Technical Reports

Massachusetts Division of Marine Fisheries
Technical Report TR-78

River Herring Spawning and Nursery Habitat Assessment

Mattapoisett River Watershed, 2013-2014

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Massachusetts Division of Marine Fisheries
Department of Fish and Game
Executive Office of Energy and Environmental Affairs
Commonwealth of Massachusetts

August 2022

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River Herring Spawning and Nursery Habitat Assessment

Mattapoisett River Watershed, 2013-2014

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August 2022

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A view of the Mattapoisett River during the summer of 2013 (**A and B**), a natural buffer along Snipatuit Pond (**C**), and Mattapoisett River stream maintenance at low flow during the summer of 2013 (**D**) (Credit: DMF).

Abstract

River herring (the collective name for alewife, *Alosa psuedoharengus*, and blueback herring, *Alosa aestivalis*) are native, anadromous fish that migrate each spring to spawn in coastal watersheds that have suitable freshwater habitat for egg incubation and juvenile rearing. River herring provide important forage for many species of fish and wildlife and formerly supported valuable commercial, recreational, and subsistence fisheries. The Massachusetts Division of Marine Fisheries (DMF) conducts river herring spawning and nursery habitat assessments to assist habitat and population restoration efforts and contributes to Massachusetts Department of Environmental Protection (*Mass*DEP) water quality assessments. The spawning and nursery habitat of Snipatuit Pond and Tinkham Pond, in the Mattapoisett River watershed, were assessed during 2013–2014. Water quality conditions in both ponds were assessed as well as fish passage and stream flow conditions in the Mattapoisett River. Both ponds were classified as *Impaired* for exceedances of pH, Secchi disk, total nitrogen (TN), and total phosphorus (TP) based on habitat assessment criteria. Additionally, Tinkham Pond was also classified as *Impaired* for low dissolved oxygen (DO) levels. Overall, Tinkham Pond displayed significant impairment throughout the water column, resulting in poor suitability for river herring spawning and nursery habitat. Both ponds were shallow with little seasonal stratification. This feature contributed to the uncommon and positive finding of no DO exceedances in Snipatuit Pond. The migratory habitat in the Mattapoisett River is challenged by low outflow from Snipatuit Pond. The long route to tidal waters and routine low flow during summer and early fall is a concern for juvenile river herring survival. Another concern was the presence of the invasive fanwort (*Cabomba sp.*) that is found in high densities in some locations of Snipatuit Pond.

Introduction

The Mattapoisett River Watershed is located on the western shores of Buzzards Bay in southeastern Massachusetts (**Figure 1**). The Mattapoisett River is in Plymouth County, flowing through the Towns of Mattapoisett and Rochester. This watershed is one of the larger river basins in Buzzards Bay and was designated by the state as containing core habitat for rare plants and animals and natural communities (Massachusetts Division of Fisheries and Wildlife [*Mass*Widlife] & The Nature Conservancy 2022).

The headwaters of the Mattapoisett River is Snipatuit Pond, a 710-acre (287 hectares) freshwater lake located in Rochester. In 1755 an artificial ditch was created to join Snipatuit Pond and the Mattapoisett River (Belding 1921). Snipatuit Brook connects Great Quitticas Pond to the western shore of Snipatuit Pond. Great Quitticas is a 1,125-acre (455 hectares) lake, one of six lakes that make up the Assawompset Pond Complex in Lakeville. On the southeastern side of Snipatuit is Long Pond, a 33-acre (13 hectares) pond which also contributes to the Mattapoisett River drainage. From Snipatuit Pond, the Mattapoisett River flows for approximately 18 kilometers (km), covering 18,000 acres (7,284 hectares) of underdeveloped forests and wetlands as well as cranberry bogs. As it nears Route 6, it becomes tidal, draining into the Mattapoisett Harbor. The US Geological Survey (USGS) has maintained a stream river flow gauge off River Road in Mattapoisett since October 2006 (No.01105917, drainage area = 24 km^2). The mean monthly discharge at this station for May 2007-2020 was 45 cubic feet per second (cfs).

