	Smallmouth Bass	222	64	158	494	3	93	1450
	Spottail Shiner	422	49	93	126	1	11	840
	Tessellated Darter	31	39	65	80	1	3	5
	White Perch	1	69	69	69	5	5	5
	White Sucker	51	84	310	520	7	600	1800
	Yellow Bullhead	29	104	183	297	15	95	310
Yellow Perch	18	80	156	287	5	75	325	
Gill Net	Alewife	2	101	101	101	11	12	12
	Bluegill	1	136	136	136	52	52	52
	Channel Catfish	1	296	296	296	290	290	290
	Common Carp	1	552	552	552	2400	2400	2400
	Fallfish	3	219	299	354	120	353	540
	Golden Shiner	1	95	95	95	9	9	9
	Margined Madtom	1	114	114	114	14	14	14
	Pumpkinseed	1	173	173	173	115	115	115
	Redbreast Sunfish	5	131	150	180	45	63	99
	Smallmouth Bass	5	178	217	270	80	132	240
	Spottail Shiner	2	110	118	125	15	18	20
	Walleye	1	630	630	630	2800	2800	2800
	White Sucker	4	358	398	430	550	788	950
	Yellow Bullhead	25	160	202	254	49	122	240
Yellow Perch	2	178	223	268	70	175	280	

**Table 5–12. Physical habitat measurements recorded for sample units upstream of Pawtucket Dam during spring, summer, and fall, 2019**

Season	Mesohabitat Type	Sample Unit	Habitat Parameter			
			Dominant Substrate	Pct. SAV	Pct. Cover	Mean Depth (ft)
Spring	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Run	LIMP-004	Sand-Silt-Clay	0-25%	0-25%	9.7
	Pool	LIMP-005	Sand-Silt-Clay	0-25%	0-25%	9.4
	Pool	LIMP-012	Sand-Silt-Clay	0-25%	0-25%	9.6
	Pool	LIMP-015	Sand-Silt-Clay	0-25%	0-25%	8.8
	Run	LIMP-016	Sand-Silt-Clay	0-25%	0-25%	6.4
	Impoundment	LIMP-017	Sand-Silt-Clay	0-25%	0-25%	8.4
	Impoundment	LIMP-021	Sand-Silt-Clay	0-25%	0-25%	11.6
	Impoundment	LIMP-027	Sand-Silt-Clay	0-25%	0-25%	6.8
	Impoundment	LIMP-049	Sand-Silt-Clay	0-25%	0-25%	14.6
	Impoundment	LIMP-050	Sand-Silt-Clay	0-25%	0-25%	12.6
	Impoundment	LIMP-069	Sand-Silt-Clay	0-25%	0-25%	16.1
Summer	Run	LIMP-001	Sand-Silt-Clay	0-25%	0-25%	11.0
	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Pool	LIMP-006	Sand-Silt-Clay	25-50%	0-25%	6.9
	Pool	LIMP-011	Sand-Silt-Clay	0-25%	0-25%	8.5
	Pool	LIMP-014	Sand-Silt-Clay	0-25%	0-25%	5.9
	Impoundment	LIMP-020	Sand-Silt-Clay	0-25%	0-25%	8.7
	Impoundment	LIMP-021	Sand-Silt-Clay	0-25%	0-25%	11.6
	Impoundment	LIMP-042	Sand-Silt-Clay	0-25%	0-25%	13.7
	Impoundment	LIMP-045	Sand-Silt-Clay	0-25%	0-25%	17.3
	Impoundment	LIMP-056	Sand-Silt-Clay	0-25%	0-25%	19.2
	Impoundment	LIMP-065	Sand-Silt-Clay	0-25%	0-25%	17.4
	Impoundment	LIMP-068	-	-	-	17.0
Fall	Run	LIMP-002	Sand-Silt-Clay	0-25%	0-25%	16.3
	Run	LIMP-003	Sand-Silt-Clay	0-25%	0-25%	6.4
	Pool	LIMP-005	Sand-Silt-Clay	0-25%	0-25%	9.4
	Pool	LIMP-011	Sand-Silt-Clay	0-25%	0-25%	8.5
	Pool	LIMP-015	Sand-Silt-Clay	0-25%	0-25%	8.8
	Impoundment	LIMP-023	Sand-Silt-Clay	0-25%	0-25%	9.7
	Impoundment	LIMP-037	Sand-Silt-Clay	0-25%	0-25%	14.8
	Impoundment	LIMP-044	Sand-Silt-Clay	0-25%	0-25%	19.8
	Impoundment	LIMP-058	Sand-Silt-Clay	0-25%	0-25%	13.4
	Impoundment	LIMP-060	Sand-Silt-Clay	0-25%	0-25%	14.7
	Impoundment	LIMP-061	Sand-Silt-Clay	0-25%	0-25%	17.4
	Impoundment	LIMP-067	Sand-Silt-Clay	0-25%	0-25%	14.3



**Table 5–13. Water quality parameters recorded upstream of Pawtucket Dam during spring, summer, and fall, 2019**

Season	Mesohabitat Type	Sample Unit	Water Quality Parameter				
			Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH	Turbidity (NTU)
Spring	Run	LIMP-002	21.6	8.8	98.0	7.4	1.6
	Run	LIMP-004	21.4	8.7	100.0	6.6	2.5
	Pool	LIMP-005	21.5	8.8	97.0	6.6	2.2
	Pool	LIMP-012	21.6	8.9	99.0	6.7	2.4
	Pool	LIMP-015	22.1	8.7	114.0	6.5	3.1
	Run	LIMP-016	22.0	9.0	112.0	6.5	3.7
	Impoundment	LIMP-017	22.0	8.8	114.0	6.6	2.2
	Impoundment	LIMP-021	21.9	8.7	120.0	6.6	3.2
	Impoundment	LIMP-027	20.8	8.6	115.0	6.7	2.5
	Impoundment	LIMP-049	20.6	8.5	133.0	6.6	2.7
	Impoundment	LIMP-050	20.7	8.5	131.0	6.6	3.5
	Impoundment	LIMP-069	21.2	8.4	139.0	6.6	2.0
Summer	Run	LIMP-001	26.0	8.3	169.0	7.5	1.9
	Run	LIMP-002	26.0	8.3	169.0	7.5	1.9
	Pool	LIMP-006	25.9	8.3	166.0	7.5	1.9
	Pool	LIMP-011	25.5	8.1	171.0	7.3	1.9
	Pool	LIMP-014	25.2	8.1	169.0	7.0	1.8
	Impoundment	LIMP-020	25.4	8.2	176.0	6.8	1.8
	Impoundment	LIMP-021	25.4	8.3	180.0	6.8	1.8
	Impoundment	LIMP-042	25.8	8.4	191.0	6.9	1.7
	Impoundment	LIMP-045	25.7	8.4	187.0	6.7	1.6
	Impoundment	LIMP-056	25.7	8.8	199.0	6.9	1.6
	Impoundment	LIMP-065	25.7	8.6	195.0	6.9	1.6
	Impoundment	LIMP-068	25.4	8.4	195.0	6.9	1.5
Fall	Run	LIMP-002	10.3	11.1	91.0	6.5	2.2
	Run	LIMP-003	10.4	11.1	91.0	6.6	2.1
	Pool	LIMP-005	10.4	11.1	92.0	6.7	2.0
	Pool	LIMP-011	10.5	11.1	95.0	6.9	2.0
	Pool	LIMP-015	10.5	11.0	96.0	7.4	1.9
	Impoundment	LIMP-023	10.8	10.9	96.0	6.9	2.2
	Impoundment	LIMP-037	11.0	10.8	125.0	7.0	1.8
	Impoundment	LIMP-044	10.9	10.6	123.0	7.1	1.9
	Impoundment	LIMP-058	11.2	10.1	145.0	7.2	0.9
	Impoundment	LIMP-060	11.2	10.1	146.0	7.2	1.0
	Impoundment	LIMP-061	11.3	10.0	152.0	7.2	0.9
	Impoundment	LIMP-067	11.5	9.8	151.0	7.3	0.8

## 5.2 Lowell Bypassed Reach

### 5.2.1 Habitat Evaluation and Sample Unit Selection

Changes in general habitat types within the Lowell bypassed reach were visually identified and marked in ArcGIS. The approximately 0.75 mile reach downstream of Pawtucket Dam was subdivided into a total of 23, 55-yard (50-meter) segments. The bypassed reach was subdivided into habitat classifications associated with the upper chute (i.e., the area between Pawtucket Dam and School Street Bridge), pooled section immediately downstream of the School Street Bridge, ledge channel area in the vicinity of the University Avenue Bridge, and the lower bypassed reach downstream of the power canal surge gate. Site conditions were considered inappropriate or unsafe for sampling in the upper chute reach and downstream of the spill gate. As a result back pack electrofish sampling in the bypassed reach occurred within the two middle reaches. Sampling locations were randomly selected on a seasonal basis. The spatial distribution of habitat classifications and 50-m segments within the 0.75 mile bypassed reach is provided in Appendix C.

Table 5-14 provides a listing of the habitat units downstream of the Pawtucket Dam and within the Lowell bypassed reach that were randomly selected for sampling during the spring, summer, and fall periods of 2019. A total of three, 50-m segments were selected per season.

### 5.2.2 Sampling Effort

Fish community data were collected from a total of 12, 50-m sample units during the spring, summer, and fall of 2019 (12 sites per season). Effort expended at a sample unit during each of the three seasons consisted of an approximately 50-m back pack electrofish sample. Fish community sampling in the Lowell bypassed reach occurred on June 28 (spring), August 27 (summer) and October 21 (fall). Table 5-15 provides a summary of the back pack electrofish sampling in the Lowell bypassed reach. Bypassed reach sample units selected by season are presented visually in Appendix C.

### 5.2.3 Species Richness and Composition

A total of 526 individuals representing fourteen fish species were collected during back pack electrofishing efforts within the Lowell bypassed reach during 2019 when all sampling seasons and sample units are considered (Table 5-16). Table 5-17 provides a summary of the bypassed reach community composition by season. Fallfish (39.9%), smallmouth bass (20.3%) and spottail shiner (16.7%) were the three most numerically abundant species within the Lowell bypassed reach during the 2019 sampling. When examined by species, spottail shiner were most abundant during the spring (48.8%), fallfish during the summer (55.0%) and fallfish during the fall (39.9%).

Total catch and community composition from sampling units within the pooled and ledge channel sections of the bypassed reach downstream of Pawtucket Dam are presented in Table 5-18. Fallfish were the most abundant fish species collected within the pooled habitat within the Lowell bypassed reach and downstream of Pawtucket Dam, representing 47% of the total catch. Fish catch from the ledge channel habitat located in the lower portion of the bypassed

reach was dominated by smallmouth bass which represented 60.6% of the total catch from that area. American eel represented 13.8% of the total electrofish catch from the ledge channel habitat within the Lowell bypassed reach.

#### *5.2.4 Relative Abundance*

CPUE values for back pack electrofish sampling within the Lowell bypassed reach downstream of Pawtucket Dam were standardized to a fixed unit of time or distance using the equations and methods provided in Section 5.1.4. Catch rates were highest for smallmouth bass, fallfish, and spottail shiner captured by back pack electrofish sampling in the 0.75 mile bypassed reach downstream of Pawtucket Dam during the 2019 sampling (Table 5-19). Values for fish per unit of effort were highest for spottail shiner and fallfish during the spring sampling event, fallfish and smallmouth bass during the summer sampling event and smallmouth bass and redbreast sunfish during the fall sampling event. A listing of CPUE rates for all species by season and habitat type is provided in Appendix D.

#### *5.2.5 Biocharacteristics*

Length frequency distributions for fish species where 25 or more individuals were collected and measured during the bypassed reach sampling are presented in Appendix E. The observed range for fish sizes recorded for species observed in the back pack electrofish catch from the reach downstream of the Pawtucket Dam fall within the expected bounds for those species in the northeastern U.S. (Table 5-11). A full listing of catch data is provided in Appendix F.

#### *5.2.6 Habitat and Water Quality Characteristics*

Tables 5-21 and 5-22 provide summaries of habitat and water quality information recorded for each of the 9, 50-m sample units surveyed within the Lowell bypassed reach during the spring, summer and fall seasons. A range of substrate types was sampled during each of the three seasons, ranging from areas of boulders to sand-silt-clay habitat. Sampled areas within the Lowell bypassed reach downstream of Pawtucket Dam were characterized by the presence of SAV over 0-25% of the sample area and the presence of general cover over 0-25% of the sample area. Mean water depth (as measured at quarter points of the electrofished area at the upper, middle, and lower points of each transect) was consistent among sample areas and season, ranging from 1.5-2.4 feet.

Water temperature was relatively consistent among sample units within each season<sup>1</sup> and averaged 22.9°C during the spring sampling, 23.8°C during the summer sampling, and 13.1°C during the fall sampling. Dissolved oxygen was measured at 8.9 mg/L or greater at all bypassed reach stations downstream of Pawtucket Dam regardless of season. Conductivity averaged 148 µs/cm during the spring sampling, 194 µs/cm during the summer sampling, and 100 µs/cm during the fall sampling. The average river pH in the bypassed reach was higher during the summer sampling event (7.8) than was observed during the spring (6.5) or fall (6.6).

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<sup>1</sup> Water quality readings were available at only sample unit LBYP-011 during the spring event due to a malfunction with the meter handset during sampling.

**Table 5–14. Sample unit habitat type and location for the spring, summer and fall Lowell bypassed reach fish community survey**

Season	Sample Unit	Mesohabitat Type	Upstream		Downstream		Efish Bank
			Latitude	Longitude	Latitude	Longitude	
Spring	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-013	Pooled Section	42.65087	-71.32739	42.65080	-71.32800	West
	LBYP-017	Pooled Section	42.65038	-71.32970	42.65007	-71.33015	West
Summer	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-014	Pooled Section	42.65080	-71.32800	42.65070	-71.32859	West
	LBYP-018	Pooled Section	42.65007	-71.33015	42.64977	-71.33059	West
Fall	LBYP-011	Ledge Channels	42.65102	-71.32619	42.65094	-71.32679	West
	LBYP-013	Pooled Section	42.65087	-71.32739	42.65080	-71.32800	West
	LBYP-016	Pooled Section	42.65058	-71.32918	42.65038	-71.32970	West

**Table 5–15. Back pack electrofish effort for the spring, summer and fall Lowell bypassed reach fish community survey**

Season	Sample Unit	Sample			Settings (V/Hz)	No. Netters	No. Runs
		Date	Time	Duration (Sec)			
Spring	LBYP-011	6/28/2019	11:11	1270	550/100	4	1
	LBYP-013	6/28/2019	9:50	978	550/100	4	1
	LBYP-017	6/28/2019	12:47	1068	550/100	4	1
Summer	LBYP-011	8/27/2019	9:55	1048	550/100	4	1
	LBYP-014	8/27/2019	11:23	887	550/100	4	1
	LBYP-018	8/27/2019	13:25	917	550/100	4	1
Fall	LBYP-011	10/21/2019	12:02	1089	550/100	4	1
	LBYP-013	10/21/2019	11:06	922	550/100	4	1
	LBYP-016	10/21/2019	9:54	1033	550/100	4	1

**Table 5–16. Number of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during the spring, summer and fall sampling, 2019**

Common Name	Spring	Summer	Fall	2019
	N	N	N	N
American Eel	10	18	5	33
Bluegill	2	1	0	3
Brown Trout	1	0	0	1
Fallfish	22	187	1	210
Largemouth Bass	0	2	0	2
Lepomis spp.	0	0	1	1
Longnose Dace	1	0	1	2
Margined Madtom	1	2	14	17
Redbreast Sunfish	1	5	7	13
Sea Lamprey	0	0	1	1
Smallmouth Bass	2	37	68	107
Spottail Shiner	39	49	0	88
Tessellated Darter	1	5	4	10
White Sucker	0	30	3	33
Yellow Bullhead	0	4	1	5
<b>Total</b>	<b>80</b>	<b>340</b>	<b>106</b>	<b>526</b>

**Table 5–17. Percent composition of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during the spring, summer and fall sampling, 2019**

Common Name	Spring	Summer	Fall	2019
	Pct.	Pct.	Pct.	Pct.
American Eel	12.5	5.3	4.7	6.3
Bluegill	2.5	0.3	0.0	0.6
Brown Trout	1.3	0.0	0.0	0.2
Fallfish	27.5	55.0	0.9	39.9
Largemouth Bass	0.0	0.6	0.0	0.4
Lepomis spp.	0.0	0.0	0.9	0.2
Longnose Dace	1.3	0.0	0.9	0.4
Margined Madtom	1.3	0.6	13.2	3.2
Redbreast Sunfish	1.3	1.5	6.6	2.5
Sea Lamprey	0.0	0.0	0.9	0.2
Smallmouth Bass	2.5	10.9	64.2	20.3
Spottail Shiner	48.8	14.4	0.0	16.7
Tessellated Darter	1.3	1.5	3.8	1.9
White Sucker	0.0	8.8	2.8	6.3
Yellow Bullhead	0.0	1.2	0.9	1.0

**Table 5–18. Number and percent composition of fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing within pooled and ledge channel habitat areas, 2019**

Common Name	Pooled Section		Ledge Channels	
	N	Pct.	N	Pct.
American Eel	20	4.6	13	13.8
Bluegill	3	0.7	0	0.0
Brown Trout	0	0.0	1	1.1
Fallfish	203	47.0	7	7.4
Largemouth Bass	2	0.5	0	0.0
Lepomis spp.	1	0.2	0	0.0
Longnose Dace	0	0.0	2	2.1
Margined Madtom	16	3.7	1	1.1
Redbreast Sunfish	4	0.9	9	9.6
Sea Lamprey	1	0.2	0	0.0
Smallmouth Bass	50	11.6	57	60.6
Spottail Shiner	88	20.4	0	0.0
Tessellated Darter	9	2.1	1	1.1
White Sucker	30	6.9	3	3.2
Yellow Bullhead	5	1.2	0	0.0

