

River Herring Spawning and Nursery Habitat Assessment: Four Mile Pond, 2019-2021

Introduction

Four Mile Pond is a 54-acre, partially spring fed pond located in Boxford Massachusetts. Four Mile Pond is considered a Massachusetts great pond, because it is more than 10 acres in its natural state. The pond is roughly 800 ft. wide, 1,900 ft. at its longest and 25 ft. deep at its center. While Four Mile Pond is partially spring fed, surface water flows from Spofford Pond in Boxford, to an inlet at the northwest end of the pond. The outlet is located at the east end of the pond, where water flows into Pye Brook. Pye Brook flows through Lowe Pond, past Hood Pond and eventually splits into Mile Brook and Howlett Brook which have separate confluences with the Ipswich River in Topsfield.

The Ipswich River Watershed Association (IRWA) is working with a number of partners, including the MA Division of Marine Fisheries (DMF) to improve habitat access and overall conditions for diadromous fish in the watershed. IRWA began spawning and nursery habitat assessment on Four Mile Pond in 2019 and again in 2020 and 2021.

Diadromous Fisheries

This Ipswich River watershed historically supported large runs of diadromous fish that were an important resource to Native Americans and early colonial settlers in the area. Diadromous species in the Ipswich River included river herring (alewife and blueback herring), American shad, rainbow smelt, 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. Run size estimates from visual counts at the Ipswich Mills fish ladder are frequently much less than 1,000 fish from April to June.

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 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. Waterbodies are assessed as support, impaired, or unassessed for specific designated uses, including aquatic life as part of the MassDEP 305(b) reporting requirements. Degraded waters that require a total maximum daily load (TMDL) estimate for specific pollutants are placed on the 303(d) list known as the *Integrated List of Waters*. In the final 2016 *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, 2016). Four Mile Pond is currently classified as unassessed by MassDEP.

Methods

The river herring habitat assessment follows the guidelines of a MassDEP approved Quality Assurance and Project 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 Four Mile Pond from May-September, 2019, 2020 and 2021 with the exception of May 2020. Assessments were targeted to take place during the third or fourth week of each month. 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. 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 centerline of the pond (figure 1).

The following basic water quality parameters were measured: water temperature, dissolved oxygen (DO), specific conductance, and Secchi disc transparency depth. Measurements were made near the surface (0.3 m) and bottom (0.5 m from maximum depth) in the water column. A mid-depth measurement is added to the deep sites. Water temperature and DO 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, subcoregion 84, as specified in the habitat assessment QAPP. The sampling data were combined 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. Finally,

QAPP reference conditions for eutrophication, fish passage and streamflow were assigned a designation of *Suitable* or *Impaired* base on best professional judgement.

