River Herring Spawning and Nursery Habitat Assessment: Martins Pond, 2016-2017

Introduction

Martins Pond is a 92 acre pond located in the Ipswich River watershed in North Reading, MA. Martins Pond is a naturally formed lake with the inlet formed by the Skug River on the north end of the pond and the outlet being formed by Martins Brook, a major tributary to the Ipswich River, at the south end. Martins Brook flows through a series of wetlands with several culverts and road crossings before joining the Ipswich River near Park St. in North Reading. The Ipswich River then flows through North Reading, Middleton, Topsfield and Ipswich to its mouth in Plum Island Sound.

The Ipswich River Watershed Association (IRWA) is working with a number of partners, including the MA Division of Marine Fisheries (MA DMF) to improve habitat access and overall conditions for diadromous fish in the watershed. Martins Pond was selected, as was Hood Pond, for monitoring based on an expectation that it may provide opportunity for restoration of alewife populations in the Ipswich watershed based on its size and location in relation to planned fish passage improvements downstream. IRWA began two years of spawning and nursery habitat assessment on Martins Pond in 2016 in partnership with MA DMF. There are a variety of resident fish in Martins Pond, including; yellow perch, chain pickerel, brown bullhead, largemouth bass, pumkinseed, bluegill, golden shiner, black crappie, swamp darter (Merrimack College and Malcolm Pirnie, Inc, 2003).

Diadromous Fisheries

This Ipswich River watershed historically supported large runs of diadromous fish that were an important resource to the Native American and early colonial settlers in the area. Native Americans called the area Agawam, a term which was apparently used to refer to places “where fish of passage resorted” (Felt 1834). The Ipswich River and the Plum Island Sound Estuary once supported large and diverse runs of diadromous fish. Diadromous species in the Ipswich River included alewife, blueback herring, American shad, rainbow smelt, Eastern brook trout, sea lamprey and American eel. While many of these species are still present in the Ipswich River, their abundance is lower than it was historically.

While the Ipswich River was known to have once supported a healthy herring fishery (Belding and Corwin, 1921), and although no historical documentation could be found about the presence of alewife in Martins Pond, this has been identified as potential spawning habitat (Purinton, *et al*. 2003). In general, few alewife have been observed in the Ipswich River or its tributaries since roughly 1900. This time period also roughly corresponds to the construction of the current Ipswich Mills Dam originally built without passage. Many of the once important spawning ponds have been converted into reservoirs such as Wenham Lake and Hood Pond (formerly known as Pritchard’s Pond), which was a documented spawning area for alewife. The Town of Topsfield established a public fishery in 1803, but the spawning run was apparently no longer present by the early 1870’s or before (Belding & Corwin 1921).

Water Quality Status

The Ipswich River watershed is 155 square miles and includes all or part of 21 communities in northeastern Massachusetts. The topography of this Atlantic coastal plain basin is characterized by low relief, with an average grade of 3.1 feet per mile. The length of the river is a meandering 40 miles. The surficial geology of the region consists primarily of glacial till with stratified sand and gravel deposits covering about 43 percent of the basin and alluvial deposits covering about 3 percent of the basin (Zariello and Reis, 2000). Extensive wetlands are present along the River and streams within the Ipswich River basin. These wetlands protect surrounding areas during flooding as well as positively affect the water quality of the River and streams in the basin.

Water quality issues have been identified in the Ipswich River and the Ipswich River watershed by both independent researchers and Massachusetts Department of Environmental Protection (MassDEP). Section 305(b) of the Clean Water Act identifies waters as to whether or not they support designated uses as defined by Massachusetts Surface Water Quality Standards. The 305(b) Waterbodies are assessed as *Support*, *Impaired*, or *Unassessed* for specific designated uses, such as Aquatic Life, as part of the MassDEP 305(b) reporting requirements. Degraded waters that require a total maximum daily load (TMDL) estimate for specified pollutants are placed on the 303(d) list known as the *Integrated List of Waters*. In the final 2014 *Integrated List of Waters*, impairments for the Ipswich River include: repeated, exaggerated low flows, low dissolved oxygen, excessive nutrients, fecal coliform and many others (MassDEP, 2014). Water quality assessments have identified 53% of named river miles throughout the watershed as impaired for supporting healthy populations of aquatic life (MassDEP, 2000). Martins Pond (segment ID: MA92038) is listed under category 5; waters listed as *Impaired* and requiring a TMDL. The impairments identified are excess algal growth, turbidity, non-native aquatic plants and mercury in fish tissue.

Methods

The river herring habitat assessment follows the guidelines of a MassDEP approved Quality Assurance and Program Plan: *Quality Assurance Program Plan (QAPP) for Water Quality Measurements Conducted for Diadromous Fish Habitat Monitoring* (Chase, 2010). The goal of the habitat assessment is to aid in the management and restoration of diadromous fish resources. The QAPP relates river herring life history characteristics to three categories of reference conditions: Massachusetts surface water quality standards (MassDEP 2013); US Environmental Protection Agency (US EPA) nutrient criteria recommendations (US EPA 2001); and the Best Professional Judgment (BPJ) of the staff performing the assessment (Chase 2010).