**Table 5–19. Catch per unit of effort for fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofishing during spring, summer, and fall, 2019**

Backpack E-Fish								
Common Name	Spring		Summer		Fall		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	12.40	7.83	12.00	8.00	1.81	0.83	8.74	5.56
Bluegill	0.76	0.33	0.28	0.17	0.00	0.00	0.35	0.17
Brown Trout	1.48	1.00	0.00	0.00	0.00	0.00	0.49	0.33
Fallfish	20.65	11.17	48.72	31.17	0.36	0.17	23.24	14.17
Largemouth Bass	0.00	0.00	0.56	0.33	0.00	0.00	0.19	0.11
Lepomis spp.	0.00	0.00	0.00	0.00	0.84	0.33	0.28	0.11
Longnose Dace	1.48	1.00	0.00	0.00	1.48	1.00	0.98	0.67
Margined Madtom	1.48	1.00	0.52	0.33	6.03	2.67	2.68	1.33
Redbreast Sunfish	1.48	1.00	2.55	1.67	10.33	7.00	4.79	3.22
Sea Lamprey	0.00	0.00	0.00	0.00	0.84	0.33	0.28	0.11
Smallmouth Bass	2.95	2.00	40.15	27.00	63.33	38.17	35.48	22.39
Spottail Shiner	32.83	13.00	12.78	8.17	0.00	0.00	15.20	7.06
Tessellated Darter	0.38	0.17	2.52	1.67	1.93	0.83	1.61	0.89
White Sucker	0.00	0.00	7.83	5.00	4.43	3.00	4.09	2.67
Yellow Bullhead	0.00	0.00	1.11	0.67	0.36	0.17	0.49	0.28

**Table 5–20. Minimum, mean, and maximum total length (mm) and weight (g) for fish captured within the bypassed reach downstream of Pawtucket Dam by back pack electrofish sampling during spring, summer, and fall, 2019**

Common Name	No. Individuals	Total Length (mm)			Total Weight (g)		
		Min.	Mean	Max.	Min.	Mean	Max.
American Eel	33	100	285	550	2	78	325
Bluegill	3	35	107	175	1	50	120
Brown Trout	1	225	225	225	110	110	110
Fallfish	210	22	46	86	1	10	415
Largemouth Bass	2	69	72	75	5	6	7
Lepomis spp.	1	31	31	31	1	1	1
Longnose Dace	2	80	90	99	6	8	10
Margined Madtom	17	50	85	133	1	7	21
Redbreast Sunfish	13	37	165	395	1	53	180
Sea Lamprey	1	160	160	160	7	7	7
Smallmouth Bass	107	79	118	215	6	24	110
Spottail Shiner	88	40	75	97	1	8	180
Tessellated Darter	10	56	66	86	1	3	6
White Sucker	33	55	87	279	2	14	240
Yellow Bullhead	5	59	70	87	4	6	9

**Table 5–21. Physical habitat measurements recorded for sample units within the bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019**

Season	Habitat Type	Sample Unit	Habitat Parameter			
			Dominant Substrate	Pct. SAV	Pct. Cover	Mean Depth (ft)
Spring	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-013	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-017	Sand-Silt-Clay	0-25%	0-25%	1.7
Summer	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-014	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-018	Sand-Silt-Clay	0-25%	0-25%	2.4
Fall	Ledge Channels	LBYP-011	Boulder/Rip-Rap	0-25%	0-25%	1.5
	Pooled Section	LBYP-013	Cobble-Gravel	0-25%	0-25%	1.8
	Pooled Section	LBYP-016	Sand-Silt-Clay	0-25%	0-25%	1.6

**Table 5–22. Water quality parameters recorded within the bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019**

Season	Habitat Type	Sample Unit	Water Quality Parameter			
			Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µs/cm)	pH
Spring	Ledge Channels	LBYP-011	22.9	9.5	148	6.5
	Pooled Section	LBYP-013	*	*	*	*
	Pooled Section	LBYP-017	*	*	*	*
Summer	Ledge Channels	LBYP-011	23.4	9.6	191	7.4
	Pooled Section	LBYP-014	23.9	9.1	195	7.8
	Pooled Section	LBYP-018	24.1	9.4	197	8.1
Fall	Ledge Channels	LBYP-011	13.2	9.8	104	6.3
	Pooled Section	LBYP-013	13.1	8.9	102	6.6
	Pooled Section	LBYP-016	13.0	10.6	95	6.8

\* Water quality readings were available at only sample unit LBYP-011 during the spring event due to a malfunction with the meter handset during sampling



### 5.3 Historic Data

As described in the Lowell relicensing Pre-Application Document (PAD), the Merrimack River is home to a diverse assemblage of fishes, including cold water and warm water species. Stolte (1982; as cited in the Technical Committee for Anadromous Fishery Management of the Merrimack River Basin [Technical Committee] 1997) noted that during the last 150 years, over 15 non-indigenous species such as largemouth bass, smallmouth bass, walleye, common carp, rainbow trout, brown trout, various catfish species and goldfish have established through human introductions within the Merrimack River. At that time, the Merrimack River was identified as home to approximately 50 species of fish, nine of which were anadromous. The slower moving, ponded reaches of the Merrimack contain a higher predominance of warm water species whereas those areas with higher gradient contain the majority of cold water species. Hartel et al. (2002) identified a total of 57 reproducing fish species within the drainage; 21 primary species (i.e., those living full life cycle in freshwater), 8 secondary species (i.e., those with physiological capacity to move between fresh and salt water), 18 introduced species, and 10 diadromous species.

Fish assemblage sampling within the Lowell impoundment and bypassed reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species (Table 5-23). Of those species, 21 are considered freshwater and 3 are considered as diadromous. Based on information presented in Hartel et al. (2002) species observed during the 2019 fish sampling considered to be native to the Merrimack River watershed in Massachusetts represented 53% of the total catch across all seasons (12 species, 1,249 individuals). Conversely, species classified by Hartel et al. (2002) as introduced to the Merrimack River watershed represented 47% of the total catch across all seasons (12 species, 1,119 individuals).

**Table 5–23. Classifications for fish species recorded within the Lowell impoundment and bypassed reach downstream of Pawtucket Dam during spring, summer, and fall, 2019**

Common Name	Freshwater Resident	Diadromous	Native	Introduced
Alewife		X	X	
American Eel		X	X	
Black Crappie	X			X
Bluegill	X			X
Brown Trout	X			X
Channel Catfish	X			X
Common Carp	X			X
Fallfish	X		X	
Golden Shiner	X		X	
Largemouth Bass	X			X
Longnose Dace	X		X	
Margined Madtom	X			X
Pumpkinseed	X		X	
Redbreast Sunfish	X		X	
Rock Bass	X			X
Sea Lamprey		X	X	
Smallmouth Bass	X			X
Spottail Shiner	X			X
Tessellated Darter	X		X	
Walleye	X			X
White Perch	X		X	
White Sucker	X		X	
Yellow Bullhead	X			X
Yellow Perch	X		X	

## 6 Summary

The Lowell RSP identified two specific objectives for the fish assemblage study including (1) sampling to describe the fish assemblage structure, distribution, and abundance within the Project affected area along spatial and temporal gradients, and (2) a comparison of historical records of species occurrence with observations from this study.

Fish community sampling was conducted over spatial (impoundment versus bypassed reach) and temporal (spring, summer, and fall) gradients during 2019. Within the Lowell impoundment, fish were collected from standardized 500-m transects using a stratified random sampling design where mesohabitat type (i.e., impoundment, run, pool) was used to stratify. Once sites were identified, impoundment sampling was conducted via nighttime boat electrofishing, experimental gill netting, and minnow traps. Fish community data were collected from a total of 36, 500-m sample units during the spring, summer, and fall of 2019 (12 sites per season). A total of 1,847 individuals representing twenty-two fish species were collected from the Lowell impoundment during 2019 when all sampling seasons and sample units are considered. Spottail shiner (23.0%), redbreast sunfish (20.5%) and smallmouth bass (12.3%) were the three most numerically abundant species within the Lowell impoundment during the 2019 sampling. Centrarchid species were the most abundant within impoundment habitat with redbreast sunfish (24.2%), pumpkinseed (14.2%), and smallmouth bass (12.5%) representing the three most abundantly sampled species. Spottail shiner were the most abundantly sampled fish species in the pool (28.4%) and run (46.3%) habitat areas. The majority of catch in the impoundment was observed during boat electrofishing efforts.

Within the Lowell bypassed reach, fish were collected from standardized 50-m transects using a stratified random sampling design where habitat type was used to stratify. Site conditions were considered inappropriate or unsafe for sampling in two portions of the bypassed reach (i.e., the upper chute reach and downstream of the spill gate) and as a result back pack electrofish sampling in the bypassed reach occurred within the two middle reaches (i.e., the pooled section immediately downstream of the School Street Bridge and ledge channel area in the vicinity of the University Ave Bridge). A total of 526 individuals representing fourteen fish species were collected during back pack electrofishing efforts within the Lowell bypassed reach during 2019 when all sampling seasons and sample units are considered. Fallfish (39.9%), smallmouth bass (20.3%) and spottail shiner (16.7%) were the three most numerically abundant species within the Lowell bypassed reach during the 2019 sampling. Fallfish were the most abundant fish species collected within the pooled habitat within the Lowell bypassed reach and downstream of Pawtucket Dam, representing 47% of the total catch. Fish catch from the ledge channel habitat located in the lower portion of the bypassed reach was dominated by smallmouth bass which represented 60.6% of the total catch from that area.

Fish assemblage sampling within the Lowell impoundment and bypassed reach during the spring, summer and fall of 2019 resulted in the identification of 24 fish species. Approximately 53% of individuals collected during the 2019 sampling were classified as fish species native to the Merrimack River watershed in Massachusetts (12 species, 1,249 individuals). Conversely,

47% of the total catch across all seasons were classified as introduced to the Merrimack River watershed (12 species, 1,119 individuals).

## 7 Variances from FERC-Approved Study Plan

There was no variance from the methodologies and schedule as described in the FERC-approved study plan.

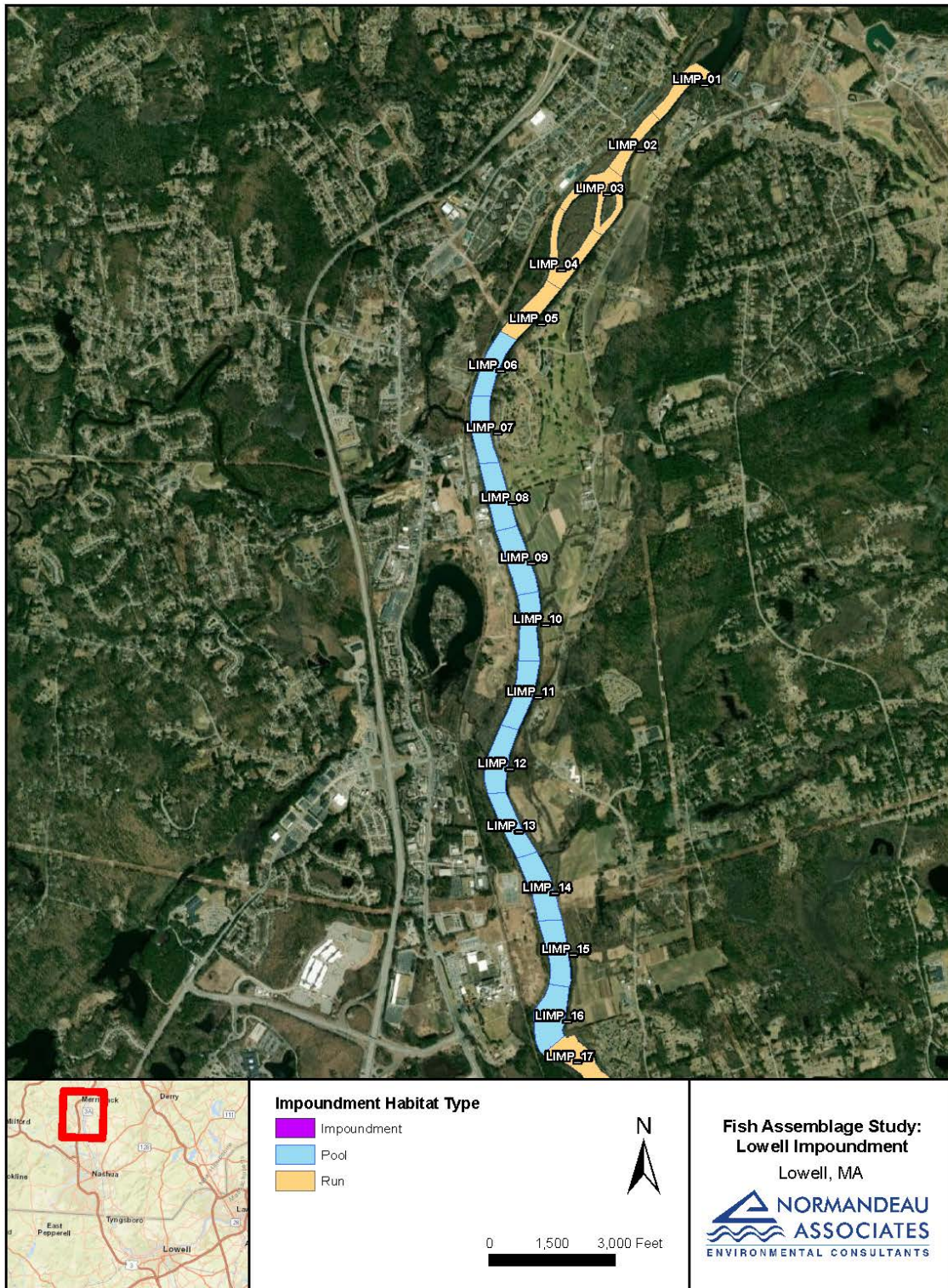
## 8 References

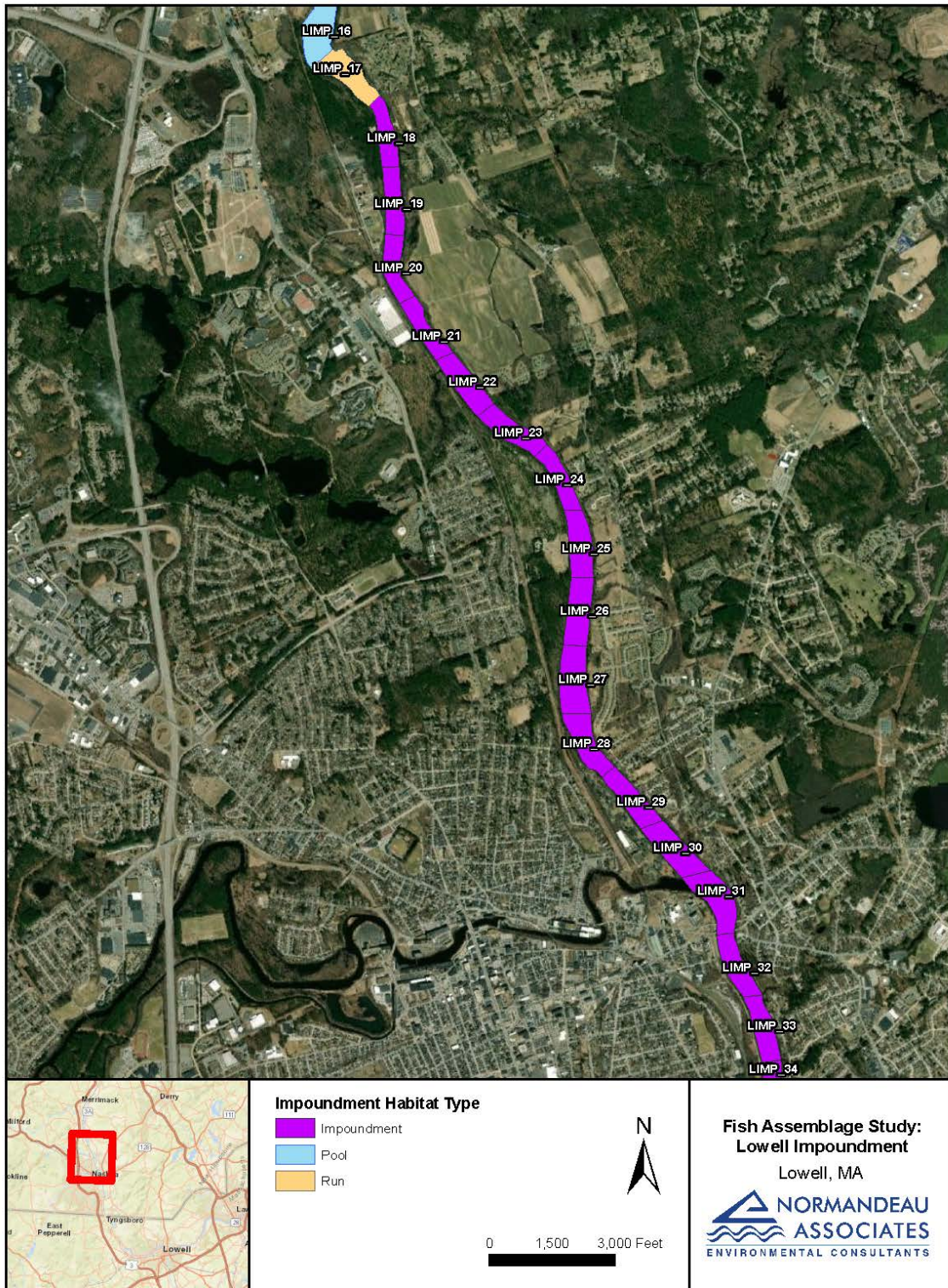
Hartel, K.E., D.B. Halliwell, and A.E. Launer. 2002. *Inland Fishes of Massachusetts*. Massachusetts Audubon Society.