The Division on Marine Fisheries (DMF) is responsible for managing river herring populations in the Commonwealth of Massachusetts. This management includes improving fish passageways between marine and fresh waters and evaluating options for restoring degraded populations and habitats. While DMF does not actively monitor the Mattapoisett River Watershed's diadromous fisheries populations, they have assisted the towns and local organizations in the management of the herring run. The Towns of Rochester, Mattapoisett, and Marion managed the fishery jointly through the Tri-Town River Committee, one of only a few herring runs in Massachusetts run by multiple towns. In addition, an organization called Alewives Anonymous Inc. has aided in the maintenance of this run since 1984. The goals of Alewives Anonymous are to bring awareness to the importance of the river herring fishery and to continue to gain support for scientific research directed at preserving and increasing river herring populations and other anadromous fish species (Alewives Anonymous 2020).

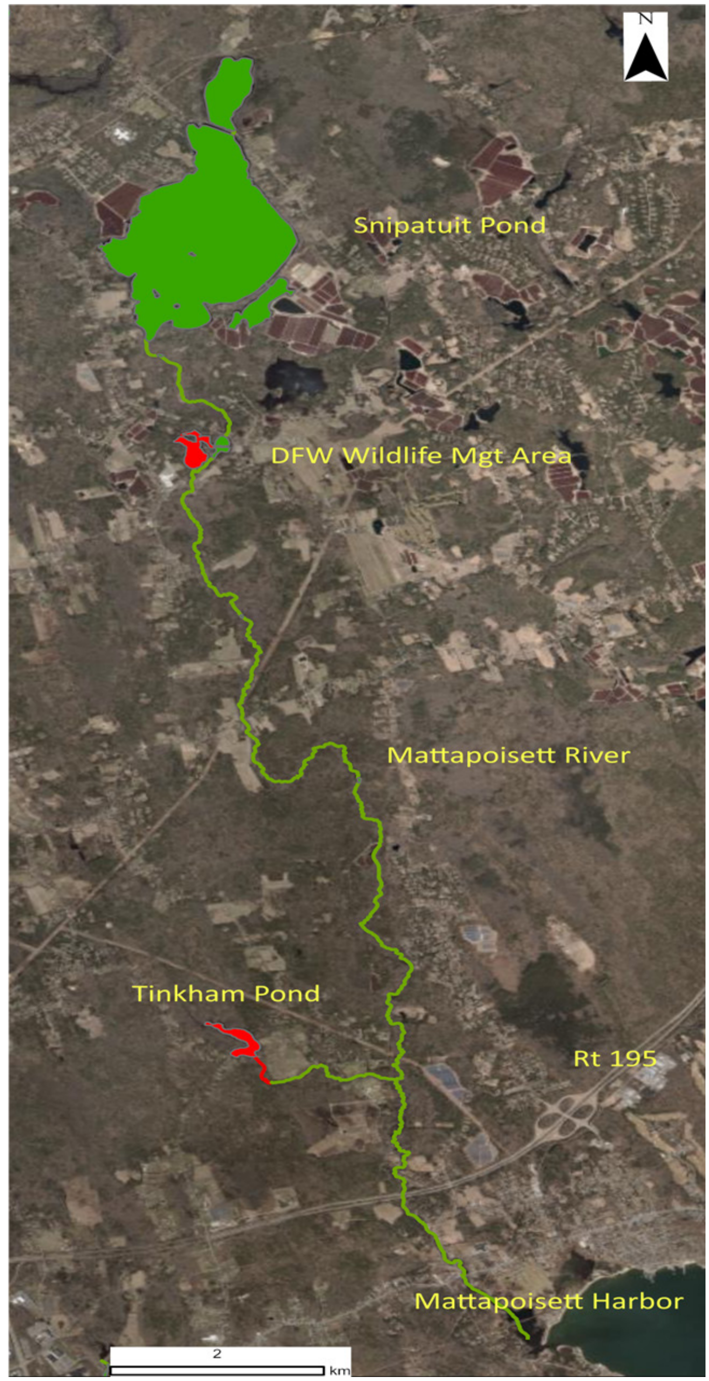


Figure 1. Mattapoisett River Watershed. Ponds and rivers colored in green indicate areas accessible to river herring, and red colored areas are currently inaccessible to river herring.