FOUR MILE POND ASSESSMENT SITES

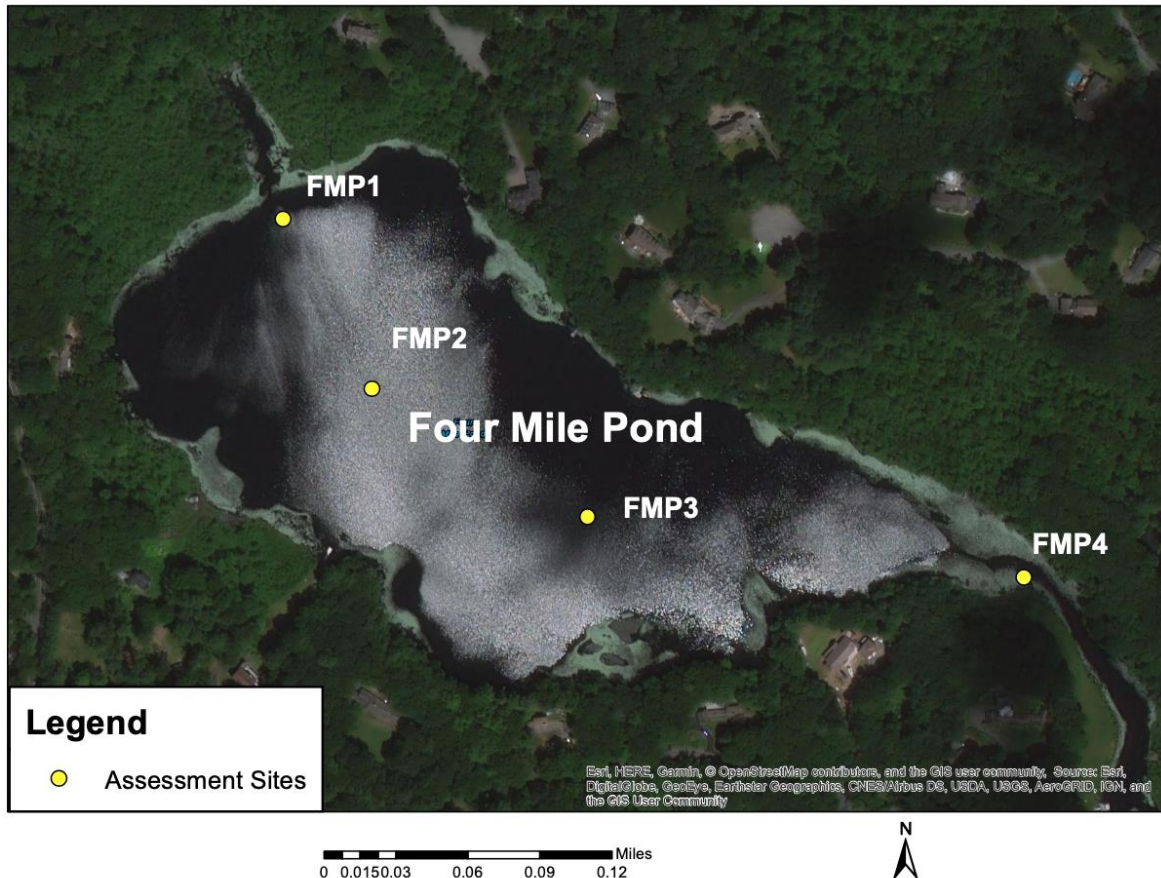


Figure 1. Habitat assessment monitoring sites at Four Mile Pond

Results

Water temperature, dissolved oxygen concentration, specific conductance and pH were evaluated at each monitoring station on Four Mile Pond. There were limitations on measurements in 2020 and August-September, 2021 due to not having access to the water quality sonde. Handheld meters were used instead that limited measurements at depth. Measurements for specific conductance were only recorded at the surface. Dissolved oxygen was not recorded for the bottom strata at the deep sites and pH was not recorded. 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. According to the assessment QAPP, during the spawning period of May-June, water temperatures should not exceed 26.0°C.

During the nursery period of July-September, water temperature should not exceed 28.3 °C to support the development of juvenile herring. Dissolved oxygen levels should be greater than or equal to 5mg/L, and 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 Four Mile Pond exceeded the spawning threshold of 26.0 °C during the spawning period on June 23, 2020 at site FMP1 with a temperature of 28.5°C, site FMP2 with a temperature of 27.4°C, site FMP3 with a temperature of 27.1°C, and at site FMP4 with a temperature of 26.2°C. There were no spawning or nursery temperature exceedances in 2019, 2020 or 2021. Average water temperatures were suitable for both spawning and nursery periods (figure 2, table 1).