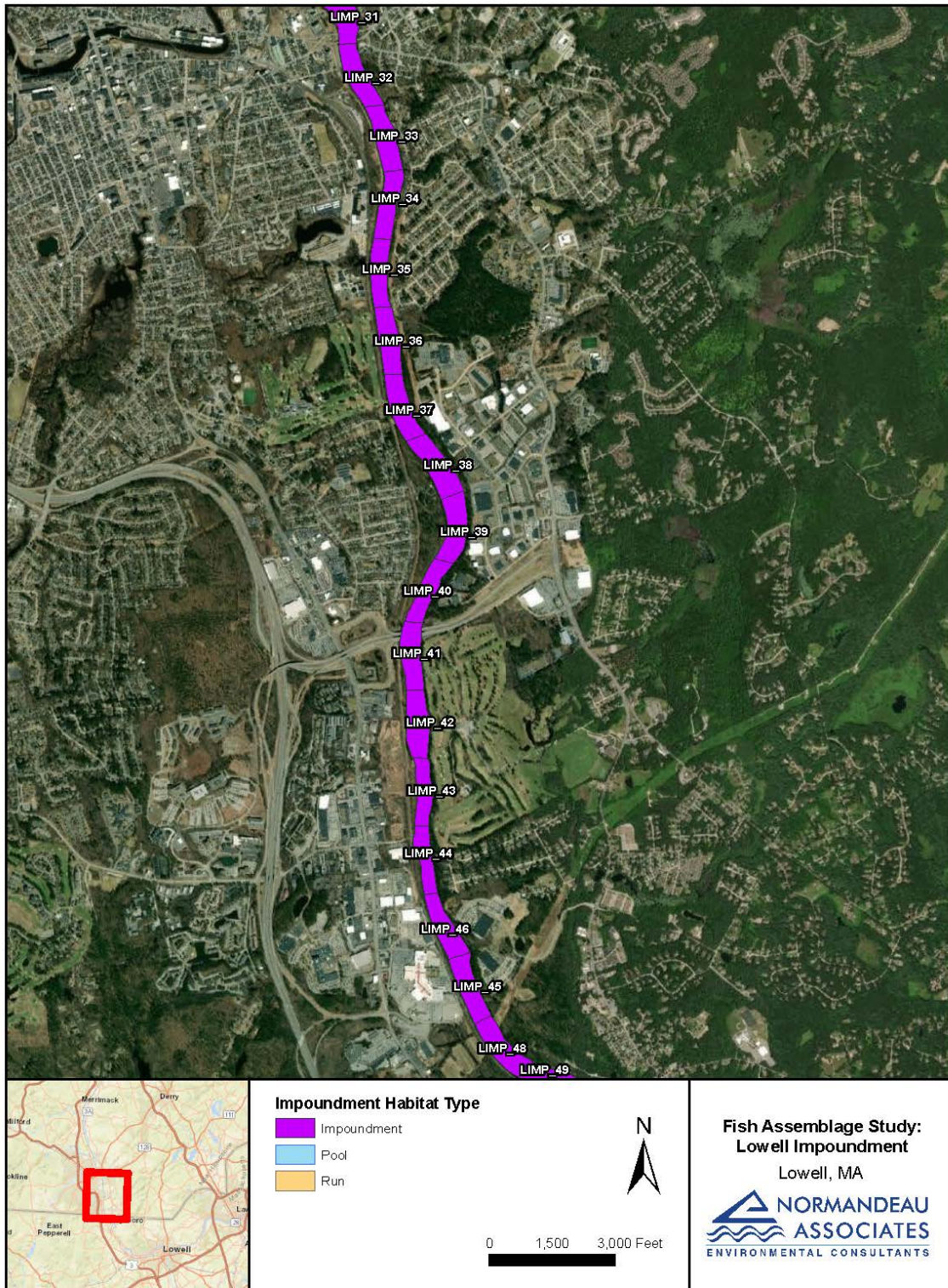
Technical Committee for Anadromous Fishery Management of the Merrimack River Basin (Technical Committee). 1997. *Strategic Plan and Status Review Anadromous Fish Restoration Program Merrimack River*. Technical Committee for Anadromous Fishery Management of the Merrimack River Basin and Advisors to the Technical Committee.

## 9 Appendices

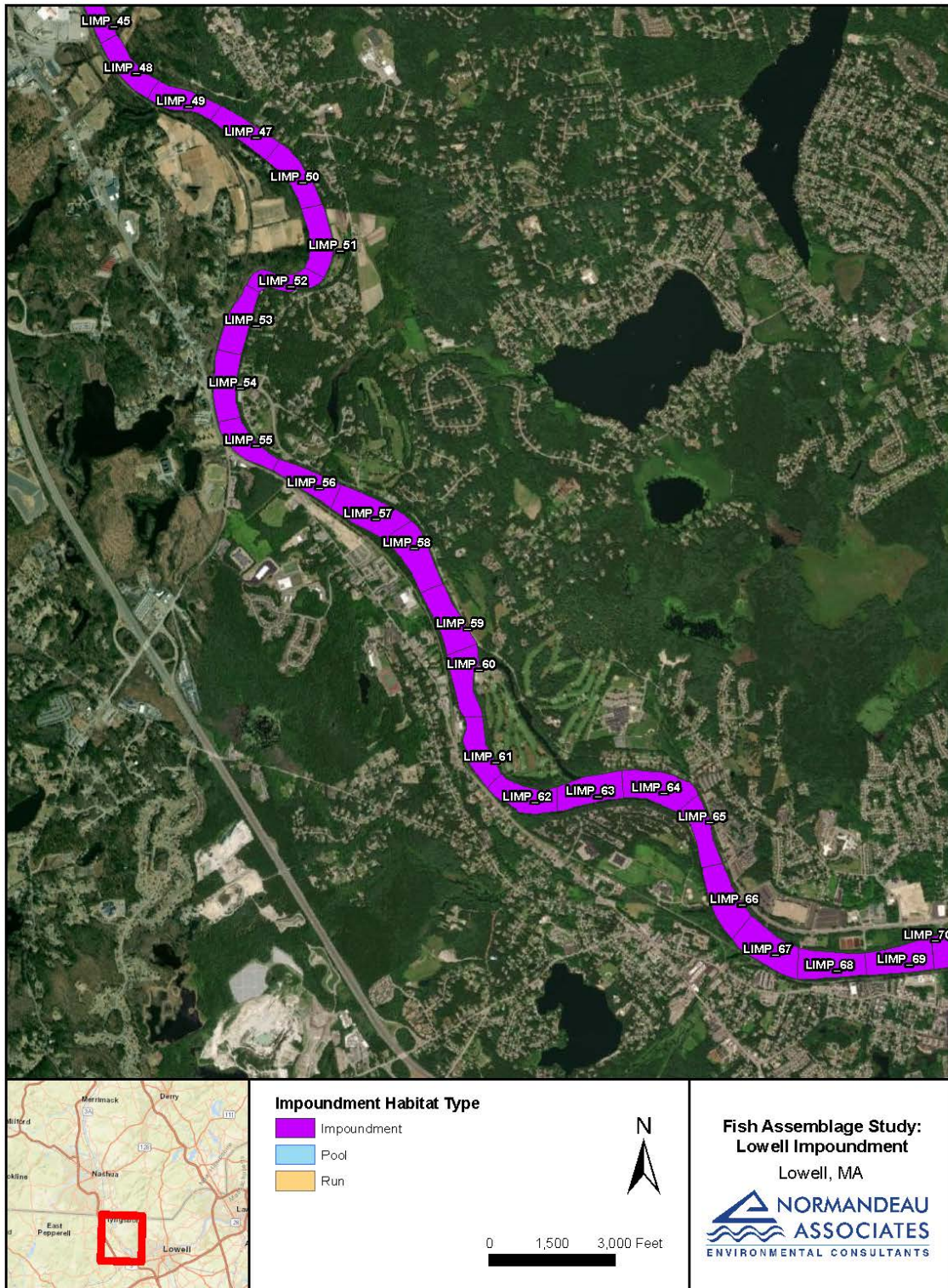
Appendix A. Spatial distribution of 500-m mesohabitat units for the 23.0 mile reach upstream of Pawtucket Dam.