Monthly assessment trips were made to Martins Pond from May to September, 2016-2017 targeting the third or fourth week of each month. Sampling trips for June and August, 2016 were cancelled due to the pond being closed for herbicide treatment of invasive aquatic plants. This period is recommended by the QAPP, because it is when water quality can exhibit the most impairment and adult river herring spawning and juvenile occupation of Martins Pond would likely occur. The assessment criteria for all

parameters are summarized in Table 1. Data from individual monitoring stations are summarized in the Appendix.

Monitoring stations were selected to represent shoal (shallow) areas along the margins of the pond as well as deep areas distributed along the center of the pond (figure 1). Martins Pond is relatively shallow, with an average depth around 5-6' with the deepest area being just over 7' (figure 2). The Skug River forms the inlet at the north end of the pond and Martins Pond exits at the southern end. Four monitoring stations were selected based on this information; 2 shoal sampling locations near the inlet and outlet of the pond and 2 stations at deep locations, roughly along the center line of the pond, to capture the deeper areas along the north-south axis of the pond.

The following basic water quality parameters were measured: water temperature, dissolved oxygen (DO), pH, specific conductance, turbidity, and Secchi disc transparency depth. Measurements were made near the surface (0.3 m depth) and bottom (0.5 m from maximum depth) in the water column, with an additional measurement taken at mid-depth for stations HP2 and HP3. Water temperature, DO, conductivity, pH, and turbidity were measured using a YSI 6920 Sonde. Water temperature, DO, and pH were related to MassDEP surface water quality standards (SWQS) for class B waters. The Secchi disc data were related to US EPA nutrient criteria recommendations for nutrient ecoregion XIV, subecoregion 84, as specified in the habitat assessment QAPP. Finally, QAPP reference conditions for eutrophication were assigned with each monthly visit based on best professional judgement. The sampling data were combined for the three seasons to produce a classification (Suitable or Impaired) for each parameter. Parameter measurements less than or equal to 10% of samples at stations are acceptable for a *Suitable* classification. Parameter measurements greater than 10% of transect samples result in an *Impaired* classification.

Figure 1. Habitat assessment monitoring sites at Martins Pond

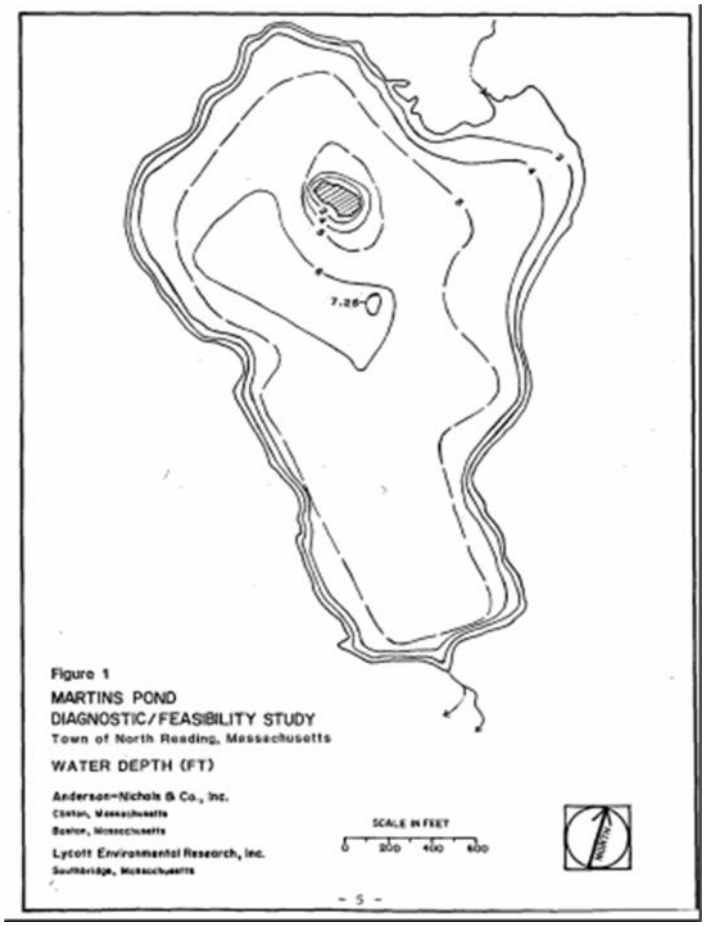

Figure 2. Bathymetry in Martins Pond in 1985 (from Martins Pond Diagnostic/Feasibility Study Report 1985).

Results

Water temperature, dissolved oxygen concentration and pH were evaluated at each monitoring station on Martins Pond during 2016 and 2017. Results were evaluated against the water quality standards described in the habitat assessment QAPP and adopted from MassDEP surface water quality standards for supporting aquatic life in class B waters. For this standard, water temperature should not exceed 28.3 °C during the nursery period of July-October to support the development of juvenile herring. During the spawning period of May-June, water temperatures should not exceed 26.0°C which was adopted by the assessment QAPP. Dissolved oxygen levels should be greater than or equal to 5mg/L and pH should be in the range of $\geq$ 6.5 and $\leq$ 8.3. Minimum Secchi disk transparency should be 2.0m.

Temperature

Temperature is an important measure of water quality, as temperatures higher than the natural observed range can reduce the amount of dissolved oxygen that the water can hold. This can create a stressful environment for aquatic organisms.