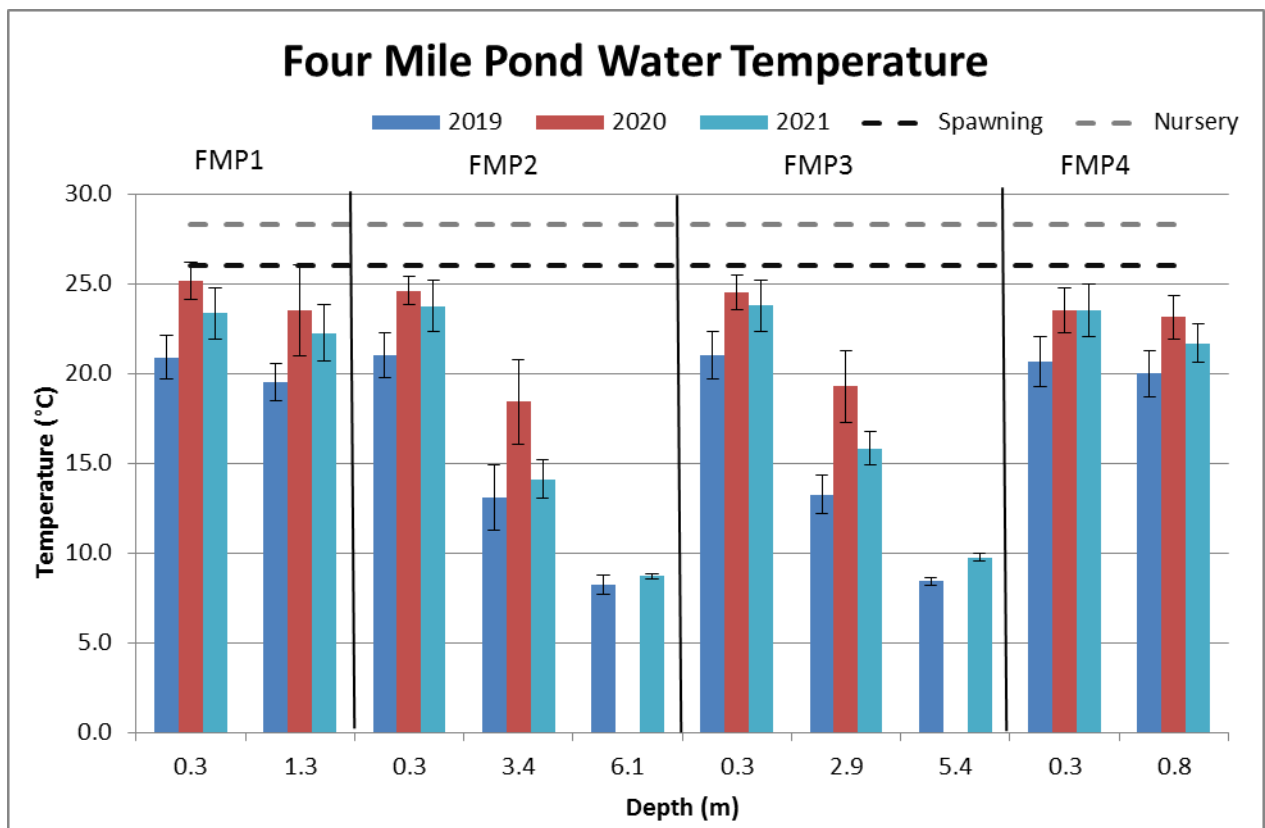


Figure 2. Average water temperature (May-September) at Four Mile Pond monitoring stations, +/- 2 S.E.

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 45% of the total samples. Most exceedances occurred at the deepest strata of sites FMP2 and FMP3 (figure 3). Average surface water DO levels were generally suitable from 2019-2-2021.