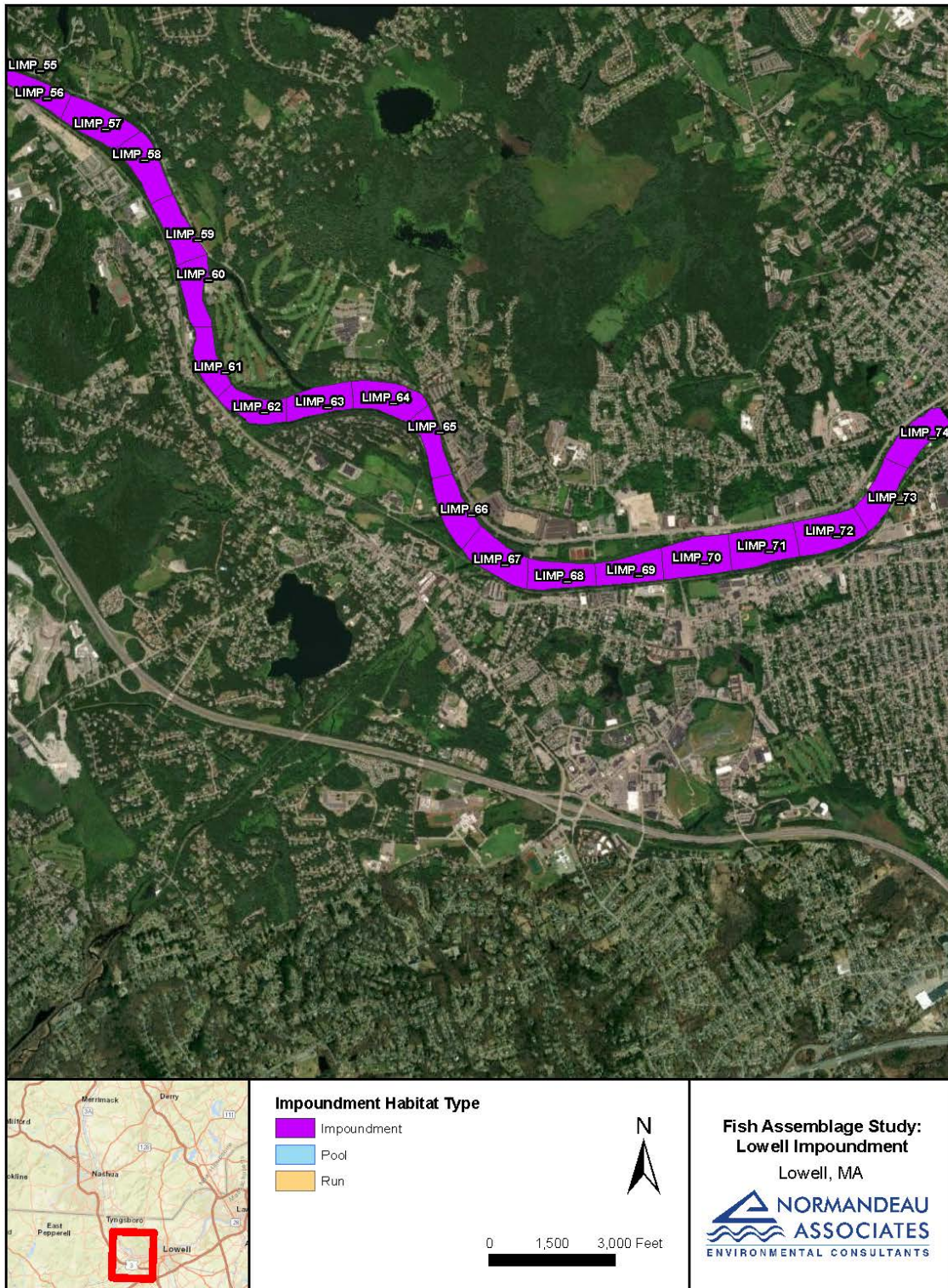




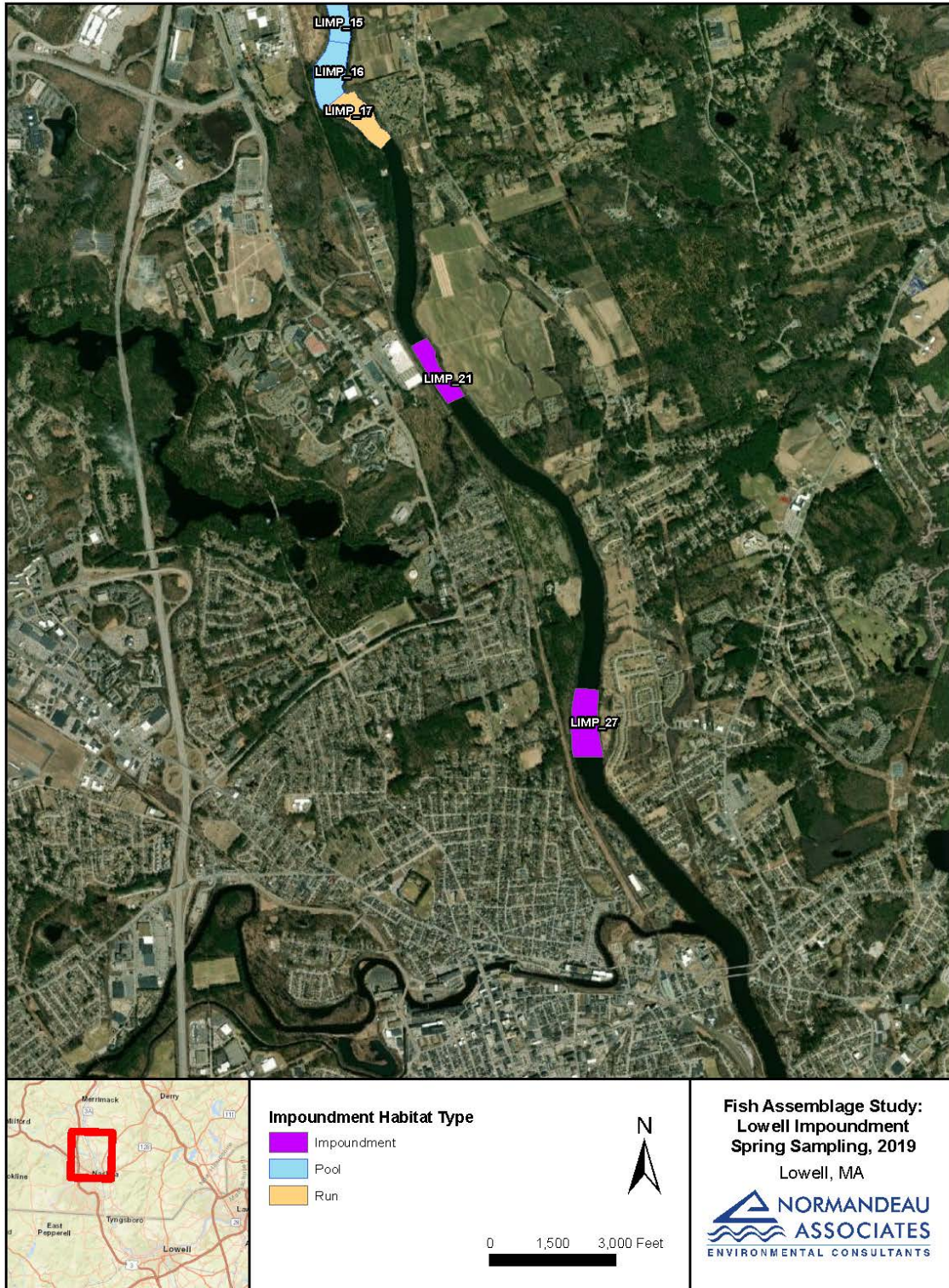






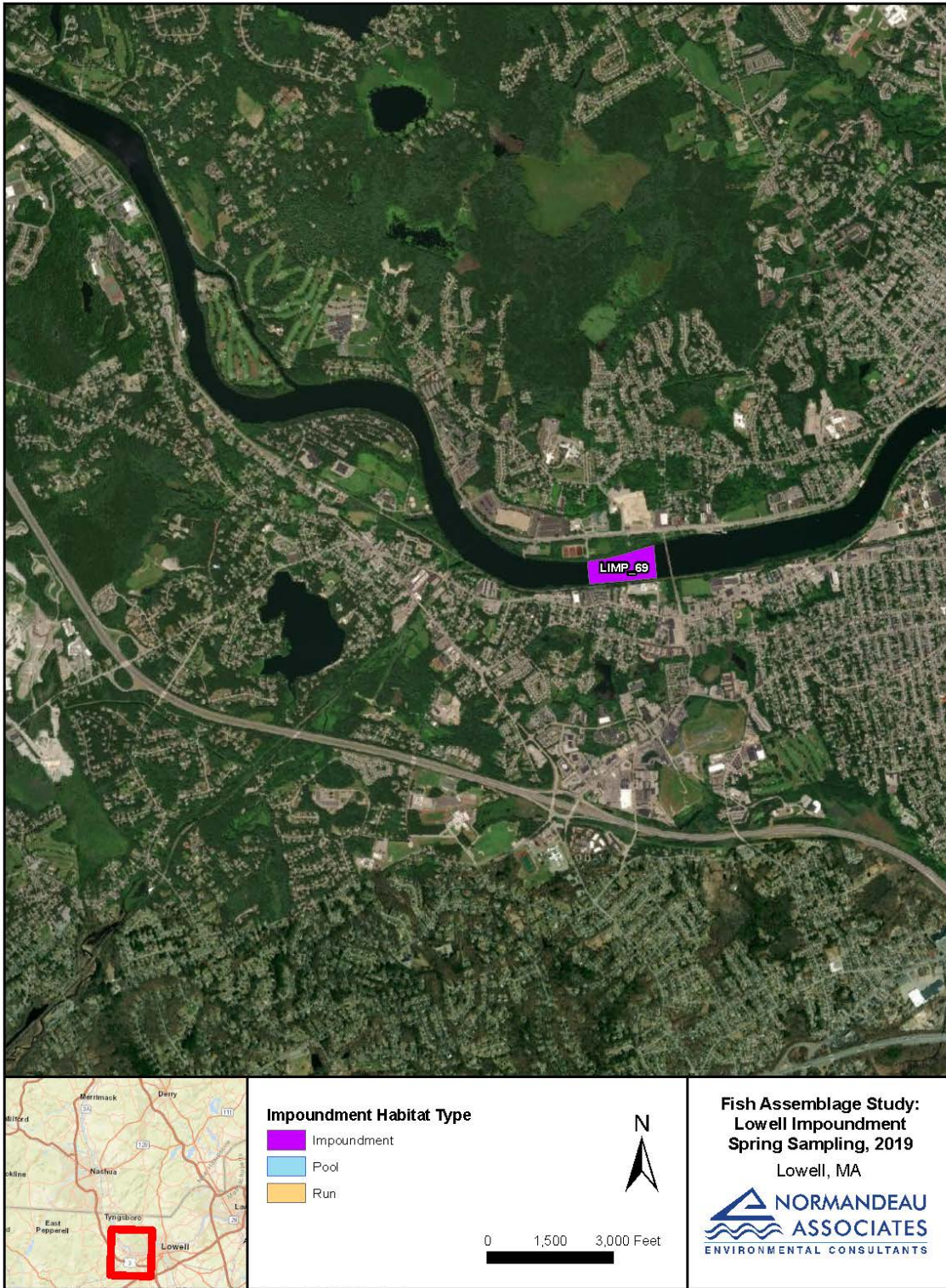


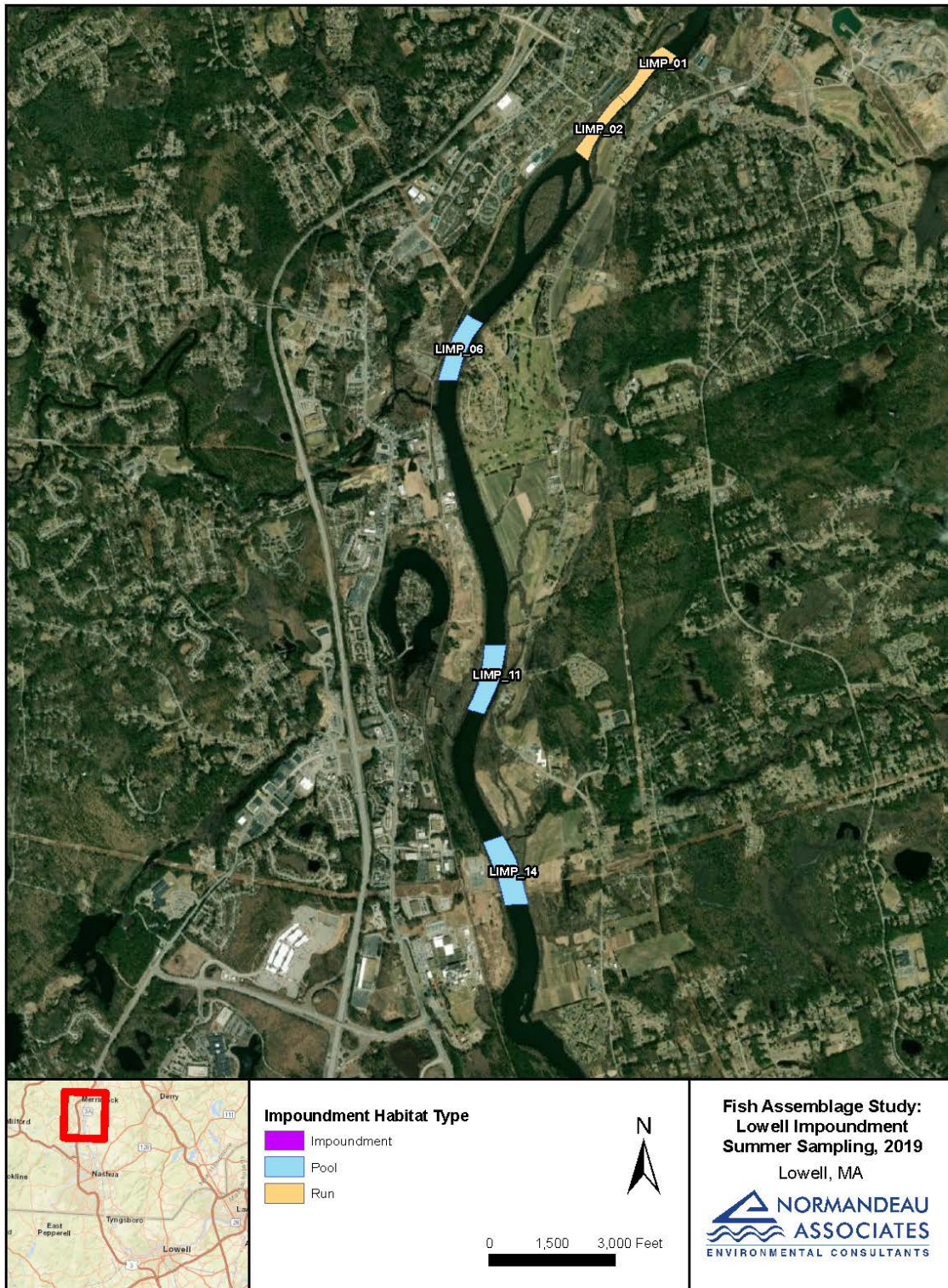




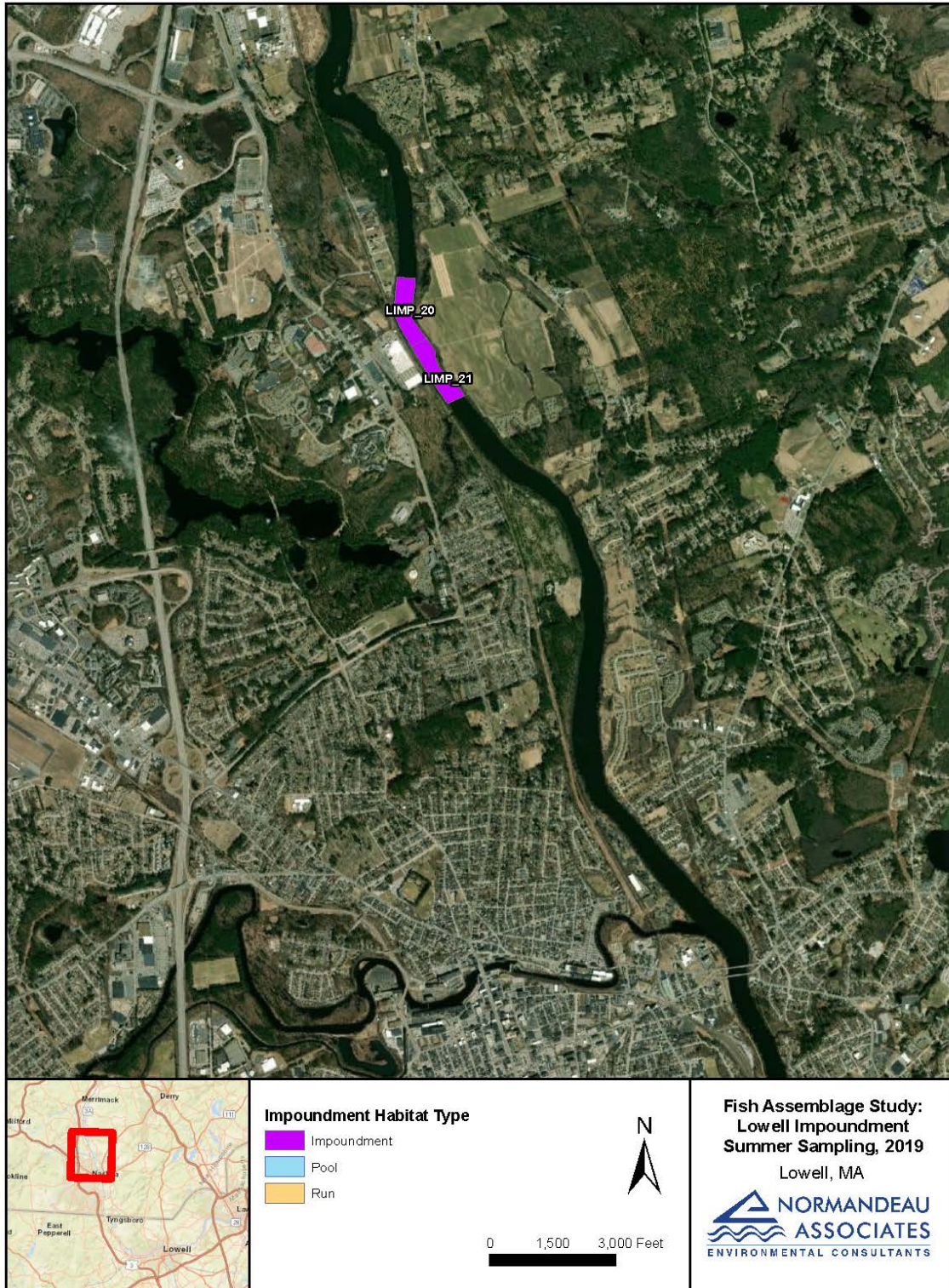


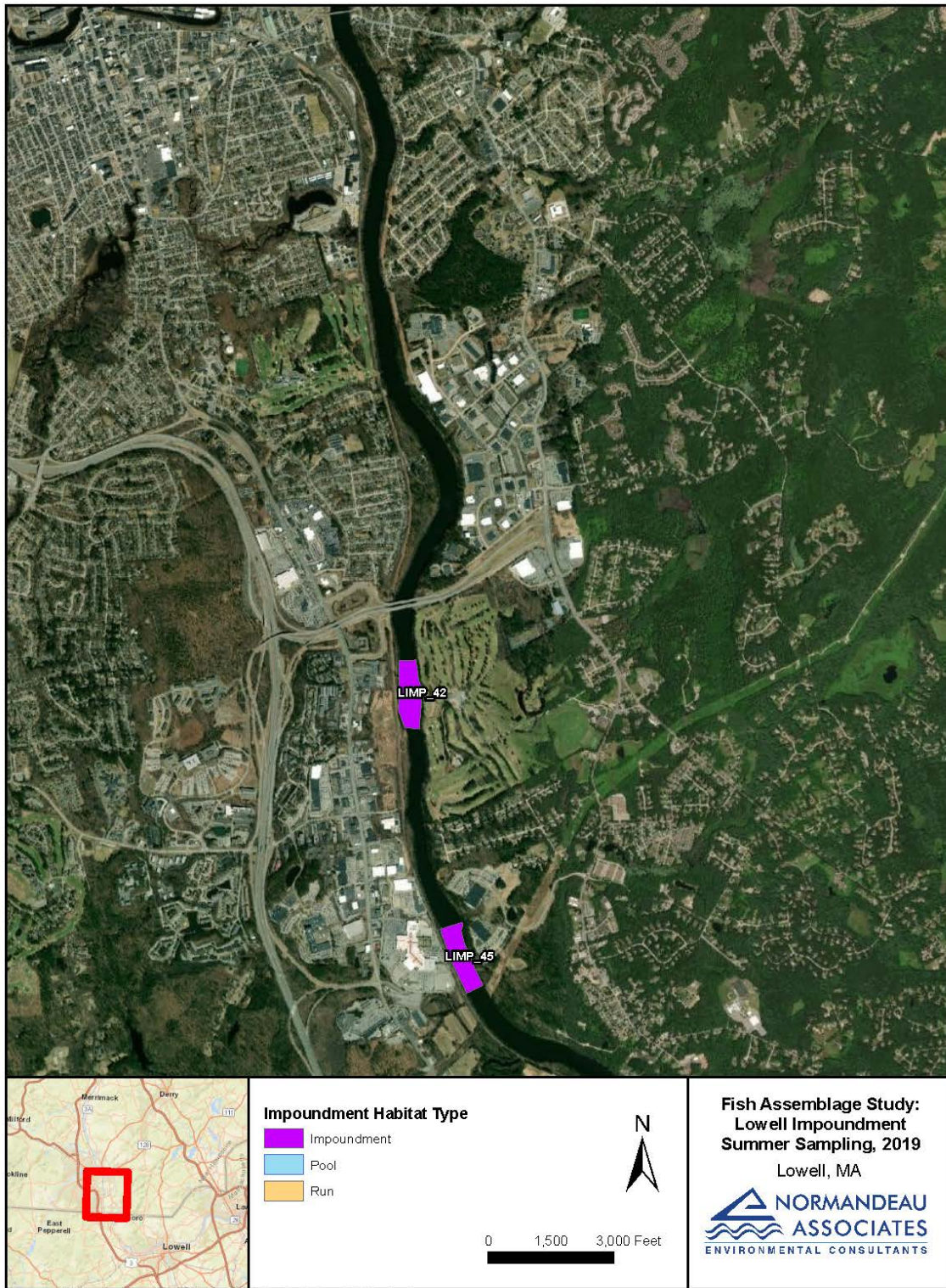


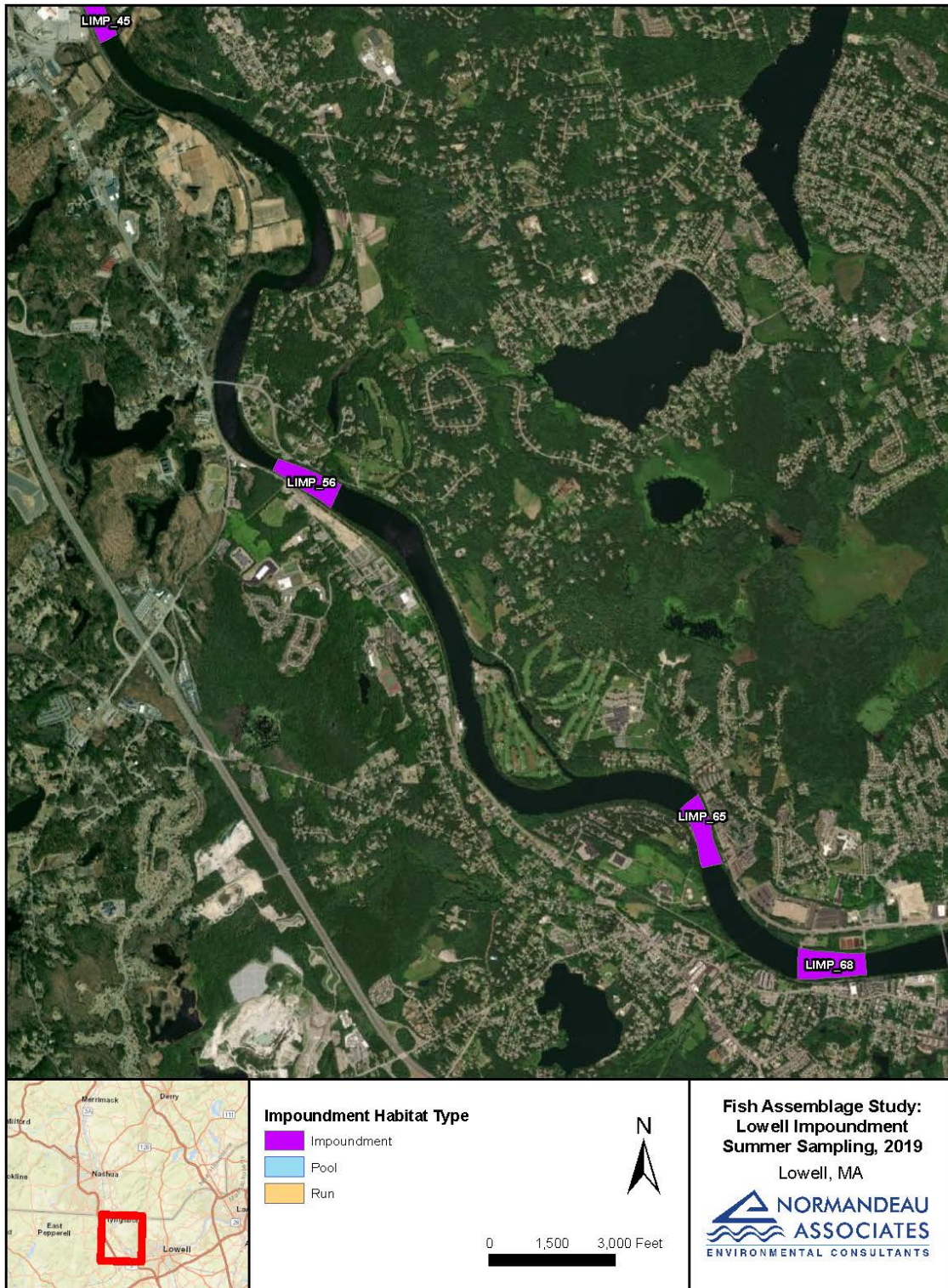


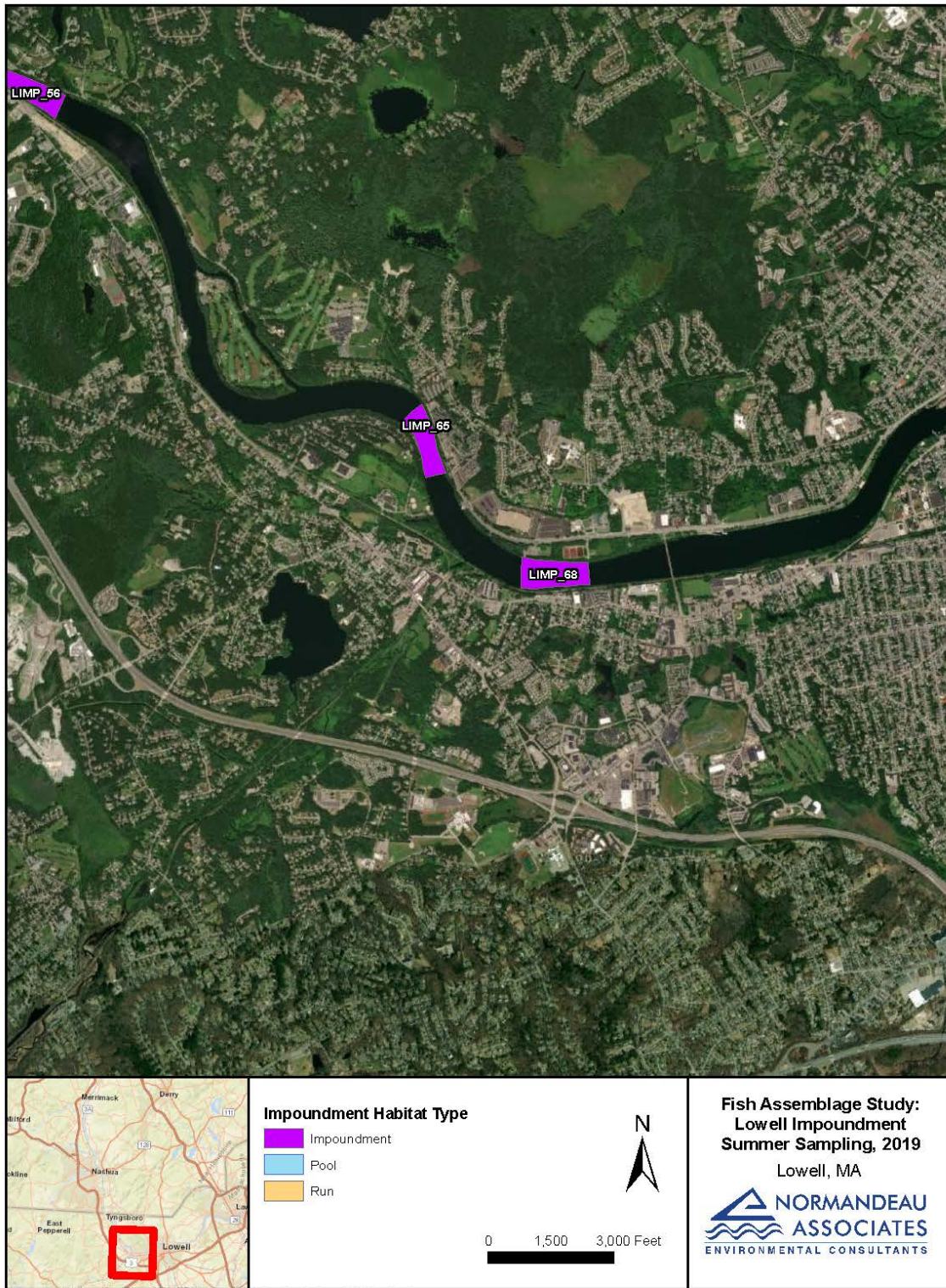


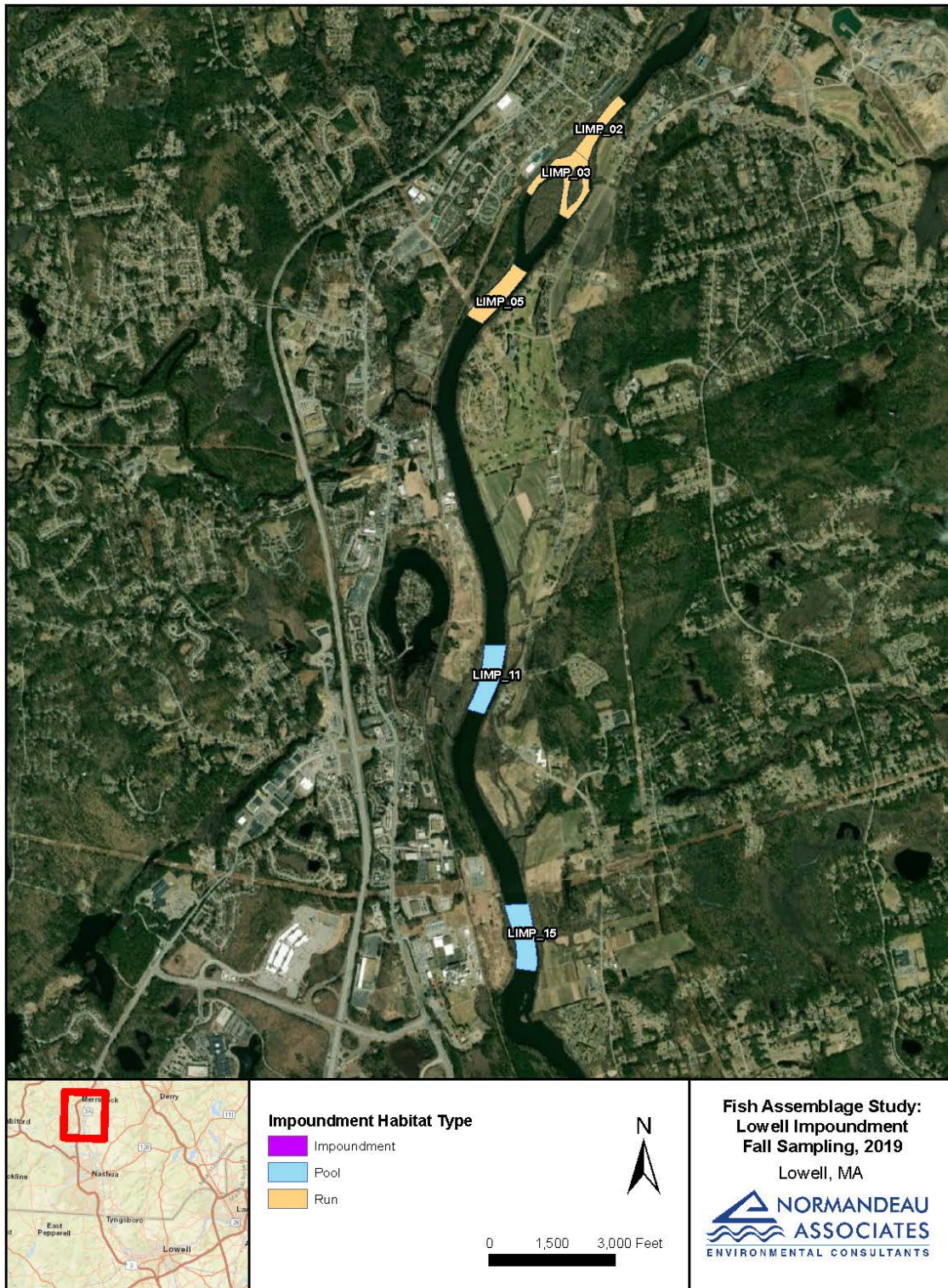