Surface water temperatures at Martins Pond did not exceed the spawning threshold of 26.0 °C on Monitoring dates during the spawning months of May and June, resulting in a classification of *Suitable* for water temperature from 2016-2017. Monitoring did not take place during June, 2016, however. Temperatures also did not exceed the nursery period threshold of 28.3°C on any instances, also resulting in a *Suitable* designation Table 1, Figure 3).

Temperature also provides cues for fish migrations and is a vital factor for lake stratification and productivity. The deepest site monitored on Martins Pond was site MP3 with a maximum depth of 2.2m. At the deepest strata of 1.5m, the minimum water temperature observed was 15.78°C on May 31st, 2017 and the maximum temperature at this strata was 27.55°C on July 28th, 2016.

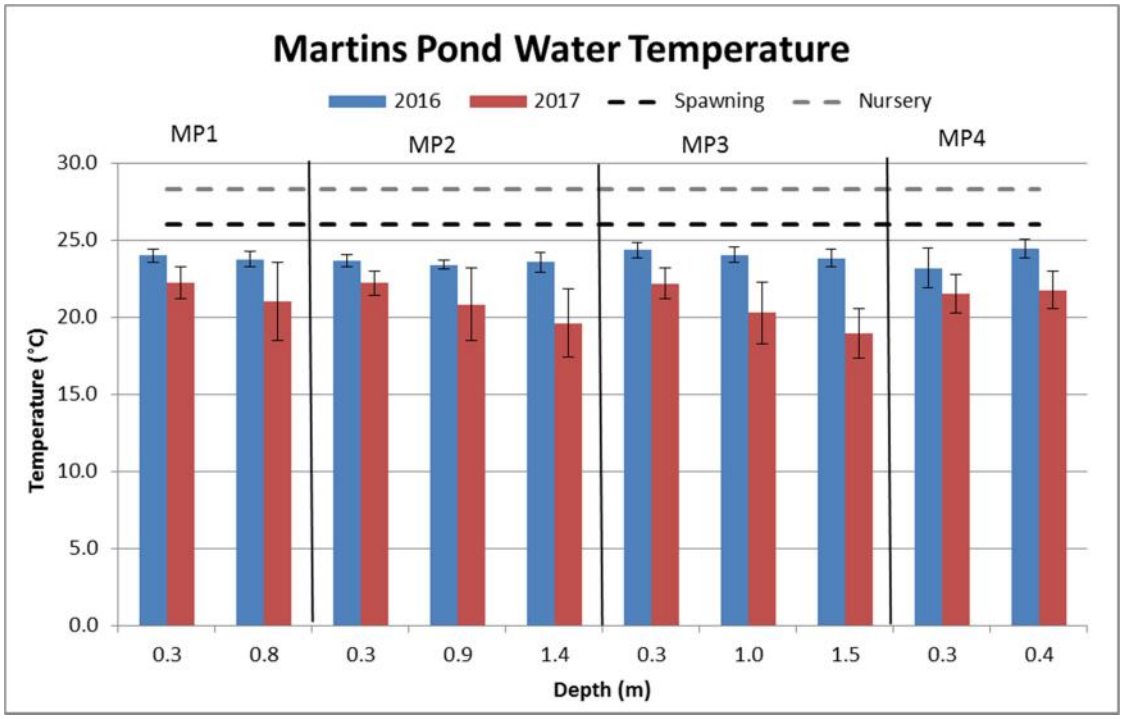

Figure 3. Average water temperature (May-September) at Martins Pond monitoring stations, +/- 2 S.E.

Dissolved Oxygen

The amount of dissolved oxygen (DO) in water depends on numerous factors, including the temperature of the water and the gas exchange across the air-water interface. DO concentration is inversely related to water temperature, so will decrease when water temperatures increase. Other primary factors affecting DO include oxygen production through photosynthesis and depletion through biochemical oxygen demand due to respiration and other oxygen-demanding processes. DO changes on a diurnal basis as well as seasonally, and is affected by cloud cover and other weather conditions. The most critical time for organisms is in the early morning hours in the summer when water temperatures are high, and photosynthesis has ceased producing oxygen since sunset. Stratification can also occur when water temperatures prevent surface waters from replenishing oxygen at the deepest strata.

Dissolved oxygen measurements exceeded the water quality criteria of 5mg/L among 8% of the samples (table 1, Figure 4) when excluding bottom strata measurements according to the QAPP exemption. This results in a *Suitable* designation.