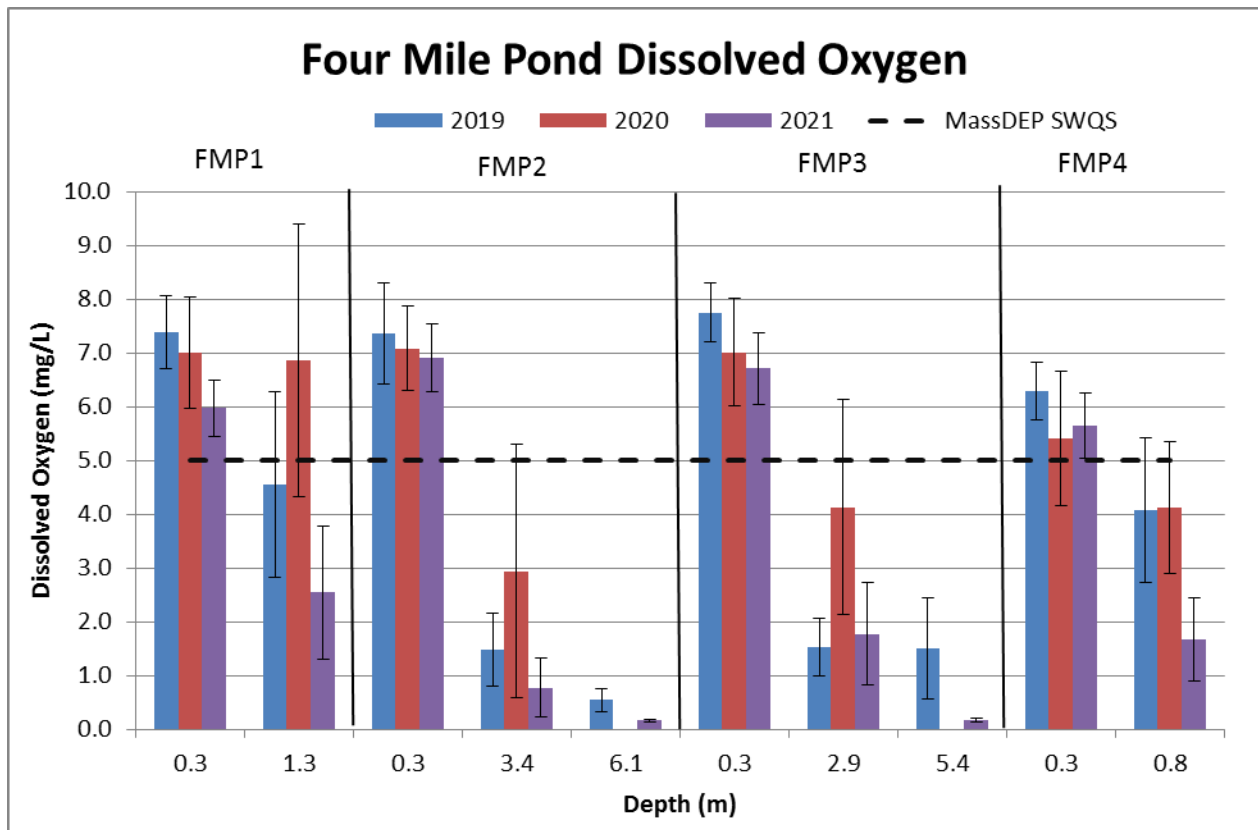


Figure 3. Average dissolved oxygen concentration (May-September) at Four Mile Pond monitoring sites, +/-2 S.E.

pH

Suitable pH conditions are also important for the life history of fish and other aquatic organisms. Monitoring for pH was limited to 2019 and May-July 2021, since the water quality sonde was not available in 2020 or August-September 2021. During this time, the preferred range of ≥ 6.5 and ≤ 8.3 was exceeded among 36% of samples (table 1). This would technically lead to an *Impaired* designation, however, exceedances were slight and average pH was within the preferred range (figure 4), so a best professional designation of *Suitable* was applied. The minimum pH value recorded was 5.96 at the bottom strata (1.3m) depth FMP1 on 6/25/2019. The maximum value observed was 7.45 at the bottom strata (6.1m) of site FMP2 on 8/24/2019.