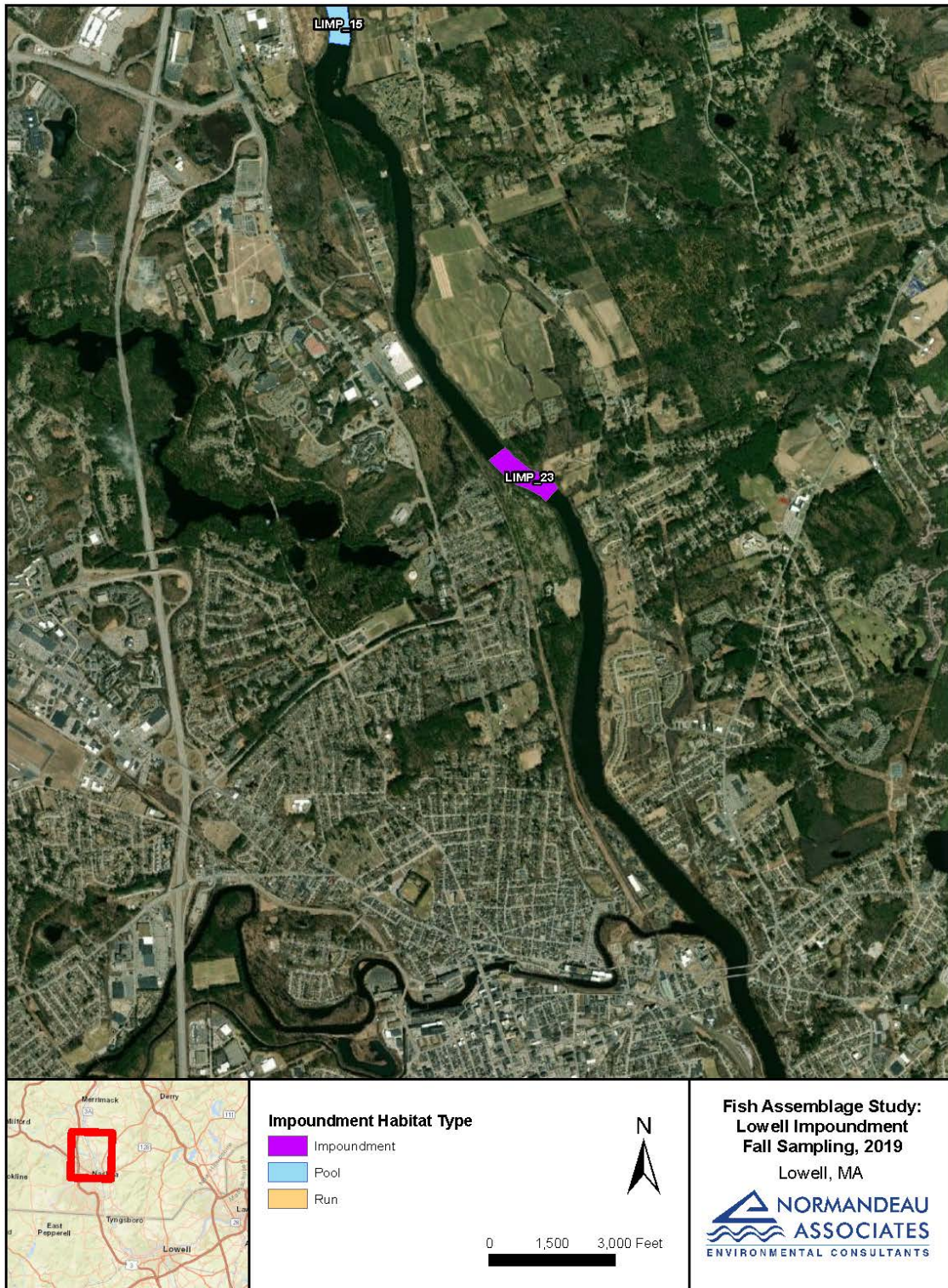






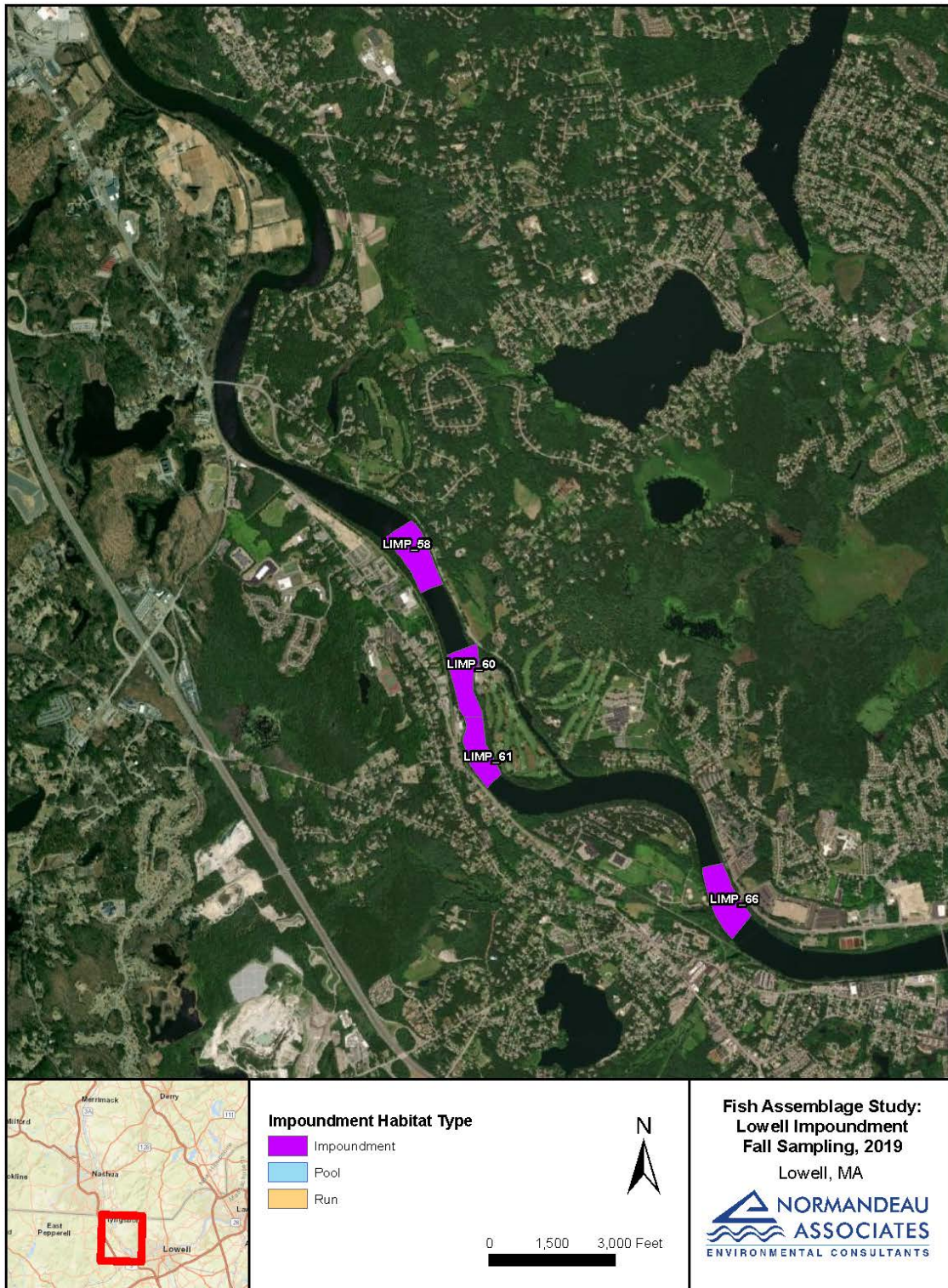




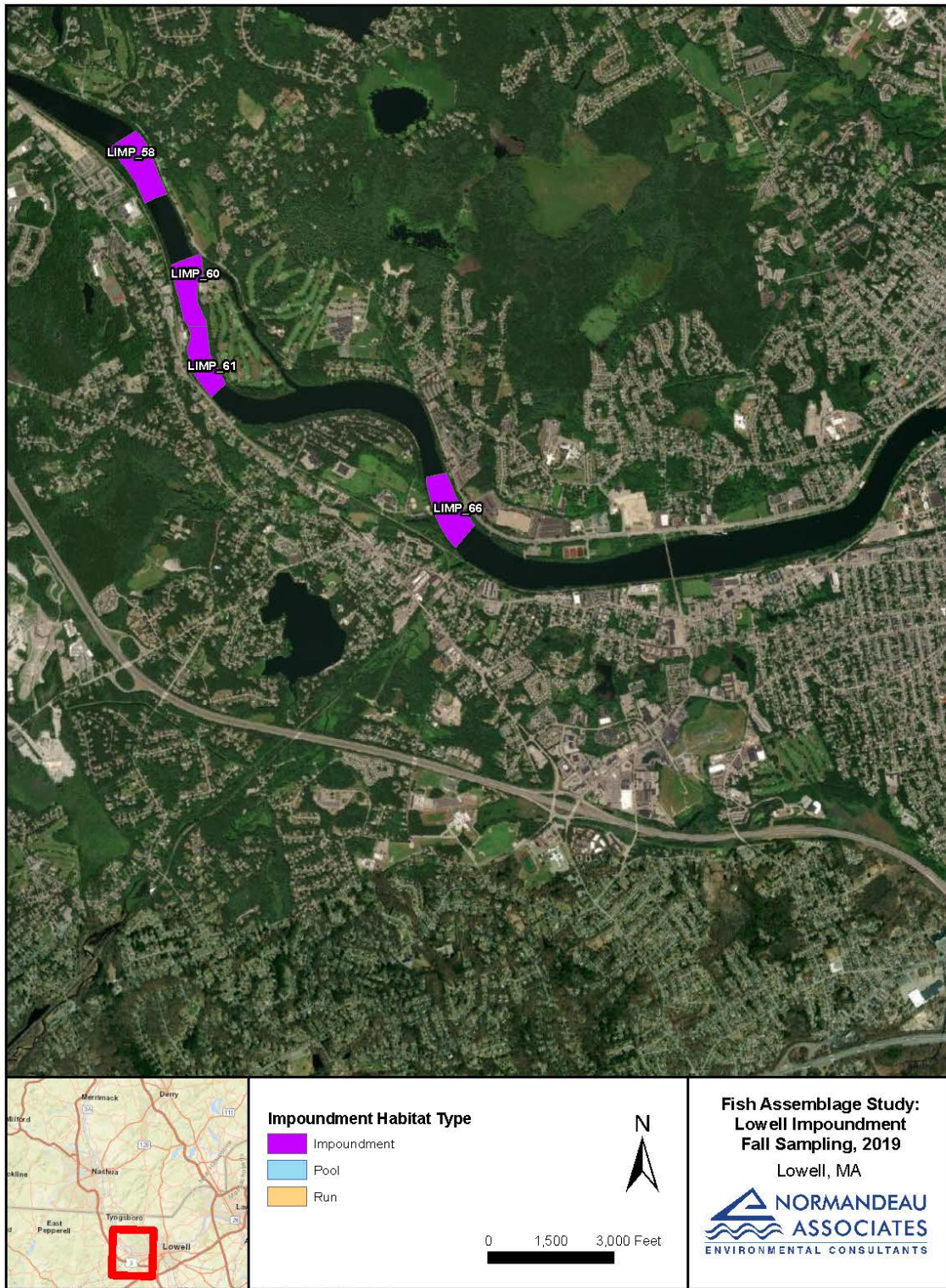


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Appendix B. Catch Per Unit of Effort (CPUE) information for boat electrofish and gill net sampling upstream of Pawtucket dam by season (spring, summer, and fall) and mesohabitat type (impoundment, pool, run).