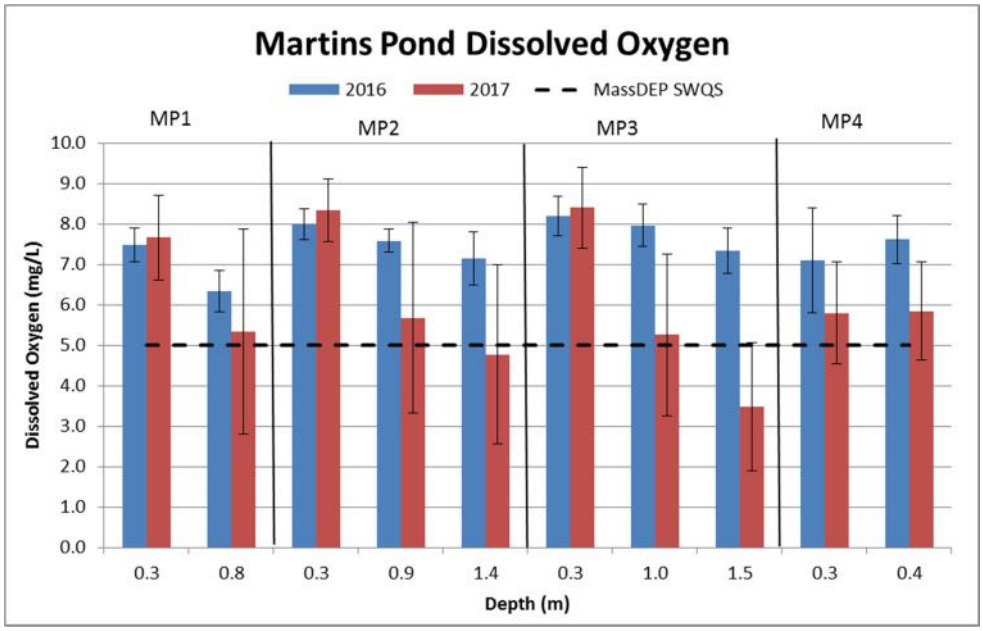

Figure 4. Average dissolved oxygen concentration (May-September) at Martins Pond monitoring sites, +/- 2 S.E.

pH

Suitable pH conditions are also important for the life history of fish and other aquatic organisms. The preferred range $\geq$ 6.5 and $\leq$ 8.3 was exceeded among 10% of samples, resulting in a designation of *Impaired* (table 1, figure 5). The minimum pH value was 6.17 observed was at the deepest strata of site MP3 on July 20th, 2017. The maximum value observed was 7.86 at the surface strata of site MP3 on September 27th, 2017.

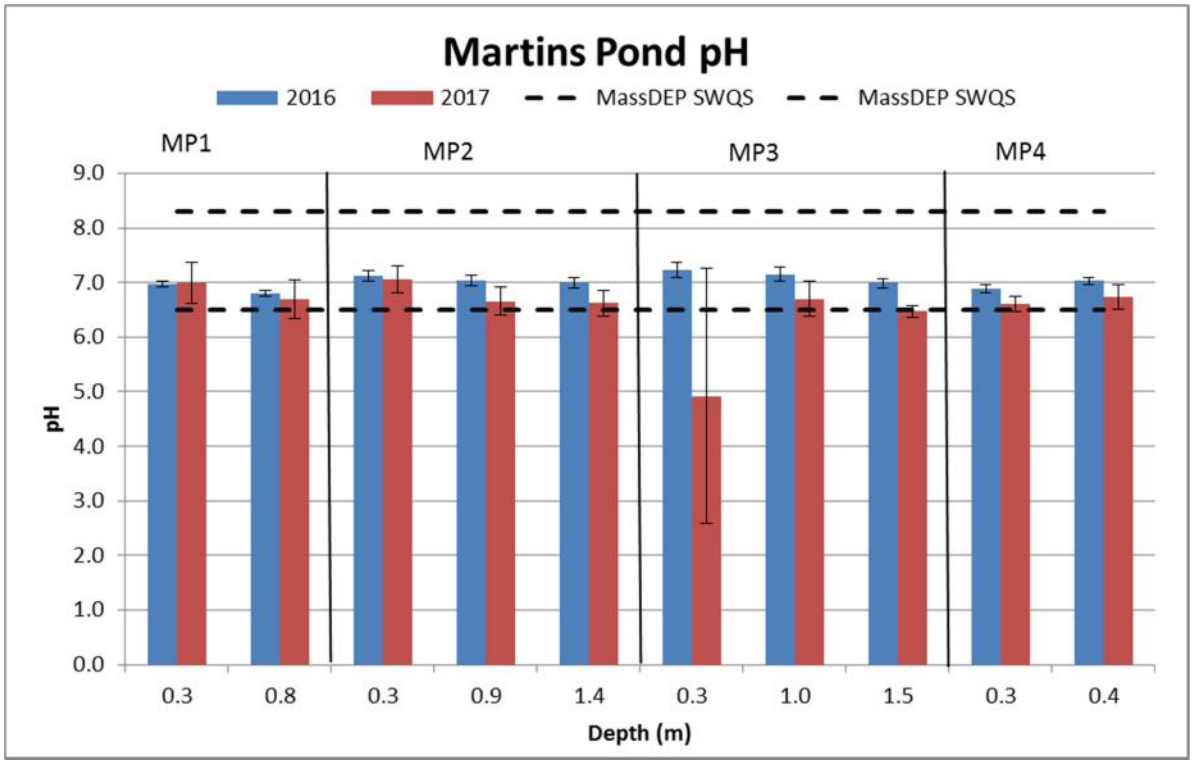

Figure 5. Average pH (May-September) at Martins Pond monitoring stations, +/- 2 S.E.

Secchi Disk Transparency

Secchi disk transparency depth indicates the degree of clarity or turbidity related to plankton and suspended solids. The monitoring sites of Martins Pond were evaluated against the minimum standard adopted by the assessment QAPP of 2.0 m. Evaluation of Secchi disk data was limited to the deep sites MP2 and MP3. In total, 100% of the samples at the deep sites did not meet the 2.0 m standard resulting in a designation of *Impaired* (table 1, figure 6). Although the minimum standard represents the point at which water quality may be considered degraded, visibility alone may not solely prevent herring spawning success. Best professional judgement observations of eutrophication as an indicator of water clarity were consistently rated as suitable during all site visits.