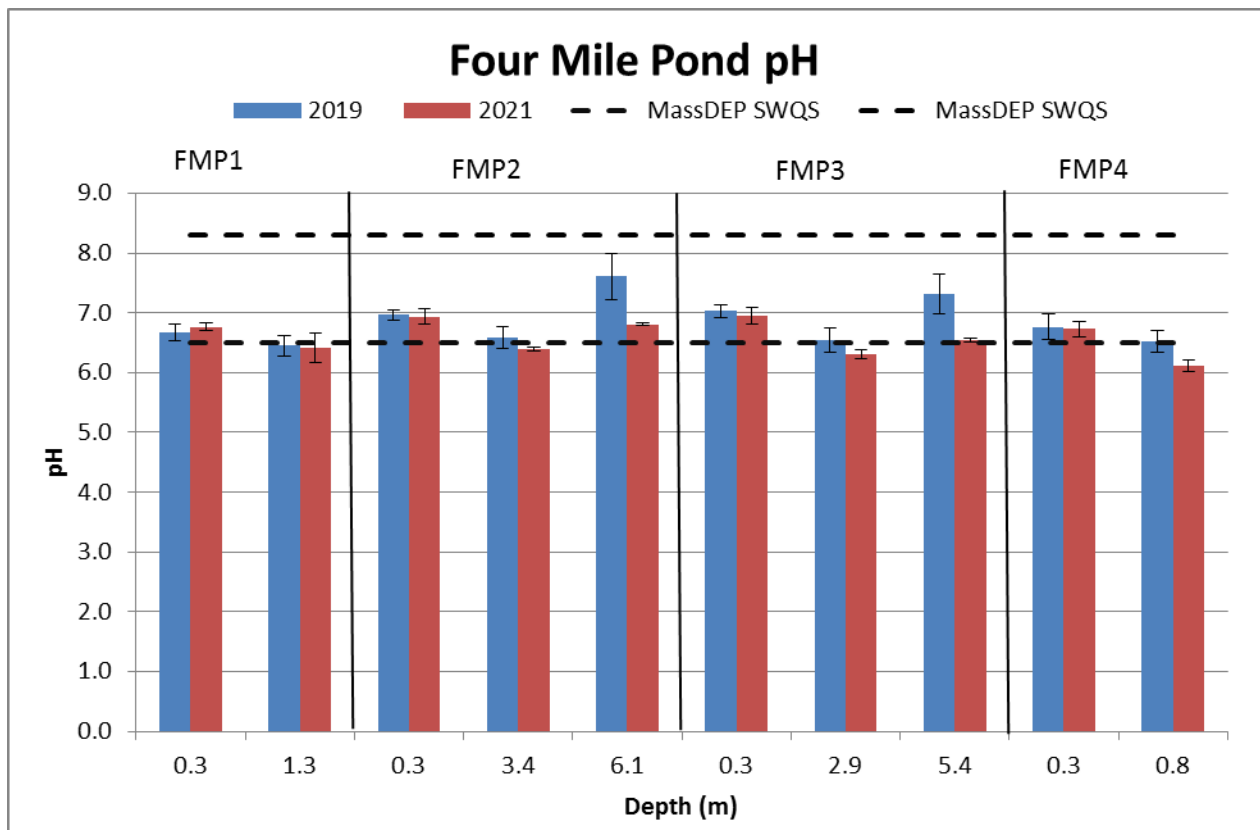


Figure 4. Average pH (May-September) at Four Mile Pond monitoring sites, +/- 2 S.E.

Secchi Disk Transparency

Secchi disk transparency depth indicates the degree of clarity or turbidity related to plankton and suspended solids. High concentrations of organic and inorganic particles can increase turbidity, making a water body less suitable for aquatic life. The monitoring sites of Four Mile 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 FMP2 and FMP3. The minimum visibility standard of 2.0 m represents the point at which water quality may be considered degraded, but this alone may not prevent herring spawning success and may not be a critical factor where spawning would more likely occur in shoal areas, where visibility is at maximum depth when the substrate is not obscured by vascular plants. Due to this, observations of eutrophication as an indicator of water clarity were rated as *Impaired*, however a best professional judgement classification of *Suitable* may be acceptable (table 1).