**Boat electrofish: Spring 2019**

Common Name	Impoundment		Pool		Run		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	1.07	0.05	0.00	0.00	0.53	0.03	0.53	0.03
Black Crappie	0.00	0.00	1.06	0.04	0.53	0.03	0.53	0.02
Bluegill	5.29	0.24	2.78	0.13	1.06	0.06	3.04	0.14
Common Carp	0.20	0.01	0.00	0.00	0.00	0.00	0.07	0.00
Fallfish	3.15	0.14	4.56	0.20	14.09	0.69	7.27	0.34
Golden Shiner	0.18	0.01	0.00	0.00	0.00	0.00	0.06	0.00
Largemouth Bass	0.00	0.00	0.51	0.02	0.53	0.03	0.34	0.02
Lepomis spp.	0.20	0.01	0.00	0.00	0.00	0.00	0.07	0.00
Margined Madtom	0.18	0.01	0.93	0.04	0.00	0.00	0.37	0.02
Pumpkinseed	1.87	0.09	0.00	0.00	0.53	0.03	0.80	0.04
Redbreast Sunfish	24.57	1.13	15.24	0.67	28.57	1.34	22.79	1.05
Rock Bass	0.47	0.02	1.06	0.04	2.05	0.09	1.19	0.05
Sea Lamprey	0.00	0.00	2.78	0.13	2.12	0.11	1.63	0.08
Smallmouth Bass	21.89	1.02	16.41	0.73	38.22	1.71	25.51	1.16
Spottail Shiner	38.11	1.64	23.84	1.04	43.91	1.97	35.29	1.55
Tessellated Darter	0.63	0.03	6.31	0.27	2.12	0.11	3.02	0.14
White Sucker	1.25	0.07	3.98	0.18	7.34	0.37	4.19	0.21
Yellow Bullhead	1.12	0.05	0.00	0.00	1.59	0.09	0.90	0.05
Yellow Perch	0.85	0.04	12.59	0.53	0.53	0.03	4.66	0.20

**Boat electrofish: Summer 2019**

Common Name	Impoundment		Pool		Run		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	4.17	0.19	0.00	0.00	0.00	0.00	1.39	0.06
American Eel	1.30	0.06	0.48	0.02	4.72	0.20	2.17	0.09
Black Crappie	0.22	0.01	0.48	0.02	0.00	0.00	0.23	0.01
Bluegill	14.99	0.68	11.79	0.58	0.62	0.03	9.13	0.43
Common Carp	0.22	0.01	0.00	0.00	2.05	0.09	0.76	0.03
Fallfish	4.61	0.21	1.52	0.07	13.17	0.57	6.43	0.28
Golden Shiner	0.00	0.00	1.01	0.04	1.24	0.06	0.75	0.03
Largemouth Bass	4.04	0.19	6.13	0.29	2.67	0.11	4.28	0.20
Lepomis spp.	0.22	0.01	0.48	0.02	2.05	0.09	0.92	0.04
Margined Madtom	0.63	0.03	0.51	0.02	2.05	0.09	1.06	0.05
Pumpkinseed	26.72	1.21	1.45	0.07	0.62	0.03	9.60	0.44
Redbreast Sunfish	29.42	1.34	12.18	0.58	64.10	2.74	35.24	1.55
Rock Bass	0.22	0.01	0.51	0.02	0.00	0.00	0.24	0.01
Sea Lamprey	1.27	0.06	0.00	0.00	0.00	0.00	0.42	0.02
Smallmouth Bass	5.32	0.24	8.06	0.40	14.41	0.63	9.26	0.42
Spottail Shiner	0.45	0.02	18.23	0.82	59.13	2.51	25.94	1.12
Tessellated Darter	2.39	0.11	2.31	0.11	0.00	0.00	1.56	0.07
White Perch	0.23	0.01	0.00	0.00	0.00	0.00	0.08	0.00
White Sucker	0.00	0.00	1.95	0.09	1.86	0.09	1.27	0.06
Yellow Bullhead	2.92	0.13	2.46	0.11	0.62	0.03	2.00	0.09
Yellow Perch	0.00	0.00	0.00	0.00	0.62	0.03	0.21	0.01

**Boat electrofish: Fall 2019**

Common Name	Impoundment		Pool		Run		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
Alewife	13.23	0.83	3.98	0.18	13.23	0.83	10.15	0.61
American Eel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Black Crappie	0.00	0.00	0.93	0.04	0.00	0.00	0.31	0.01
Bluegill	2.21	0.12	5.04	0.22	2.21	0.12	3.15	0.15
Common Carp	0.20	0.01	0.00	0.00	0.20	0.01	0.13	0.01
Fallfish	7.81	0.38	26.66	1.20	7.81	0.38	14.09	0.65
Golden Shiner	0.37	0.02	4.24	0.18	0.37	0.02	1.66	0.07
Largemouth Bass	0.62	0.03	3.05	0.13	0.62	0.03	1.43	0.06
Margined Madtom	0.19	0.01	0.00	0.00	0.19	0.01	0.12	0.01
Pumpkinseed	3.20	0.19	0.00	0.00	3.20	0.19	2.13	0.13
Redbreast Sunfish	6.89	0.37	2.78	0.13	6.89	0.37	5.52	0.29
Rock Bass	0.16	0.01	0.00	0.00	0.16	0.01	0.10	0.01
Sea Lamprey	0.84	0.05	1.92	0.09	0.84	0.05	1.20	0.06
Smallmouth Bass	5.42	0.30	5.89	0.27	5.42	0.30	5.58	0.29
Spottail Shiner	5.62	0.26	13.65	0.58	5.62	0.26	8.30	0.37
Tessellated Darter	0.19	0.01	0.00	0.00	0.19	0.01	0.12	0.01
White Sucker	2.10	0.12	3.18	0.13	2.10	0.12	2.46	0.12
Yellow Bullhead	0.32	0.02	0.93	0.04	0.32	0.02	0.52	0.03
Yellow Perch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

**Experimental gill net: Spring 2019**

Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Bluegill	0.00	0.05	0.00	0.02
Fallfish	0.01	0.00	0.00	0.00
Margined Madtom	0.01	0.00	0.00	0.00
Smallmouth Bass	0.01	0.00	0.00	0.00
Spottail Shiner	0.00	0.00	0.10	0.03
White Sucker	0.01	0.00	0.03	0.02

**Experimental gill net: Summer 2019**

Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Alewife	0.02	0.00	0.00	0.01
Channel Catfish	0.01	0.00	0.00	0.00
Common Carp	0.01	0.00	0.00	0.00
Fallfish	0.01	0.03	0.00	0.01
Golden Shiner	0.00	0.00	0.10	0.03
Pumpkinseed	0.01	0.00	0.00	0.00
Redbreast Sunfish	0.05	0.00	0.00	0.02
Smallmouth Bass	0.04	0.00	0.00	0.01
Walleye	0.01	0.00	0.00	0.00
White Sucker	0.01	0.03	0.00	0.01
Yellow Bullhead	0.20	0.00	0.03	0.08
Yellow Perch	0.02	0.00	0.00	0.01

**Experimental gill net: Fall 2019**

Common Name	Impoundment	Pool	Run	Total
	Fish/hr	Fish/hr	Fish/hr	Fish/hr
Spottail Shiner	0.00	0.05	0.00	0.02
Yellow Bullhead	0.01	0.00	0.10	0.04

## Appendix C. Spatial distribution of 50-m habitat units for the 0.75 mile bypassed reach downstream of Pawtucket Dam.











Appendix D. Catch Per Unit of Effort (CPUE) information for back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam by season (spring, summer, and fall) and habitat type (pool and ledge channels).

**Back pack electrofish: Spring 2019**

Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	20.67	14.00	4.12	1.67	12.40	7.83
Bluegill	0.00	0.00	1.52	0.67	0.76	0.33
Brown Trout	2.95	2.00	0.00	0.00	1.48	1.00
Fallfish	20.67	14.00	20.62	8.33	20.65	11.17
Longnose Dace	2.95	2.00	0.00	0.00	1.48	1.00
Margined Madtom	2.95	2.00	0.00	0.00	1.48	1.00
Redbreast Sunfish	2.95	2.00	0.00	0.00	1.48	1.00
Smallmouth Bass	5.91	4.00	0.00	0.00	2.95	2.00
Spottail Shiner	0.00	0.00	65.66	26.00	32.83	13.00
Tessellated Darter	0.00	0.00	0.76	0.33	0.38	0.17

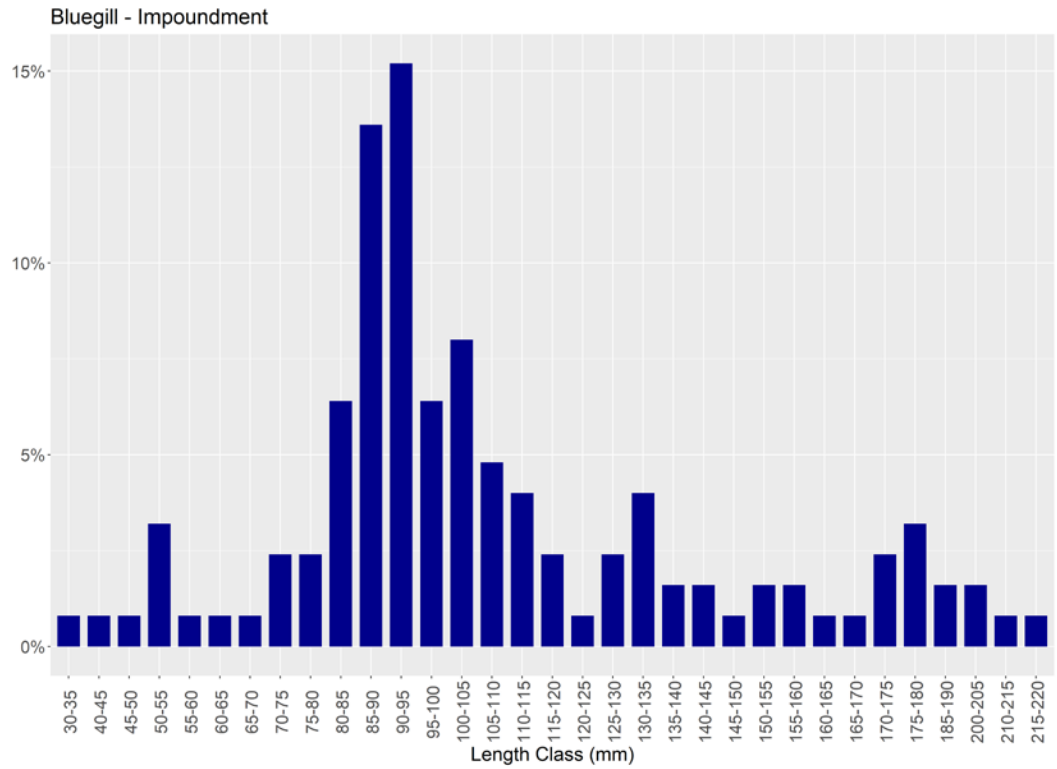
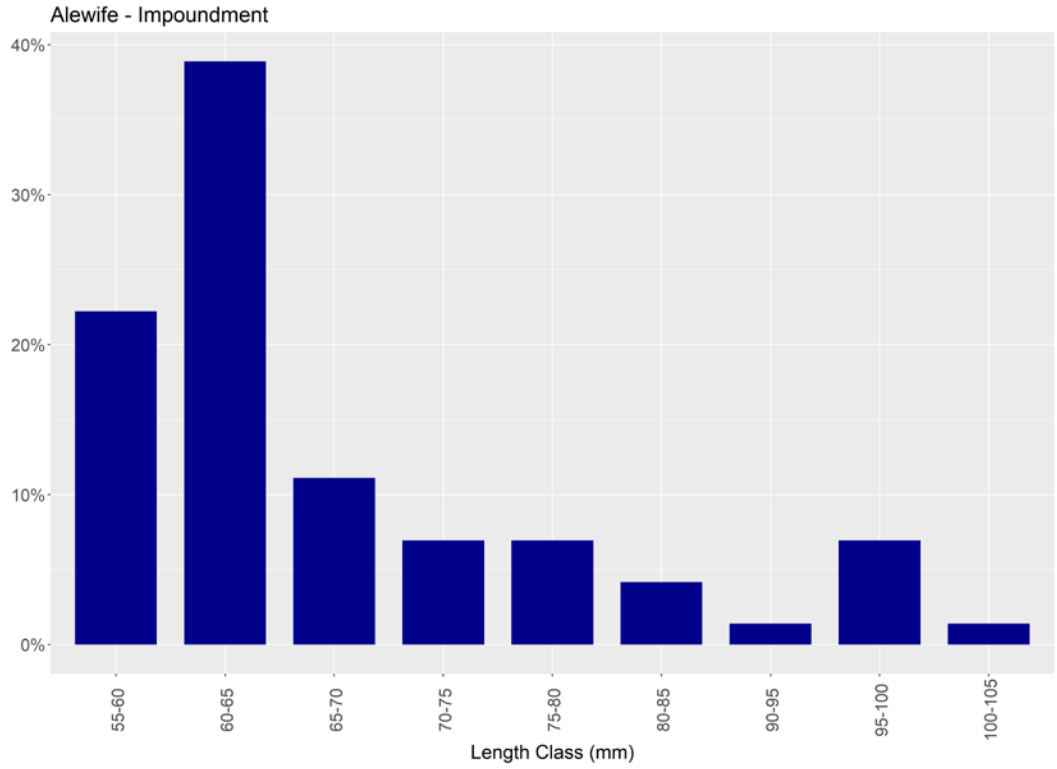
**Back pack electrofish: Summer 2019**

Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	17.72	12.00	6.28	4.00	12.00	8.00
Bluegill	0.00	0.00	0.56	0.33	0.28	0.17
Fallfish	0.00	0.00	97.43	62.33	48.72	31.17
Largemouth Bass	0.00	0.00	1.11	0.67	0.56	0.33
Margined Madtom	0.00	0.00	1.04	0.67	0.52	0.33
Redbreast Sunfish	2.95	2.00	2.15	1.33	2.55	1.67
Smallmouth Bass	73.82	50.00	6.49	4.00	40.15	27.00
Spottail Shiner	0.00	0.00	25.56	16.33	12.78	8.17
Tessellated Darter	2.95	2.00	2.08	1.33	2.52	1.67
White Sucker	0.00	0.00	15.66	10.00	7.83	5.00
Yellow Bullhead	0.00	0.00	2.22	1.33	1.11	0.67

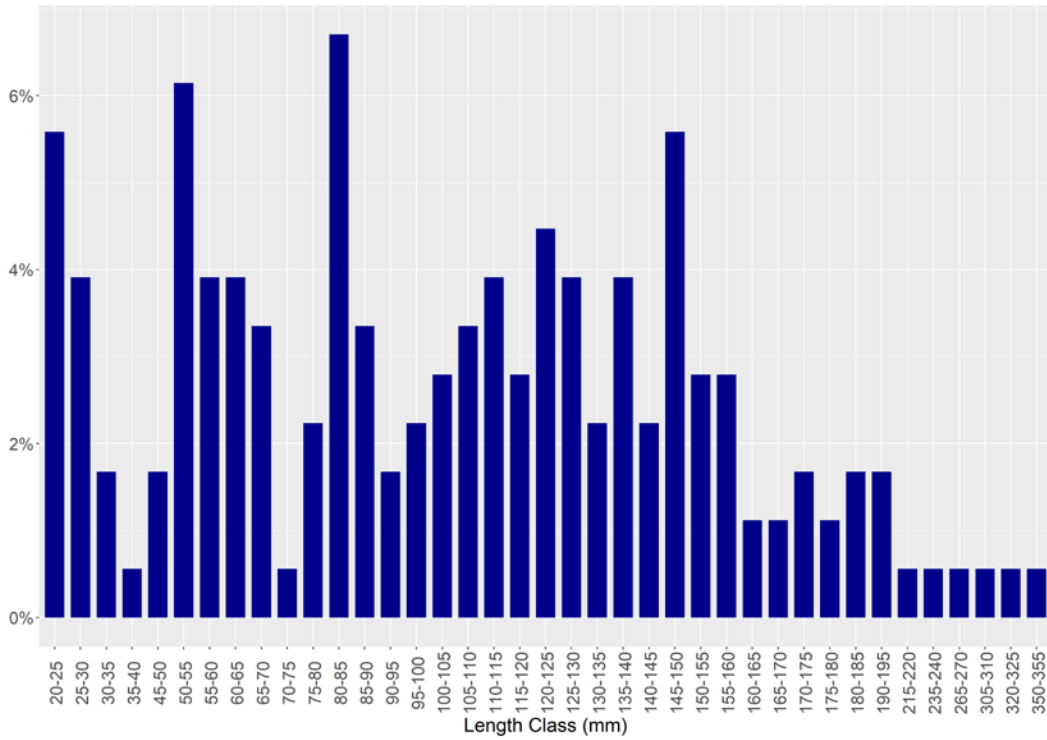
**Back pack electrofish: Fall 2019**

Common Name	Ledge Channels		Pooled Section		Total	
	Fish/hr	Fish/100m	Fish/hr	Fish/100m	Fish/hr	Fish/100m
American Eel	0.00	0.00	3.62	1.67	1.81	0.83
Fallfish	0.00	0.00	0.72	0.33	0.36	0.17
Lepomis spp.	0.00	0.00	1.68	0.67	0.84	0.33
Longnose Dace	2.95	2.00	0.00	0.00	1.48	1.00
Margined Madtom	0.00	0.00	12.06	5.33	6.03	2.67
Redbreast Sunfish	20.67	14.00	0.00	0.00	10.33	7.00
Sea Lamprey	0.00	0.00	1.68	0.67	0.84	0.33
Smallmouth Bass	88.58	60.00	38.08	16.33	63.33	38.17
Tessellated Darter	0.00	0.00	3.86	1.67	1.93	0.83
White Sucker	8.86	6.00	0.00	0.00	4.43	3.00
Yellow Bullhead	0.00	0.00	0.72	0.33	0.36	0.17