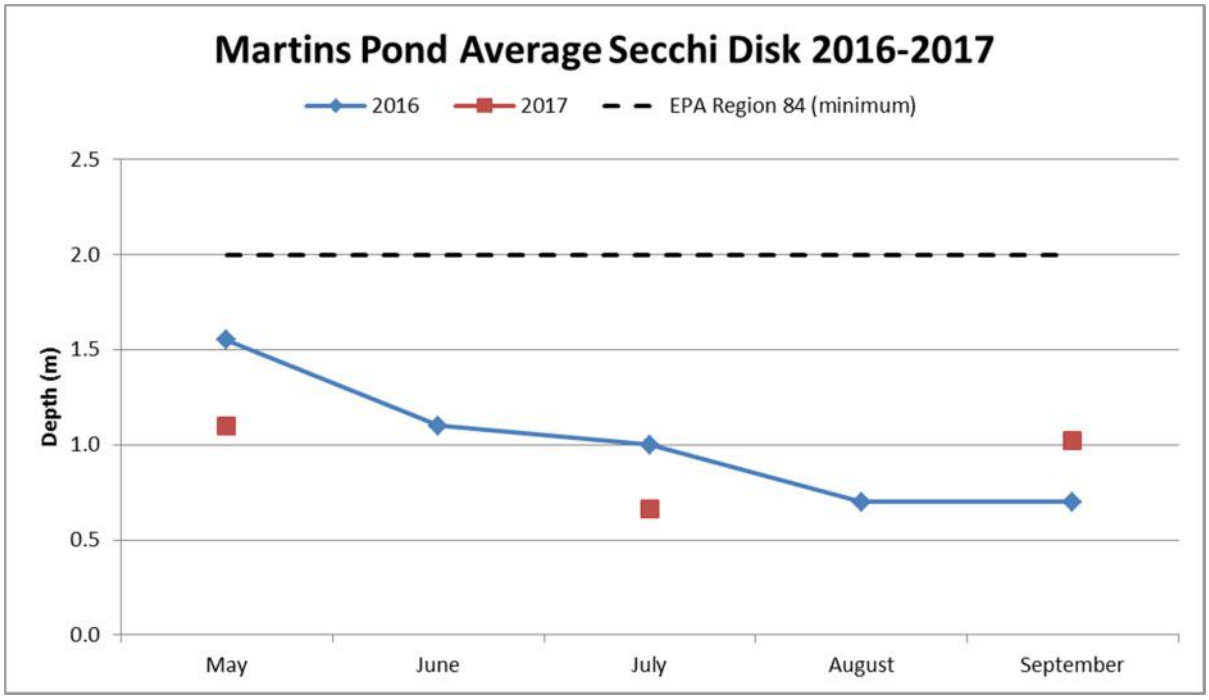

Figure 6. Average Secchi disk transparency by month at Martins Pond monitoring stations.

Best Professional Judgment

Spawning Substrate and Eutrophication

The assessment QAPP describes a preference of river herring for spawning on the shallow fringes of ponds, with no established preference for substrate material (Chase, 2010). The shoal sites, MP1 and MP4, representing the potential spawning habitat of the pond, were characterized during the 8 site visits with qualitative evaluations of substrate and eutrophication using observations and impressions of the data to form a best professional judgement of the suitability of the habitat. Substrate was evaluated through visual observations and probing with a canoe paddle as a qualitative way to identify the composition of the substrate, while eutrophication was determined by visually estimating a percentage of plant growth both horizontally and vertically in the water column as well as evaluating water clarity and dissolved oxygen using an assessment range of "good", "fair" or "poor". A final best professional judgement designation of "*Suitable*" or "*Impaired*" was assigned based on the overall impression of these individual judgements.

For spawning substrate, site MP1 at the northern end of the pond was characterized as having no gravel and sand, approximately 20% silt and high percentage of vascular plants covering the substrate. Vascular plants occupied about 10% of the vertical water column area and about 70% of the horizontal area. Site MP4 near the outlet was comprised of approximately 25% gravel, 30% sand, 10% silt and 30% vascular plants. The water column was occupied by about 20% plant growth, while the horizontal area was occupied by about 50% plant growth. Martins Pond had been treated for invasive aquatic plants,

fanwort and Eurasian milfoil, in 2016 and 2017. This should continue to be monitored as it could potentially cover substrate, inhibiting spawning and navigation throughout the pond.

Eutrophication assessments were made based on an evaluation of dissolved oxygen and water clarity ratings. For dissolved oxygen a rating of "poor" was assigned when a measurement was less than 3 mg/L at the site, fair was between 3 and 5 mg/L and good was greater than 5mg/L. Site MP1 recorded one instance of a poor DO rating, but was otherwise good. Site MP4 was rated good except for one instance where DO was considered fair. Clarity at the shoal sites was considered fair due to the shallow nature, even though the deep sites are described as impaired. The higher density of vascular plant growth at site MP1 limited visibility to the bottom more than site MP4. An overall eutrophication assessment determination of suitable was applied to the shoal sites on Martins Pond.