Diadromous Fisheries. At the start of the 20th century, the Mattapoisett River was one of the most successful herring runs in Massachusetts. Historical records from the Town of Marion report 626,000 river herring harvested in 1906 with 465,000 fish harvested in the following year (Alewives Anonymous 2020). Belding (1921) reported a harvest of 325 barrels of alewive in 1912 (approximately

314,000 fish) and described this run to be one of the largest in Massachusetts from 1900 to 1917. However, due to spawning run harvest practices, pollution, and obstructions such as mills and cranberry bogs, the herring population declined sharply after 1917 (Belding 1921). Harvest continued throughout the 20th century, although at declining levels. Reback and DiCarlo (1972) reported a harvest of approximately 77,000 fish in 1970.

Starting in the 1980s, focused efforts sought to assist the recovery of the river herring population. A fishway was built at the outlet to Snipatuit Pond by DMF in 1986 and in 1988 an electronic fish counter was installed at the same site by Alewives Anonymous. In 1996, a cooperative project replaced both the dam and fishway at Route 6 (Reback et al. 2004.) Other projects include dredging areas of the Mattapoisett River from Snipatuit Pond to Snipatuit Road, replacing culverts at Snipatuit Road, and annual stream maintenance of the river. An encouraging increase in the run occurred during 1998-2000 when the spawning run count was between 104,000 and 130,000 fish (**Figure 2**). Unfortunately, a steep decline occurred immediately after this rise and is thought to be related to drought conditions in 2000-2002.

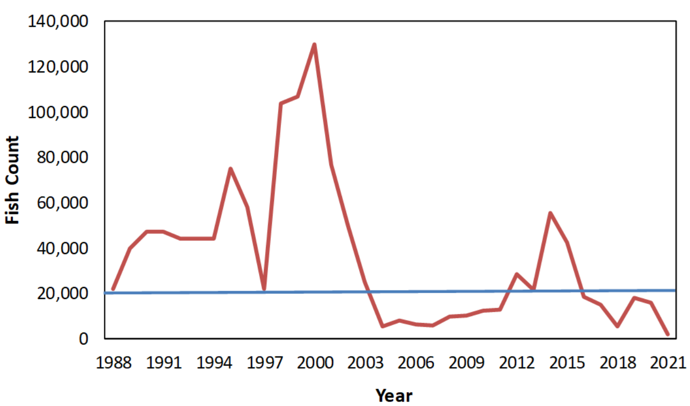


Figure 2. Mattapoisett River herring spawning run count, 1988-2021; with time series mean shown as blue line.

Outside of an increase to 55,000 fish in 2014, the Mattapoisett River herring run has been at very low levels: a condition in contrast to many other Massachusetts runs that have improved moderately since the statewide harvest ban in 2006. The stark decline and very low numbers of fish relative to the available spawning habitat in Snipatuit Pond is a significant concern regionally and one of the reasons this habitat assessment was conducted. The 2021 spawning run of 1,886 fish was the lowest count in the 34-year time series.

Water Supply Management. The Mattapoisett watershed includes an 8-mile-long sand and gravel aquifer that provides water for the Towns of Rochester, Mattapoisett, Marion, and Fairhaven (Olimpio and Lima 1984). This river basin has 10 public wells and numerous private wells serving four municipalities. Some residents of Acushnet also depend on this watershed for their water supply. In 2008 the Mattapoisett River Valley Water Treatment Facility was built in Mattapoisett to treat raw water from eight public wells. According to The Mattapoisett River Valley Water Supply Protection Advisory Committee (MRVWSPAC), in 2018 the Mattapoisett River aquifer provided 1.76 million gallons of water per day to the residents and businesses of these four towns. A list of water supply wells treated by the district treatment facility along with approved daily pumping rates can be found in the 2012 Mattapoisett River Hydrologic Monitoring Annual Report (MRVWSPAC 2012).

Water withdrawals from the Mattapoisett River Watershed have been a concern since the 1980s. A report from USGS stating that in drought conditions parts of the river may run dry as withdrawal rates exceed ground water recharge during peak water usage months (Olimpio and Lima 1984). The Massachusetts Department of Fish and Game (DFG) "Low Flow Inventory" (2004) reported that parts of the Mattapoisett River, in the vicinity of public wells, had run dry in 1999. There are also concerns of additional water withdrawals from cranberry cultivation, including both registered and unregistered bogs, and other agricultural operations (MRVWSPAC 2012). Ongoing water withdrawal monitoring related to the Mattapoisett River is presently conducted by the MRVWSPAC.