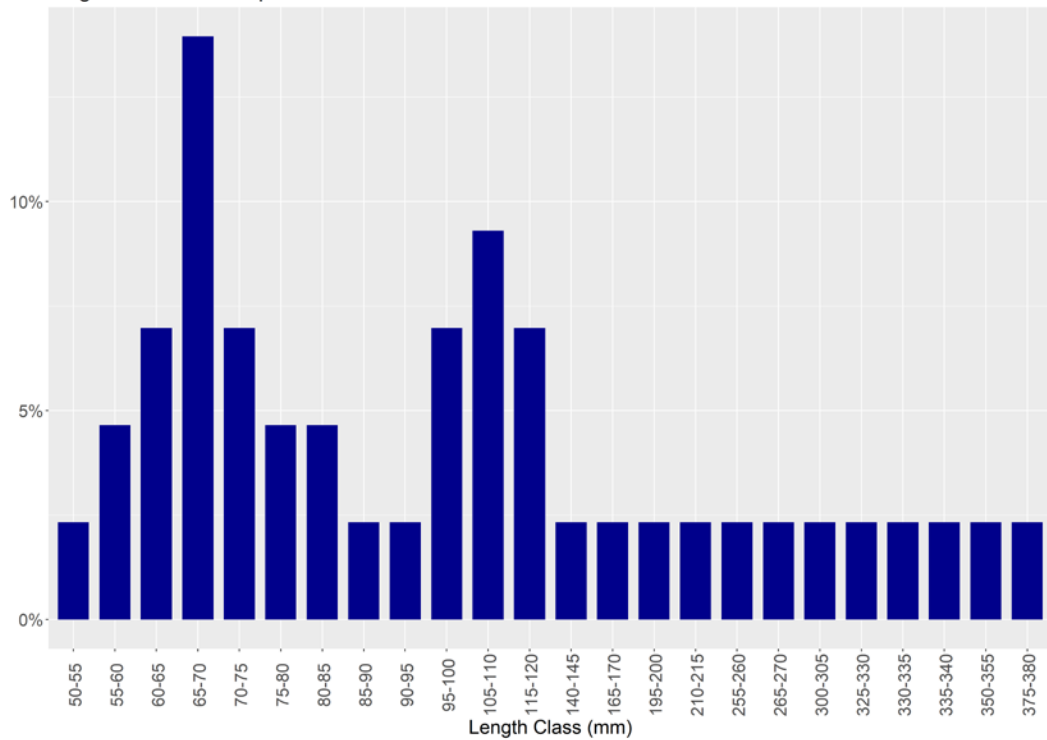
Appendix E. Length frequency distributions for common fish species collected by boat electrofish and experimental gill net sampling in the Lowell impoundment and back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam.



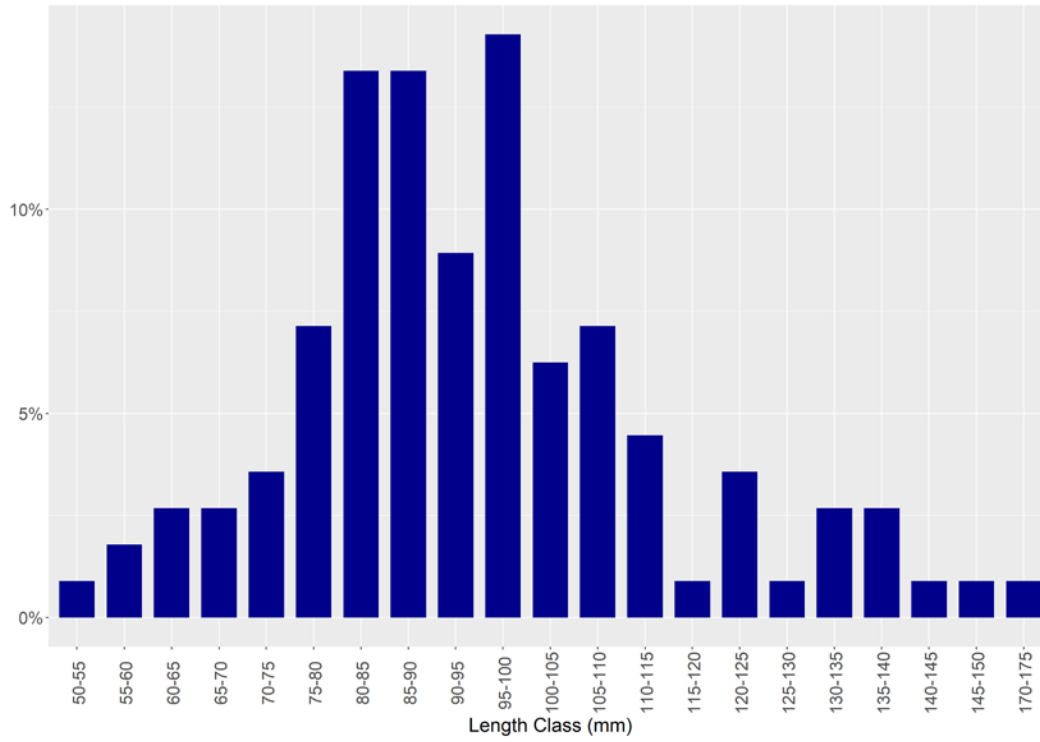
Fallfish - Impoundment



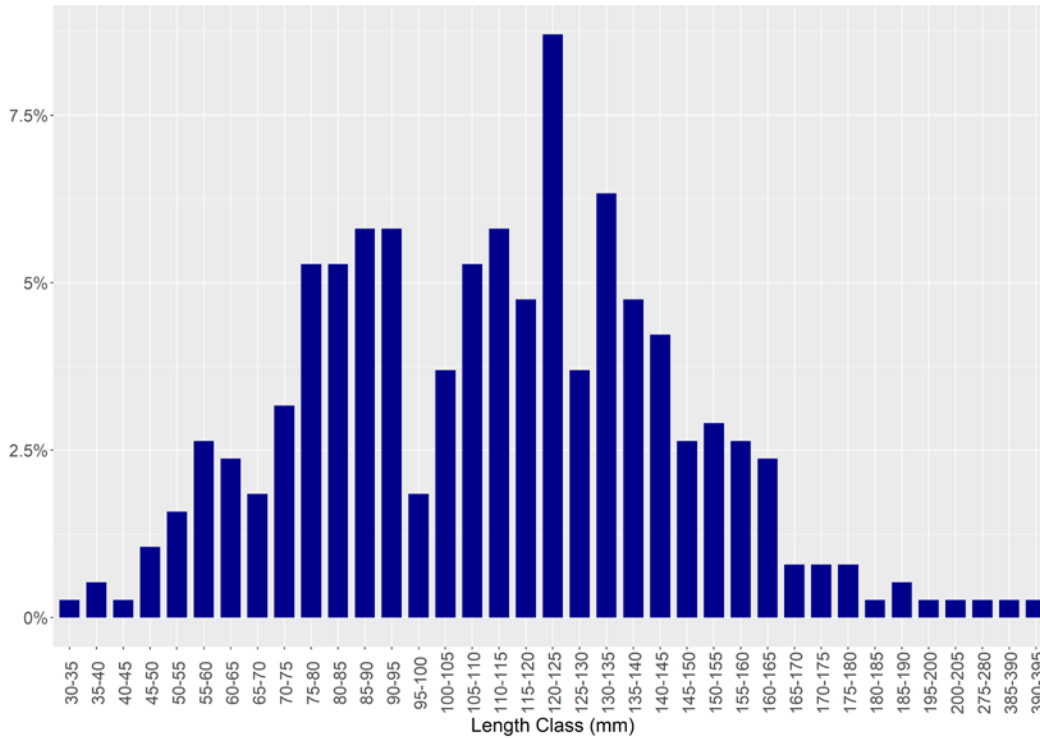
Largemouth Bass - Impoundment



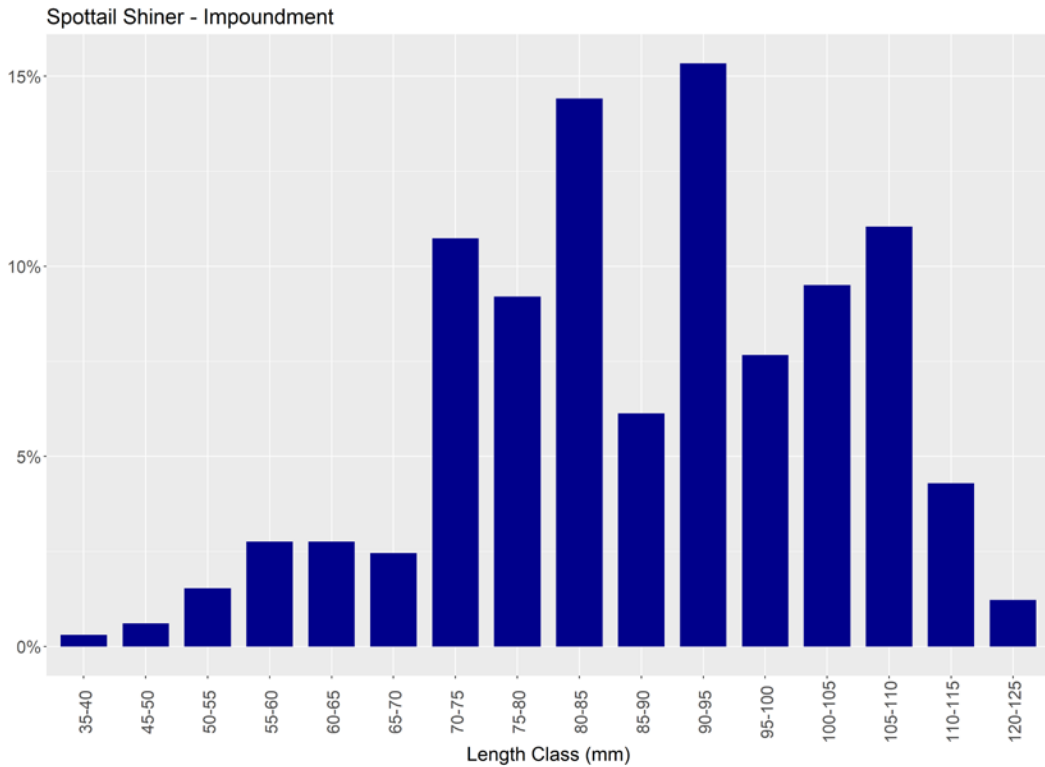
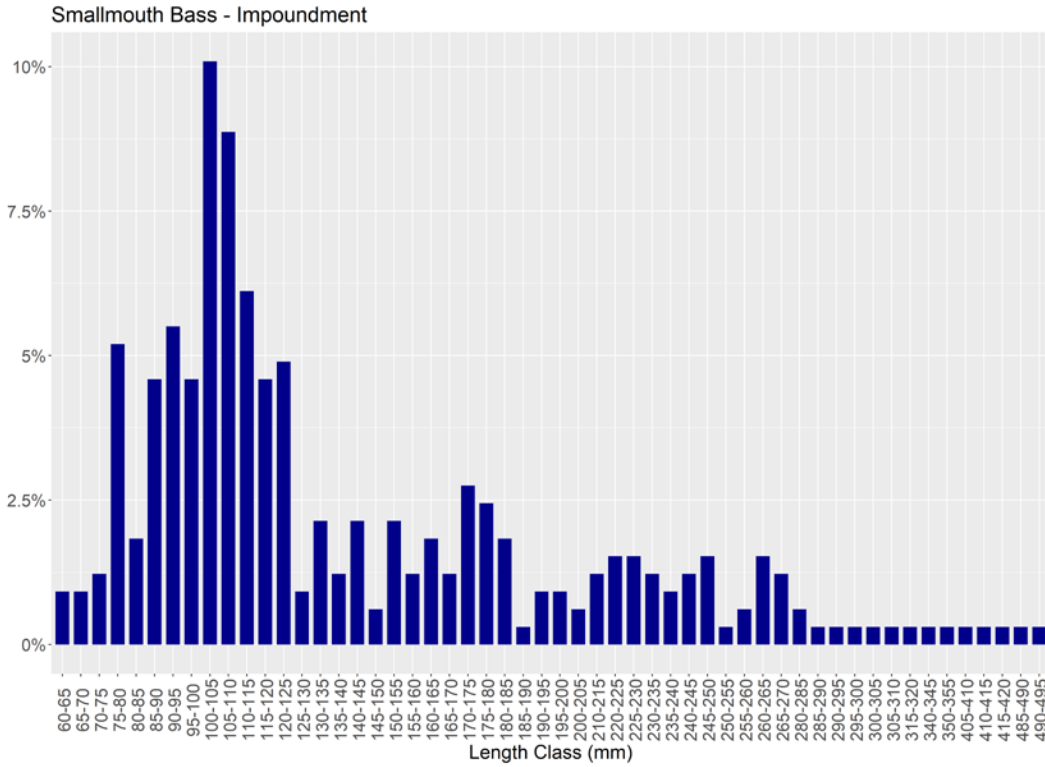
Pumpkinseed - Impoundment

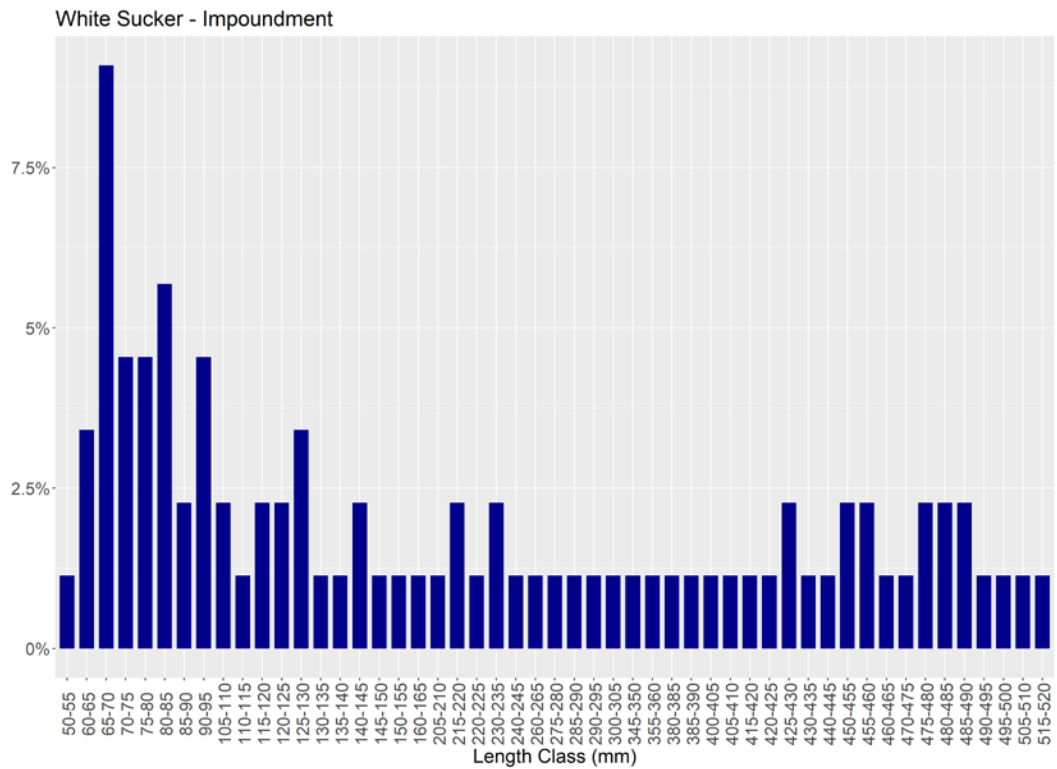
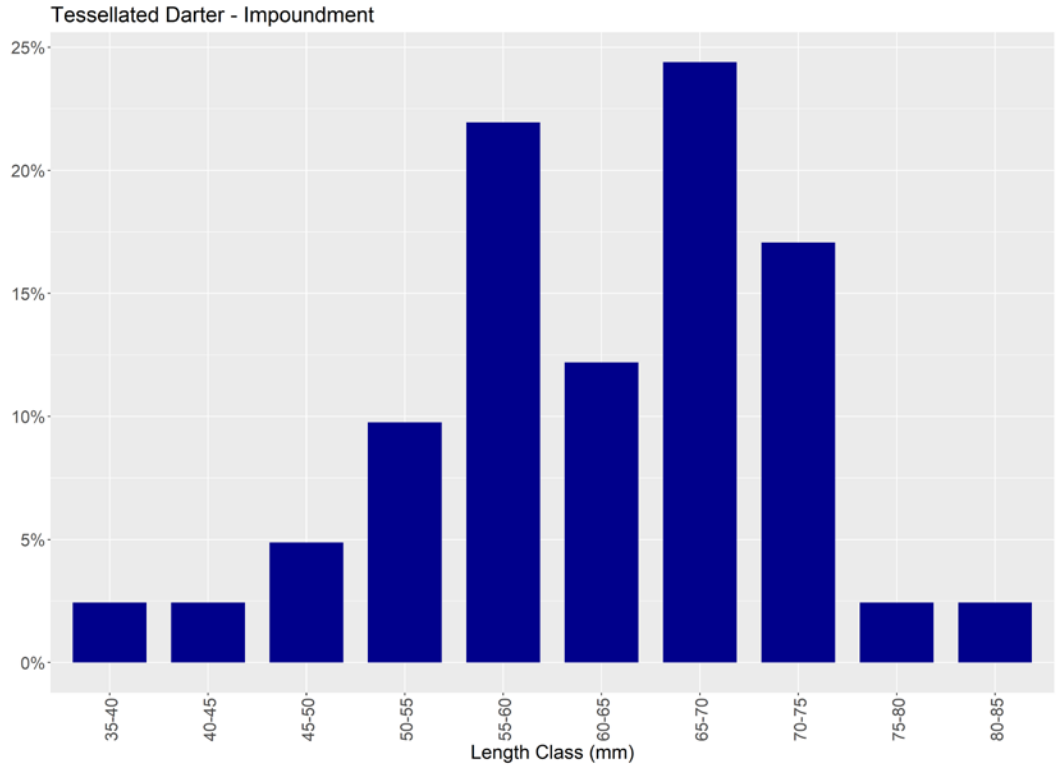