Parameter	Units	Sample Size (No.)	Acceptable Criteria	Exceedance %	Classification
Temperature (nursery)	°C	46	$\leq$ 28.3	0	Suitable
Temperature (spawning)	°C	30	$\leq$ 26.0	0	Suitable
Dissolved Oxygen*	mg/L	60	$\geq$ 5.0	8	Suitable
pH	SU	76	$\geq$ 6.5 - $\leq$ 8.3	11	Impaired
Secchi disk**	m	16	> 2.0	100	Impaired
Eutrophication	NA	15	BPJ		Suitable
Fish Passage	NA	NA	BPJ		Impaired
Streamflow	NA		BPJ		Impaired

Table 1. Summary of river herring habitat assessment criteria for Martins Pond, 2016-2017. A classification of Impaired for each water quality parameter results from exceedances of >10% or >1% (when N <10) for transect station samples during the three-season assessment.
Notes:
*Bottom measurements were excluded from DO classification due to QAPP exemption.
**Secchi disc measurements were evaluated only for deep stations MP2 and MP3.

Additional observations

Turbidity and specific conductance measurements were also made, but there are no water quality criteria specified by EPA or MassDEP and therefore, not required by the assessment QAPP. High concentrations of organic and inorganic particles can increase turbidity, making a water body less suitable for aquatic life. Average turbidity at each site was about 3-5 NTU over the course of the monitoring period 2016-2017.

Specific conductance is related to the concentration of dissolved ions and other compounds existing naturally or contributed from pollution sources in the watershed area. Specific conductance was consistent at each monitoring station and depth strata. Measurements were in the range of 0.4 to 0.44 mS/cm.

Fish Passage

Martins Pond is approximately 30 stream miles from the mouth of the Ipswich River. There are three dams along the migration path from Ipswich Bay to Martins Pond; the Ipswich Mills Dam (Ipswich River at river mile 3.7), Willowdale Dam (Ipswich River at river mile 8.5), and Bostik Dam (Ipswich River at river mile 23). In addition to these structures, there are a number of road-stream crossings, beaver dams, and stream features that may influence fish passage (figure 6). Anadromous fish passage to and from Martins Pond is critical to our river herring restoration goals. Potential fish passage barriers downstream of Martins Pond were not directly assessed as part of this study, but are briefly summarized below (beginning at the estuary and moving upstream).

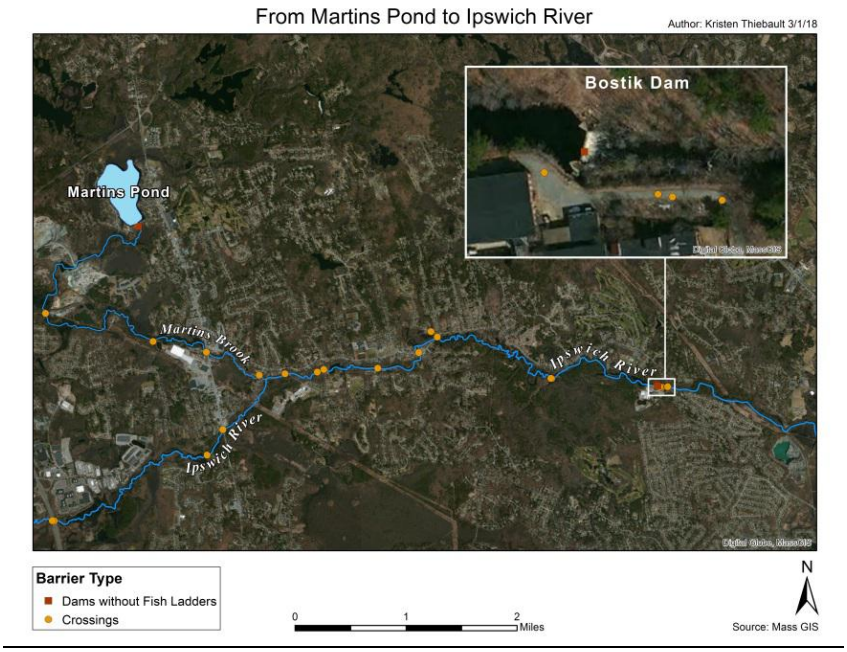

Figure 6. Location of barrier types along the stream network leading to Martins Pond.

Ipswich Mills Dam

The Ipswich Mills Dam, located at river mile 3.7, is at the head of tide on the Ipswich River and is owned by the Town of Ipswich. The dam is outfitted with a Denil fishway that was installed in 1995 and is operated according to an Operation and Maintenance Plan approved by the Division of Marine Fisheries in 2014. The Ipswich Mills fish ladder provides upstream passage for river herring, sea lamprey and other migratory species. The Ipswich River Watershed Association has conducted annual surveys to estimate upstream river herring migration using both visual survey (since 1999) and video census (since 2015) methods. Downstream passage is assumed to not be a problem at Ipswich Mills as the dam is a run of the river structure with a relatively short drop over the spillway.