Tinkham Pond. Tinkham Pond is located approximately 4 km from the mouth of the Mattapoisett River. This 17-acre impoundment (7 hectares) was once the site of a historic water-powered sawmill called Tripp Mill; however, it is unknown when the first dam was built that created Tinkham Pond. The site was known as the "box-board" mill during 1821-1830, where wooden boxes were built for the fishing and textile industry of New Bedford. In the 1930s the mill owner sold the rights to stream flow to a local Mattapoisett business owner. The mill was eventually torn down and the wooden dam was replaced with a concrete flume.

In the 20th century, flow from Tinkham Pond was mainly used as water supply for cranberry bogs that have been recently decommissioned. Tripp Mills Brook conveys flows from Tinkham Pond to the Mattapoisett River just off Acushnet Road in Mattapoisett. There is no known record of river herring migrating to Tinkham Pond.

Assessment QAPP. The assessment of river herring spawning and nursery habitat by DMF aids in the management and restoration of diadromous fish resources and the evaluation of water bodies by the Massachusetts Department of Environmental Protection (*Mass*DEP), as required by Section 305(b) of the Clean Water Act (CWA). The river herring habitat assessment follows a *Mass*DEP-approved Quality Assurance and Program Plan (QAPP) on water quality measurements for diadromous fish monitoring (Chase 2010). *Mass*DEP will only accept data for 305(b) watershed assessments that were collected under an approved QAPP. The 305(b) process evaluates the capacity of waters to support designated uses as defined by Massachusetts Surface Water Quality Standards (SWQS). Water bodies are assessed as *Support*, *Impaired*, or *Unassessed* for specific designated uses as part of the *Mass*DEP 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. Starting in 2002, *Mass*DEP combined reporting requirements for the 303(d) list and 305(b) report into an Integrated List of Waters for Massachusetts (*Mass*DEP 2013). The QAPP relates diadromous fish life history to water quality criteria, allowing the contribution of data to the 305(b) process for assessing the designated use of Aquatic Life.

MassDEP Water Quality Status. The Mattapoisett River Watershed, was last assessed by *Mass*DEP in 2016 (*Mass*DEP 2019). The assessment results are used in the *Mass*DEP Integrated List of Waters (*Mass*DEP 2019), which lists the Mattapoisett River (Segment MA95-36) and the Mattapoisett Harbor (Segment MA95-35) as Category 5 Waters (Waters requiring a TMDL). The Mattapoisett River requires a TMDL due to the presence of *Enterococcus* and *Escherichia Coli* (*E. coli*) and the harbor has indicators of eutrophication and the presence of fecal coliforms. The assessment also lists Snipatuit Pond (Segment MA95137) as Category 4a Waters (TMDL is completed). The pollutant addressed by the TMDL was mercury found in fish tissue (EPA TMDL No. 33880).

Tinkham Pond (Segment MA95148) was last assessed by *Mass*DEP in 2016 (*Mass*DEP 2019) where it is listed as Category 3 Waters (No uses assessed). Category 3 contains those waters for which insufficient or no information was available to assess any uses.

Methods

The river herring habitat assessment methodology is fully outlined in DMF's QAPP (Chase 2010). The assessment relates river herring life history characteristics to three categories of reference conditions: Massachusetts SWQS (*Mass*DEP 2013), US Environmental Protection Agency (US EPA) nutrient criteria recommendations (US EPA 2001), and Best Professional Judgment (BPJ) to relate monthly site visit observations for Fish Passage, Streamflow, and Eutrophication to QAPP reference conditions (Chase 2010). Monthly trips were made to Snipatuit and Tinkham from May to September, targeting the second and third week of each month. This period was used for sampling because it is when (1) water quality can exhibit the most impairment; and (2) adult river herring spawning and juvenile occupation of the water bodies would occur if passage were available. River herring spawning typically begins in April, but the month is not sampled by design due to the typical lack of impairment during early spring. Snipatuit Pond and Tinkham Pond were both sampled in 2013 and 2014. The assessment criteria for all parameters and assessment results are summarized in **Tables 1-2** for the two water bodies. The station specifications are in Table A1 in the **Appendix**, as are summary statistics for each station (**Tables A.1-A.12**).