Redbreast Sunfish - Impoundment

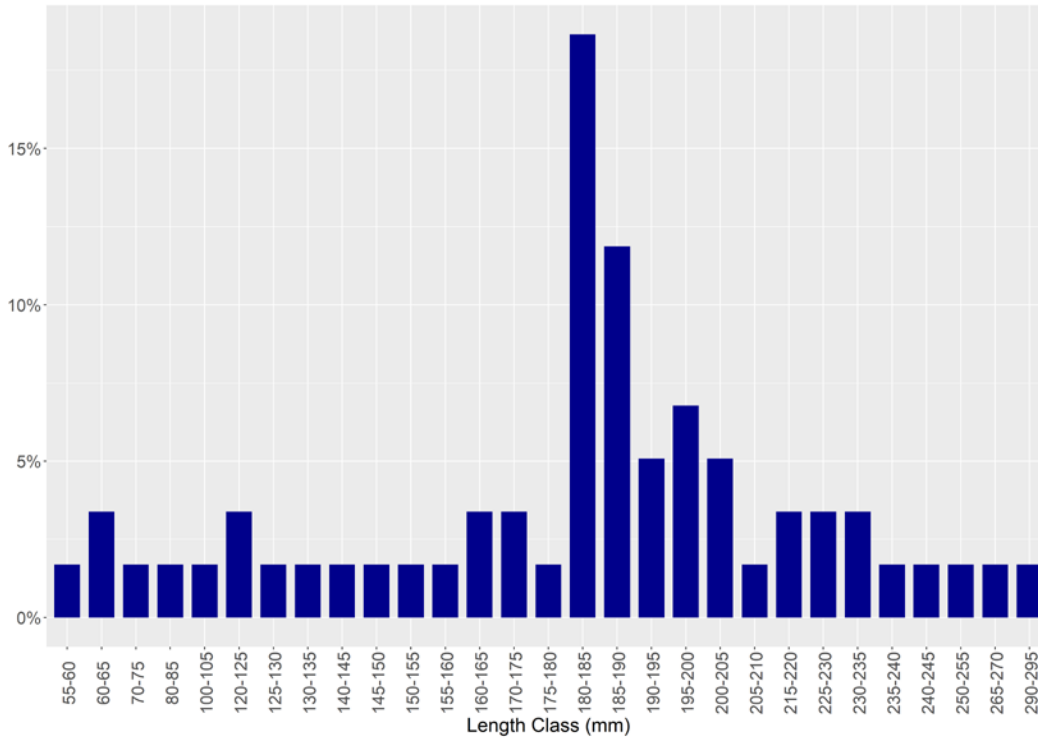




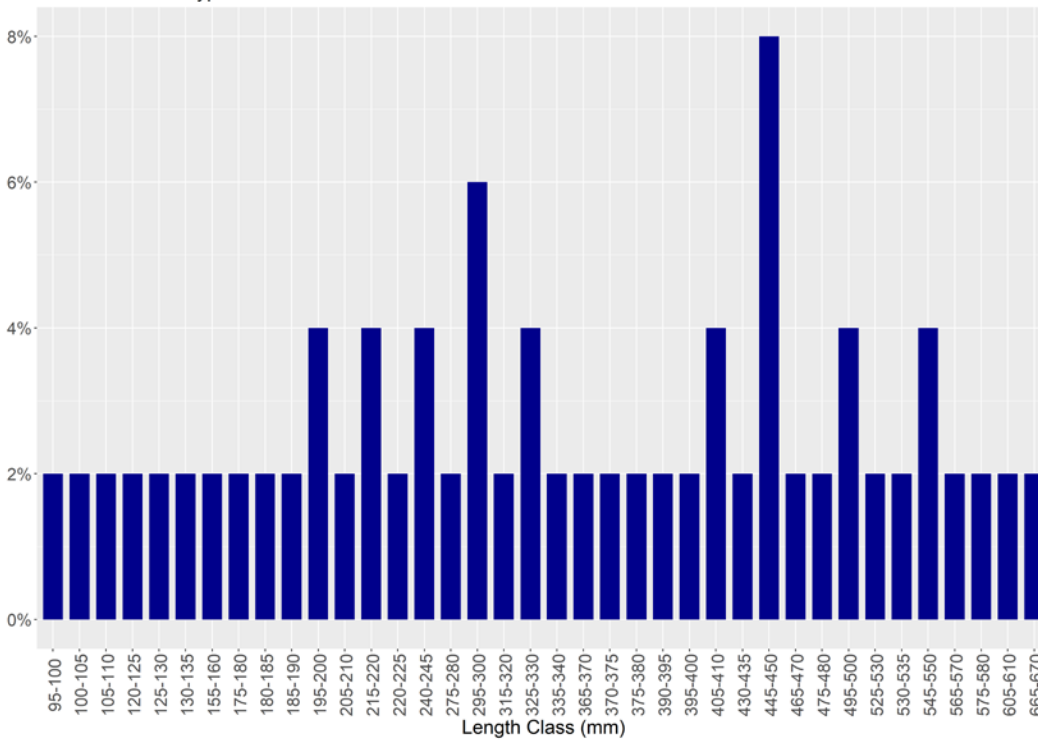




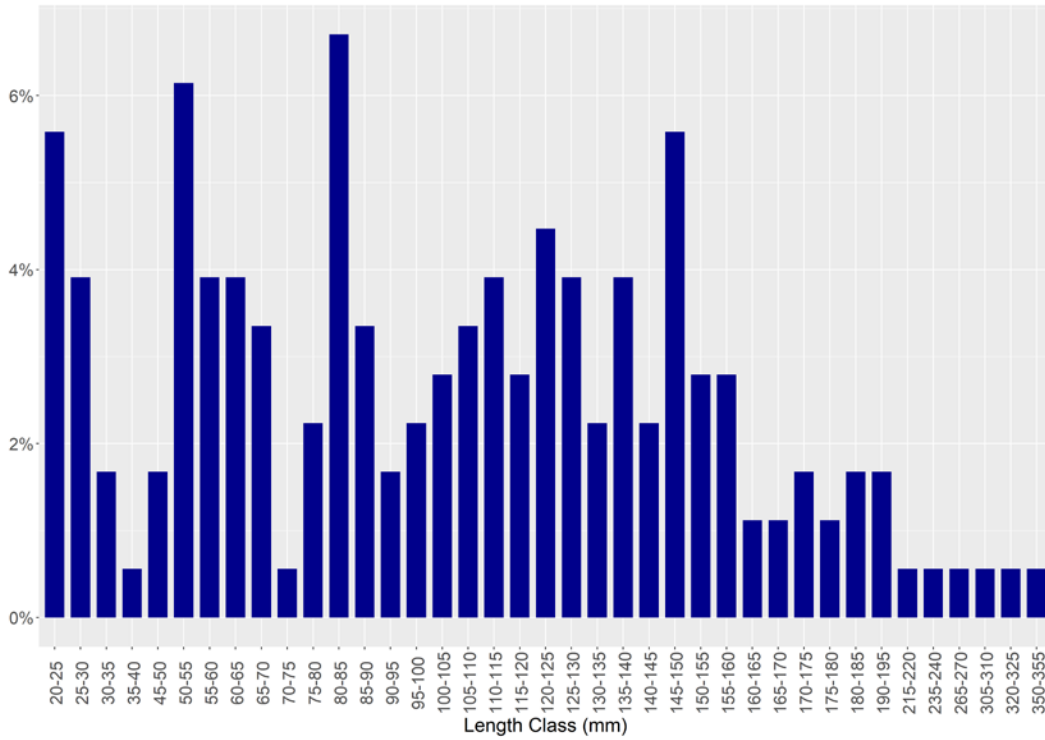
Yellow Bullhead - Impoundment



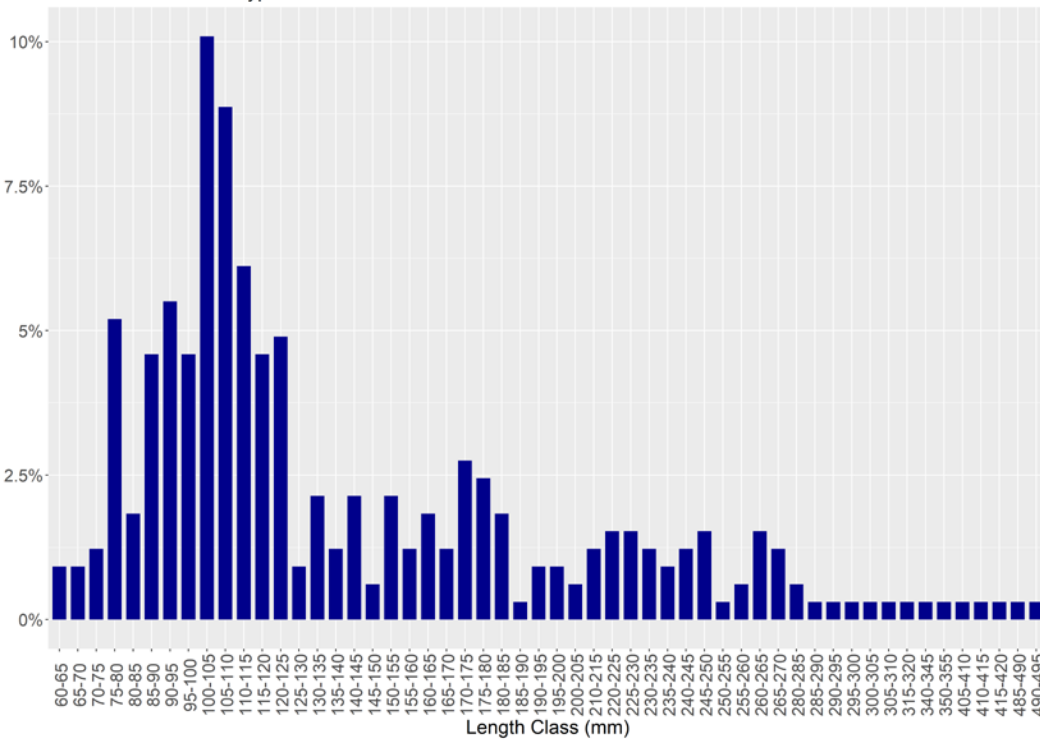
American Eel - Bypassed Reach

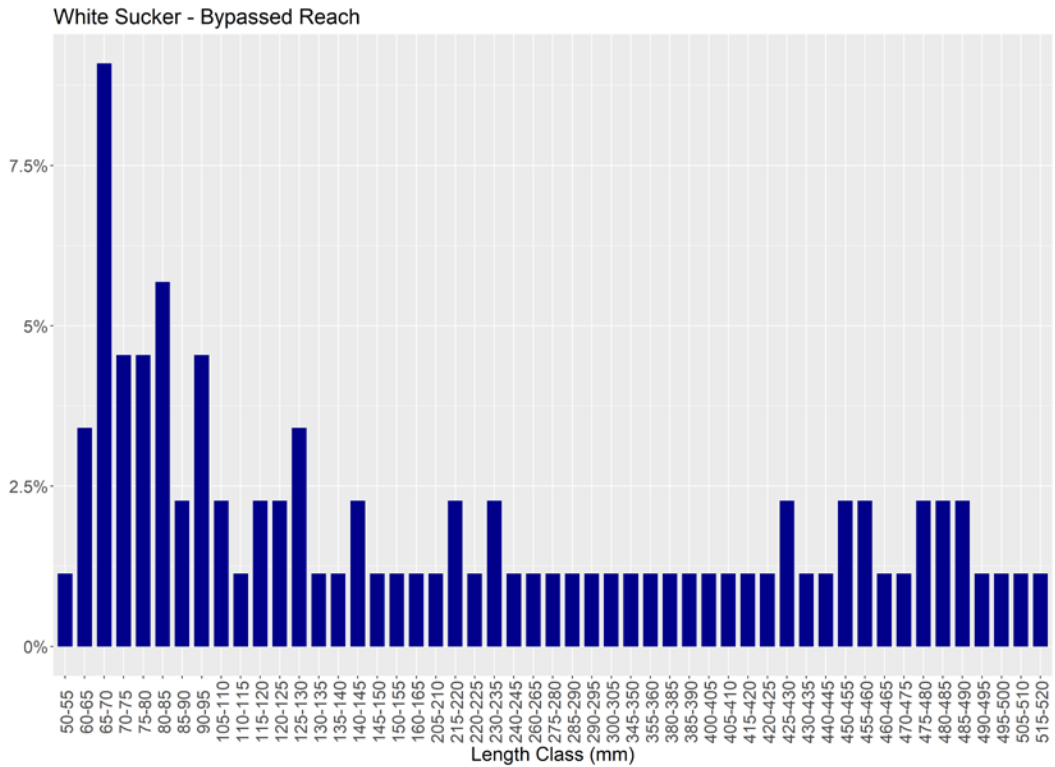
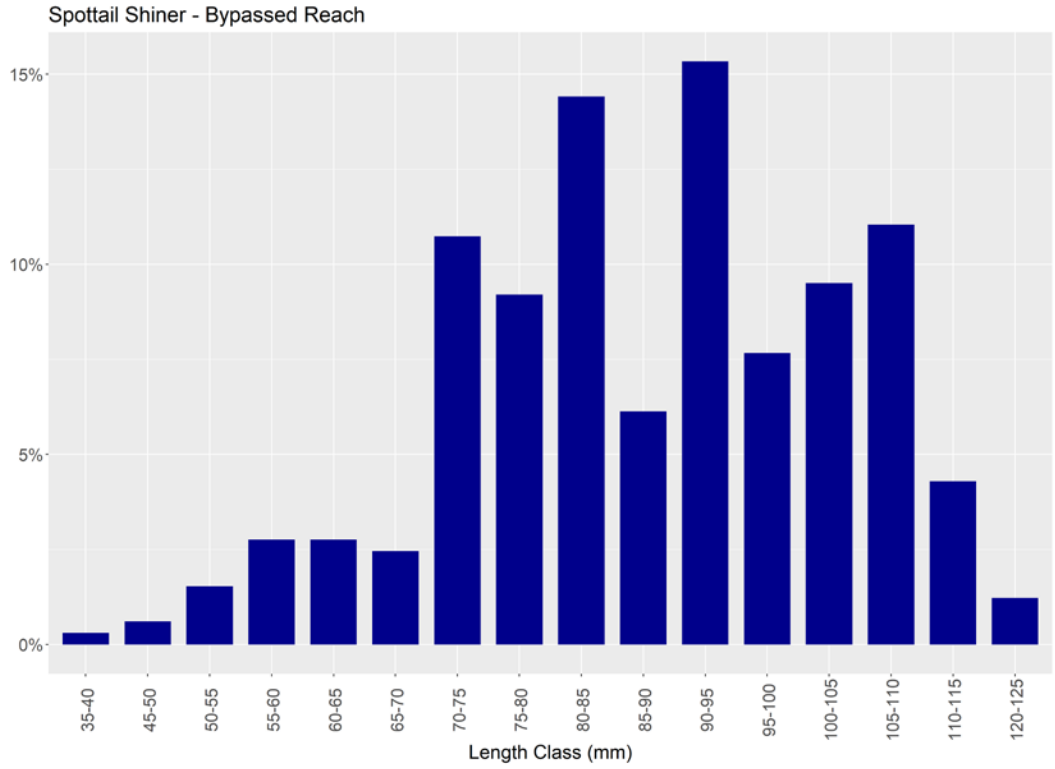


Fallfish - Bypassed Reach



Smallmouth Bass - Bypassed Reach





Appendix F. Catch information for fish species collected by boat electrofish and experimental gill net sampling in the Lowell impoundment and back pack electrofish sampling within the bypassed reach downstream of Pawtucket dam (2019).

Report Appendix F available as Microsoft Excel data listing.