Willowdale Dam

The Willowdale Dam is located on the Ipswich River at river mile 8.5. The dam is privately owned with ownership shared between Foote Brothers Canoes, Inc. (Foote Brothers) and Essex County Greenbelt Association (Greenbelt). The dam has a notched weir-pool fish ladder that is deteriorating and is in need of replacement. The existing fish ladder does provide upstream passage for river herring when actively maintained. The local Nor'East Chapter of Trout Unlimited has maintained the ladder during the river herring spawning run (April – June) since 2015. While spawning run estimates are not available for this location, upstream migration of river herring and American eel has been visually confirmed at the ladder. Adult sea lamprey have also been documented far upstream of the Willowdale Dam in recent years. Downstream passage is not thought to be directly inhibited by the dam.

The Division of Marine Fisheries is partnering with Foote Brothers and Greenbelt plan to install an Alaskan steep pass fish ladder on the Willowdale Dam to improve passage efficiency at the site. This project is in the permitting phase and was originally expected to be complete in 2018 but has now been targeted for construction in 2019.

South Middleton Dam

The South Middleton Dam is a stone and wood dam owned by Bostik, Inc. This is the only dam on the mainstem of the Ipswich River without a fish passage structure of any kind. The dam is listed as a Significant Hazard Dam by the MA Office of Dam Safety and, while currently listed in fair condition, is showing some significant signs of wear. Removal of the dam will result in an estimated 56 river miles opened to fish migration and 119 acres of historically important spawning lakes for alewife. Removal of the South Middleton Dam has undergone a feasibility study and is in the design, engineering and permitting phase. A waiver of an environmental impact review was recently granted by the Massachusetts Environmental Policy Act Office and this will increase the likelihood of the dam being removed in late 2019 or 2020.

Beaver Dams

Beaver activity is known to be present on the mainstem of the Ipswich River to the confluence with Martins Brook in North Reading. The gentle slope on sections of the river and seasonal low flows create conditions favorable to beaver damming. The river in North Reading between Washington St. and the access bridge to the City of Lynn pump station is known to have several beaver dams and there are known structures between Log Bridge Rd. and East St. in Middleton. Intermittent beaver damming has been observed at Salem Rd. in Topsfield. There are fewer dams beyond this point as the river channel widens. While beaver damming may be present along Martins Brook, it is not thought to be extensive, as the channel winds through wetland areas that may not be suitable for dam construction. The migration route should be inspected annually prior to migration season and measures should be taken to improve passage as necessary.

Beaver Exclusion Devices

There is a beaver exclusion device (a.k.a. beaver deceiver) at one location on Martins Brook, located on the upstream side at the Rt. 62 culvert. This device is constructed in a manner that could limit or block downstream and upstream migration for river herring. This device should be removed or reconfigured during the migration season to allow for upstream passage of adult river herring.

Marsh Downstream of Martins Pond

The channel of Martins Brook is visibly defined, but approximately 1.5 stream miles from the outlet of Martins Pond, the channel becomes obscured by a broad marsh. The tributary lacks a clearly defined channel for approximately 0.25 miles before reaching the culvert at Rt. 62. While this does not appear to present a physical barrier to migration, we are concerned that it will be difficult for both returning adult and emigrating juvenile river herring to navigate. Working with volunteers, we plan to use manual methods to maintain an unobstructed channel through this section of the migration route. This will need to be inspected annually and maintained as necessary.

Streamflow

Streamflow can influence fish passage independently of structural barriers; however, the two conditions are closely related for the stream network from Martins Pond to the Ipswich River. The outlet of Martins Pond is located at the south end and flows under Burroughs Rd. through 2 large openings. There is no obstruction to flow exiting the pond. There is an old weir on the downstream side of the Rt. 62 culvert but this does not generally impair flows on its own. There are wellfields adjacent to Martins Brook near Rt. 62 and seasonally low flows can occur that during a drought in the summer of 2016, resulted in much of the channel drying up. Summer flows were suitable in 2017 and 2018. Flows in the spring and fall during the migration periods are generally suitable.

The primary impairments to flow and migration are the marsh vegetation on Martins Brook and the beaver exclusion device, at Rt. 62, as well as the South Middleton Dam. Where streamflows and the

stream network would be considered navigable, these barriers result in a classification of fish passage and streamflow as as *Impaired*, with respect to alewife migration.

Conclusion

Water quality measurements at Martins Pond and best professional judgement indicate favorable conditions in support of river herring spawning and development. Water temperature and dissolved oxygen measurements were both considered suitable and pH readings exceeded water quality standards for 11% of samples, only slightly more than the 10% threshold. Spawning substrate and eutrophication were considered suitable at the shoal sites despite water clarity not meeting the minimum threshold at deep sites.

Fish passage leading to Martins Pond is currently impaired due to the absence of a passage structures on the South Middleton Dam and the presence of a beaver exclusion device and vegetation on Martins Brook. With removal of the South Middleton Dam and annual monitoring and maintenance of beaver and vegetation issues along the stream corridor, migratory access to and from Hood Pond should be suitable over the long-term.