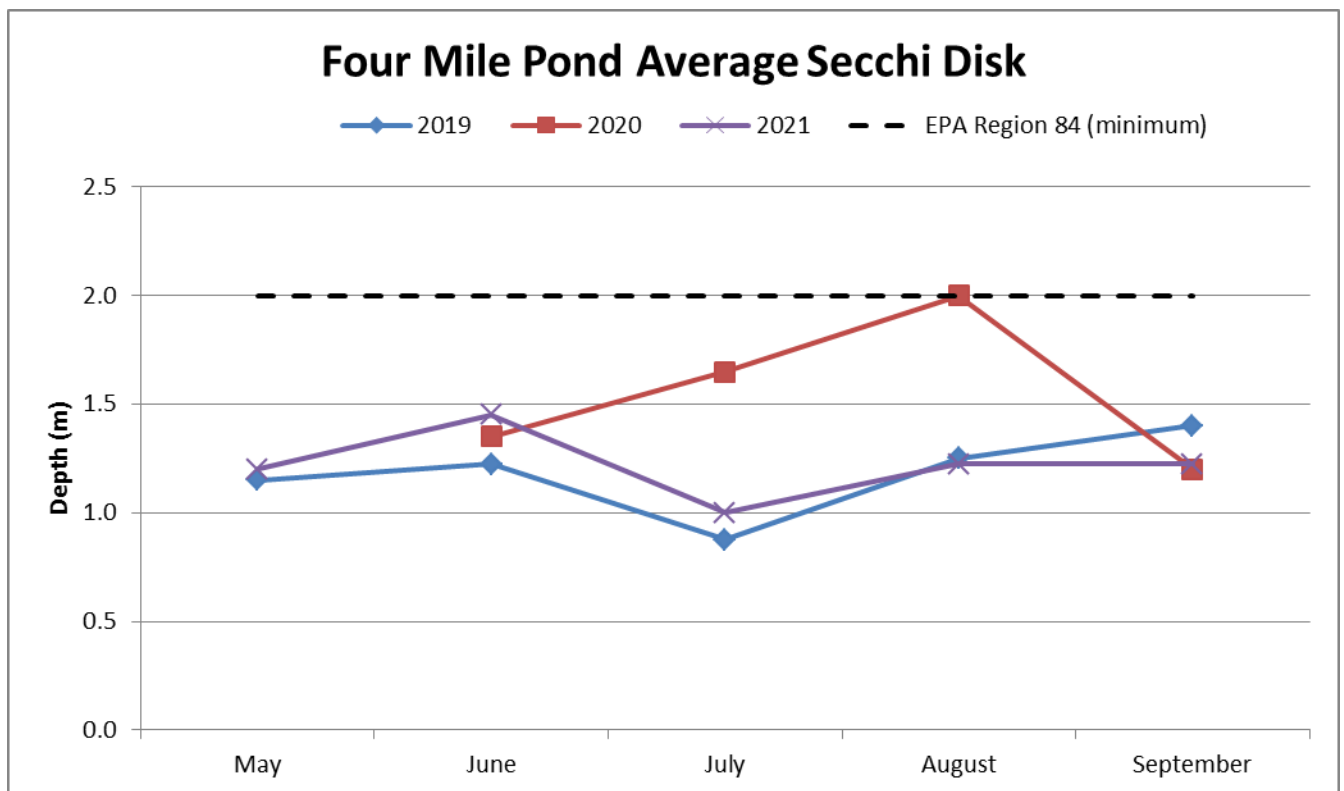


Figure 4. Average Secchi disk transparency by month at Four Mile Pond monitoring stations.

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, FMP1 and FMP4, representing the potential spawning habitat of the pond, were characterized during each site visit 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 qualitatively evaluated through visual observations 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. Based on observations, spawning substrate and eutrophication were evaluated as suitable (table 1).