Water quality measurements were taken with a YSI 6920 multi-sensor water chemistry sonde at the surface (0.3 m depth), at the bottom (0.5 m from bottom), and at mid-water column depths at stations 2 m in depth or more. The following basic water quality parameters were measured: water temperature, dissolved oxygen (DO), pH, specific conductivity, turbidity, and Secchi disk depth. Water temperature, DO, and pH were related to SWQS criteria. Monthly total phosphorus (TP) and total nitrogen (TN) samples were collected at each pond and analyzed at QAPP approved laboratories (Lakes Lay Monitoring Laboratory (TP) and the Water Quality Analysis Laboratory (TN), University of New Hampshire, Durham, NH)

The TP, TN, and Secchi disk data were related to US EPA nutrient criteria recommendations. The TP and Secchi disk data were also applied to the Carlson Trophic State Index (TSI) (Carlson 1977), a commonly used classification that relates water chemistry indicators to an expected range of trophic conditions. Finally, QAPP reference conditions for Fish Passage, Stream Flow, and Eutrophication were assigned with each monthly visit based on BPJ. The sampling data were combined for the two seasons to produce a classification (*Suitable* or *Impaired*) for each parameter. Criteria excursions of ≤10% or n = 1 (when N = 5-9) for parameter measurements at transect stations are acceptable for a *Suitable* classification. Criteria excursions >10% of transect samples result in an *Impaired* classification (when N ≥ 10).

Assessment Stations. Transect Stations were established from the pond outlet to the pond inlet in both ponds. The transects contained four to six stations to represent shallow, medium, and deep depth strata based on lake bathymetry. Additionally, off-transect stations were visited to gain information on (1) other shallow locations that could serve as river herring spawning habitat; and (2) fish passage and flow conditions at potential migration limitations in the watershed. The off-transect stations were not used for water quality classifications but provided supplemental information on the suitability of the watershed to support river herring life history.

The Snipatuit Pond assessment classification was based on stations SN1-5 selected along a transect line running from the Snipatuit Pond outlet to the Neck Road culvert (**Figure 3**). The Tinkham Pond assessment classification was based on stations TK1-4 along a transect from the outlet dam off Acushnet Road to the upper extent of the backwatering influence of the dam (**Figure 4**).

Nutrient Criteria. The US EPA nutrient criteria recommendations are based on the percentile distribution of TN and TP measurements in a designated ecoregion. The nutrient criteria were derived by calculating a 25th percentile for each of the four seasons with pooled data from all available sampling stations in an ecoregion. The median was calculated from the four seasonal 25th percentiles that represents a threshold between minimally impacted and impaired habitats. The QAPP adopted this approach by relating nutrient measurements to the EPA's 25th percentile for the Northeast Coastal Zone subecoregion #59 (US EPA 2001). The US EPA nutrient criteria for subecoregion #59 are 8.0 ug/L for TP and 0.32 mg/L for TN. The thresholds were accepted in the QAPP, while recognizing they are relatively low for urban watersheds. With additional data collected over time, the QAPP will use the US EPA approach to develop TN and TP criteria specific to river herring spawning and nursery habitat for coastal regions of Massachusetts.