Acknowledgements

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Appendix

Table A1. Station locations that were sampled in Martins Pond, 2016-2017

Station ID	Latitude	Longitude	Depth Strata	Max Depth (m)	Sample No.	Location
MP1	42°35'55.0134"	-71°7'25.6434"	Shoal	1.33	8	near inlet at north end of pond
MP2	42°35'46.0314"	-71°7'39.216"	Deep	1.89	8	~ 0.1 mi. east of Lakeside Blvd. boat landing
MP3	42°35'39.9114"	-71°7'21.3154"	Deep	2.0	8	along central transect
MP4	42°35'28.6794"	-71°7'23.4834"	Shoal	1.02	8	near outlet at south end of pond

Table A2. Summary of water chemistry data collected at station MP1 in Hood Pond, 2016-2017.

Surface (0.3m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	22.90	3.94	23.80	$\leq$28.3	100
DO	(mg/L)	8	7.58	1.24	8.05	$\geq$5.0	100
pH	(SU)	8	6.97	0.35	6.92	$\geq$6.5, $\leq$8.3	100
Turbidity	(NTU)	7	4.89	2.32	5.3	NA	NA
Specific Conductance	(mS/cm)	8	0.25	0.05	0.397	NA	NA

Bottom-water (0.8m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	22.30	3.62	23.44	$\leq$28.3	100
DO	(mg/L)	8	6.09	2.58	7.52	$\geq$5.0	88
pH	(SU)	8	6.76	0.35	6.83	$\geq$6.5, $\leq$8.3	88
Turbidity	(NTU)	7	5.01	1.90	5.4	NA	NA
Specific Conductance	(mS/cm)	8	0.437	0.05	0.396	NA	NA

Table A2. Summary of water chemistry data collected at station MP2 in Hood Pond, 2016-2017.

Surface (0.3m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	22.61	3.89	22.53	≤28.3	100
DO	(mg/L)	8	8.19	1.01	8.83	≥5.0	100
pH	(SU)	8	7.09	0.29	7.01	≥6.5, ≤8.3	100
Turbidity	(NTU)	7	4.66	2.04	4.7	NA	NA
Specific Conductance	(mS/cm)	8	0.437	0.05	0.399	NA	NA

Mid-water depth (0.9m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	21.89	3.66	21.74	≤28.3	100
DO	(mg/L)	8	6.90	2.46	8.20	≥5.0	88
pH	(SU)	8	6.88	0.36	6.90	≥6.5, ≤8.3	88
Turbidity	(NTU)	7	4.56	2.04	4.8	NA	NA
Specific Conductance	(mS/cm)	8	0.438	0.043	0.399	NA	NA

Deep-water (1.4m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	21.58	3.81	21.26	≤28.3	100
DO	(mg/L)	8	6.23	2.69	8.25	≥5.0	75
pH	(SU)	8	6.84	0.34	6.85	≥6.5, ≤8.3	88
Turbidity	(NTU)	7	4.80	1.52	5	NA	NA
Specific Conductance	(mS/cm)	8	0.438	0.05	0.398	NA	NA
Secchi	(m)	8	0.95	0.27	0.99	2.0	57

Table A3. Summary of water chemistry data collected at station MP3 in Hood Pond, 2016-2017

Surface (0.3m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	23.11	3.88	23.72	≤28.3	100
DO	(mg/L)	8	8.35	1.28	9.3	≥5.0	100
pH	(SU)	8	7.21	0.43	7.09	≥6.5, ≤8.3	100
Turbidity	(NTU)	7	4.57	2.02	4.9	NA	NA
Specific Conductance	(mS/cm)	8	0.439	0.045	0.401	NA	NA

Mid-water (1.0m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	22.20	3.7	22.31	≤28.3	100
DO	(mg/L)	8	7.03	2.54	9.15	≥5.0	88
pH	(SU)	8	6.99	0.45	6.99	≥6.5, ≤8.3	88
Turbidity	(NTU)	7	4.53	1.89	4.2	NA	NA
Specific Conductance	(mS/cm)	8	0.438	0.04	0.399	NA	NA

Deep-water (1.5m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	21.55	3.78	20.59	≤28.3	100
DO	(mg/L)	8	5.91	2.70	8.04	≥5.0	75
pH	(SU)	8	6.78	0.32	6.79	≥6.5, ≤8.3	75
Turbidity	(NTU)	7	5.14	2.13	4.6	NA	NA
Specific Conductance	(mS/cm)	8	0.439	0.044	0.401	NA	NA
Secchi	(m)	8	1.01	0.33	1.03	2.0	

Table A4. Summary of water chemistry data collected at station HP4 in Hood Pond, 2015-2017

Surface (0.3m depth)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	8	23.09	3.91	23.57	≤28.3	100
DO	(mg/L)	8	7.31	1.61	8.66	≥5.0	75
pH	(SU)	8	6.94	0.25	7.0	≥6.5, ≤8.3	75
Turbidity	(NTU)	7	4.2	1.70	3.9	NA	NA
Specific Conductance	(mS/cm)	8	0.439	0.05	0.398	NA	NA

Bottom-water (0.4m)

Parameter	Units	N	Mean	SD	Median	WQ Criteria	% Meeting Criteria
Temp	(°C)	4	22.22	4.74	23.14	≤28.3	100
DO	(mg/L)	4	5.89	1.81	5.41	≥5.0	75
pH	(SU)	4	6.71	0.23	6.69	≥6.5, ≤8.3	75
Turbidity	(NTU)	4	3.4	1.78	3.65	NA	NA
Specific Conductance	(mS/cm)	4	0.404	0.02	0.40	NA	NA