Fish Passage

Four Mile Pond is approximately 17 stream miles from the mouth of the Ipswich River. There are five dams along the migration path beginning from Ipswich Bay; the Ipswich Mills Dam, Willowdale Dam, Howlett Brook Dam, Lowe Pond Dam, and Four Mile Pond Dam. In addition to these structures, there are a number of road-stream crossings as well as beaver dams, temporary structures and stream features that may influence fish passage (figure 5). Anadromous fish passage to and from Four Mile Pond is critical to river herring restoration goals. Potential fish passage barriers downstream of Four Mile Pond were not directly assessed as part of this study, but are briefly summarized below (beginning at the estuary and moving upstream).

From Four Mile Pond to Ipswich River

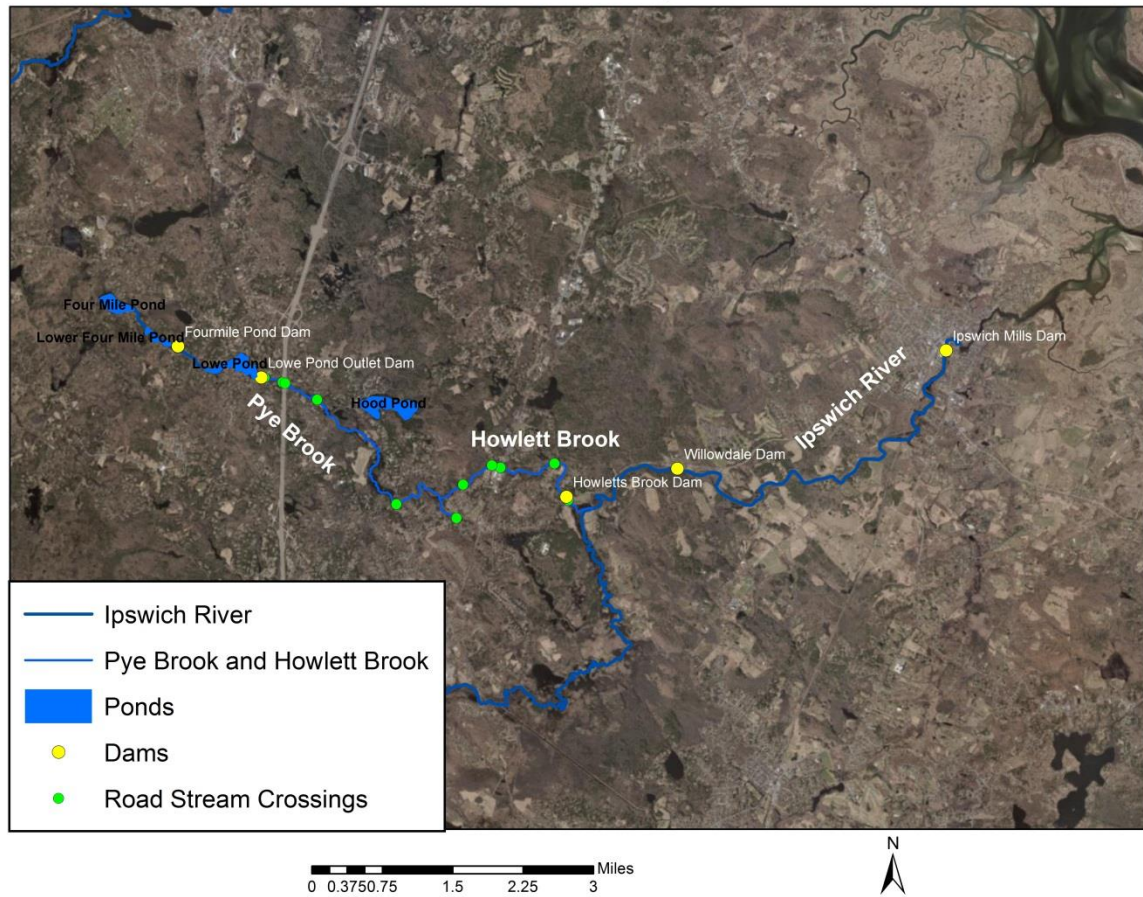


Figure 5. Dams and crossings on the river and stream network between Four Mile Pond and the Ipswich River.