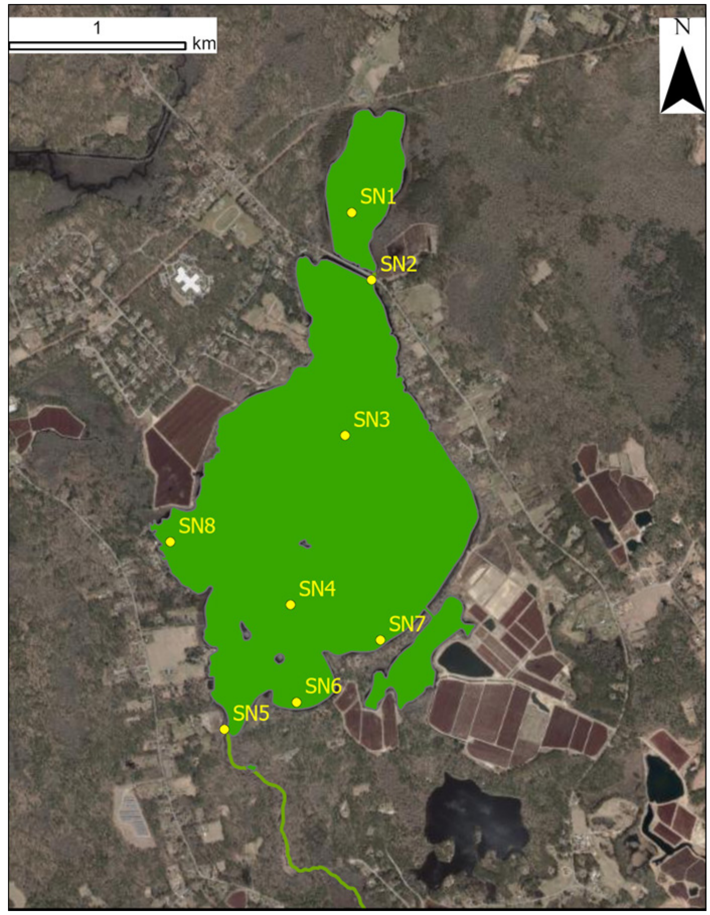


Figure 3. Habitat Assessment Sampling Stations, Snipatuit Pond, Rochester, MA. Ponds and river channels colored in green are accessible to river herring.

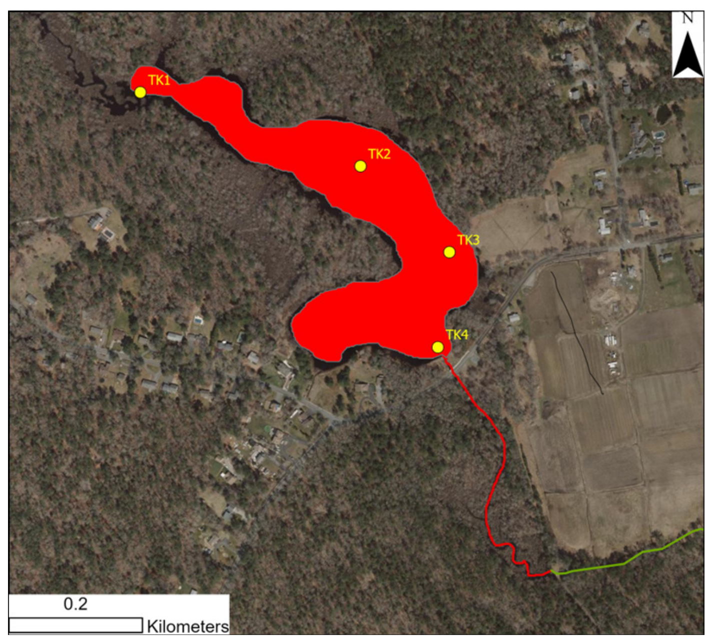


Figure 4. Habitat Assessment Sampling Stations, Tinkham Pond, Mattapoisett, MA. Ponds and river channels colored in red are inaccessible to river herring.

Table 1. Summary of river herring habitat assessment criteria for Snipatuit Pond, 2013-2014.

Parameter	Units	Sample (No.)	Sample (Mean)	Acceptable Criteria	Exceedance (%)	Classification
Temp. (spawning)	°C	36	20.75	≤26.0	0	*Suitable*
Temp. (nursery)	°C	54	22.99	≤28.3	7.4	*Suitable*
DO	mg/L	89	8.08	≥5.0	0	*Suitable*
pH	SU	90	5.74	6.5 to ≤8.3	88.9	*Impaired*
Secchi	m	38	0.9	≥2.0	100.0	*Impaired*
TN	mg/L	30	0.436	≤0.32	76.7	*Impaired*
TP	ug/L	29	43.1	≤8.0	100.0	*Impaired*
Fish Passage	BPJ	50			18.0	*Impaired*
Stream Flow	BPJ	50			18.0	*Impaired*

Notes: *Impaired* classifications result from exceedances of >10% or >1 (when N<10) for measurements at transects station (SN1-5). The number of total samples vary with number of stations, parameter type, and QA/QC review. The Fish Passage and Stream Flow classifications are best professional judgement (BPJ) for applicable stations combined.