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). 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 in partnership with Foote Brothers and Greenbelt plan to install an Alaska Steeppass fish ladder on the Willowdale Dam to improve passage efficiency at the site. This project will take place in 2021 or 2022.

Howlett Brook Dam

The Howlett Brook Dam is located on Howlett Brook, near the confluence with the Ipswich River. It is a 4.6 foot high privately owned structure which currently has no fish passage device installed. According to local knowledge and field observations, it formerly had a concrete & stone step pool fishway on river left (remnants can still be seen), which allowed for some anadromous fish passage. The dam and fishway were severely damaged in the Mother's Day Storm of 2006 and the fishway was not reconstructed when the dam was repaired. In its current configuration it provides no upstream passage for adult river herring.

The dam spillway consists of stop boards that can be removed to fully lower the impoundment. A fish passage device will be installed in 2021 or 2022 as the dam owner chooses to operate the dam with the impoundment full throughout the year. Downstream migration does not appear to be directly inhibited by the dam.



Figure 6. Howlett Brook Dam. Photo from DMF, 2005.

Low Pond and Four Mile Pond Dams

Low Pond is retained by an earthen berm and a concrete wall. The earthen berm makes up a majority of the 260' combined length of the structure with the concrete wall acting as the main spillway. There is no fish passage structure associated with this dam. Four Mile Pond is impounded by the Four Mile Pond dam on Pye Brook at the east end of the pond. This is an approximately 15' concrete dam located near Georgetown Road. No fish passage structure is present. Downstream migration would not appear to be impacted at either structure under suitable flows.



Figure 6. Four Mile Pond Dam (left) and Low Pond Dam. Photos taken on 6/23/2020.

Streamflow

Streamflow can influence fish passage independently of structural barriers. Flow conditions were noted at the Four Mile Pond dam during each monitoring visit. Drought conditions occurred during 2020 and low flows were observed at each dam as a result (figure 6). Flows could be observed downstream of each dam, however. Both Pye Brook and Howlett Brook are low gradient streams surrounded by wetlands for much of their length. Beaver dams are present along the length of this stream network and several culverts are equipped with beaver deceivers to mitigate damming. Channel maintenance work is ongoing, especially hand pulling of cattails on Pye Brook, to improve passage where dense cattail stands obscure the main channel. Downstream migration should not be impacted by streamflow under most conditions, so a classification of *Suitable* was applied.

Additional observations

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. Specific conductance is related to the concentration of dissolved ions and other compounds existing naturally or contributed from pollution sources in the watershed area. Conductivity was consistent at each monitoring station and depth strata. Measurements were typically 0.21 or 0.22 mS/cm.

Parameter	Units	Sample Size (No.)	Acceptable Criteria	Exceedance %	Classification
Temperature (nursery, July-Sept.)	°C	90	≤ 28.3	0	Suitable
Temperature (spawning, May-June)	°C	36	≤ 26.0	11%	Suitable
Dissolved Oxygen*	mg/L	110	≥ 5.0	45%	Impaired (Surface waters Suitable)
pH	SU	79	≥ 6.5 - ≤ 8.3	36%	Impaired (average pH Suitable)
Secchi disk**	m	28	> 2.0	100%	Impaired
Eutrophication	NA	18	BPJ		Suitable
Fish Passage	NA	NA	BPJ		Suitable (downstream) Impaired (upstream)
Streamflow	NA		BPJ		Suitable

Table 1. Summary of river herring habitat assessment criteria for Four Mile Pond, 2019-2020. 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 assessment period.

*Bottom measurements at FMP2-3 and FMP3-3 were excluded from dissolved oxygen classification due to QAPP exemption.

**Secchi disk measurements were evaluated for deep sites only

Conclusion

Water quality measurements at Four Mile Pond and best professional judgement indicate generally favorable conditions in support of river herring spawning and development. Water temperature measurements were all acceptable during the defined spawning and nursery periods. Dissolved oxygen levels at all but the deepest strata were nearly acceptable for the years (2019 and 2020) of monitoring.

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