Table 2. Summary of river herring habitat assessment criteria for Tinkham Pond, 2013-2014.

Parameter	Units	Sample (No.)	Sample (Mean)	Acceptable Criteria	Exceedance (%)	Classification
Temp. (spawning)	°C	28	18.44	≤26.0	3.6	*Suitable*
Temp. (nursery)	°C	40	19.98	≤28.3	0	*Suitable*
DO	mg/L	68	3.60	≥5.0	69.1	*Impaired*
pH	SU	68	5.69	6.5 to ≤8.3	100.0	*Impaired*
Secchi	m	29	0.6	≥2.0	100.0	*Impaired*
TN	mg/L	10	0.730	≤0.32	100.0	*Impaired*
TP	ug/L	10	26.1	≤8.0	100.0	*Impaired*
Fish Passage	BPJ	40			92.5	*Impaired*
Stream Flow	BPJ	40			65.0	*Impaired*

Notes: *Impaired* classifications result from exceedances of >10% or >1 (when N<10) for measurements at transect stations (SN1-5). The number of total samples vary with number of stations, parameter type, and QA/QC review. The Fish Passage and Stream Flow classifications are best professional judgement (BPJ) for applicable stations combined.

Results

Massachusetts SWQS Criteria

Water Temperature

The metabolic and reproductive processes of ectothermic fish are directly influenced by water temperature. Water temperature is also an important factor for fish migrations and the stratification and productivity of lakes. Temperature thresholds for fish typically target critical warming ranges when acute impacts occur to early life stages. The QAPP adopted a threshold of ≤ 26.0°C from Greene et al. (2009) for the spawning period of May–June, and the *Mass*DEP criterion of ≤ 28.3°C for water temperature as *Suitable* to support Aquatic Life for the nursery period of July–September.

Snipatuit Pond. Water temperature measurements at Snipatuit Pond recorded no exceedances for the spawning period and four exceedances (7.4%) for the nursery period, resulting in a *Suitable* classification for both periods (**Figure 5A**). All exceedances occurred on one date in July 2013. As a shallow pond with no measured depths exceeding 2 m, there was minimal depth stratification and no apparent thermocline. The highest temperature measured was 30.2 °C at SN6 in July 2013. As an off-transect station this measurement is not included in the temperature classification but does represent a high temperature that could stress early life stages of river herring.

Tinkham Pond. Water temperature measurements at Tinkham Pond recorded one exceedance (3.6%) for the spawning period and none for the nursery period, resulting in a *Suitable* classification for both periods (**Figure 6A**). Similar to Snipatuit Pond, Tinkham Pond depths do not exceed 2 m, resulting in limited depth stratification. Tinkham Pond did have cooler bottom temperatures that may indicate a groundwater influence. The average nursery period water temperature at Tinkham Pond was 3 °C cooler than at Snipatuit Pond for all measurements during the two-year assessment.

Water pH

The acidification of fresh water is a widely recognized concern for fish populations. Low pH can increase metal toxicity and disrupt ionoregulation in gill tissues. The QAPP adopted the *Mass*DEP criterion of ≥6.5 to ≤8.3 for pH as *Suitable* to support Aquatic Life. Water pH outside of this range can threaten the growth and development of fish eggs and larvae, while highly acidic and alkaline waters (≥9.0 pH) in some cases can cause lethal effects (NAS 1972; Haines and Johnson 1982). Environmental acidification has been linked to the elimination of anadromous populations and chronic poor recruitment of anadromous fish in North America (Klauda and Palmer 1987; Hesthagen and Hansen 1991).

Snipatuit Pond. Water pH at Snipatuit Pond was highly acidic with only 10 of 90 measurements above the 6.5 threshold (**Figure 5B**). This resulted in an *Impaired* classification for pH with an exceedance rate of 89%. The average water pH was 5.74 for all transect stations during the two-year assessment. Further raising concerns for threats to early life stages of river herring was the occurrence of 20 measurements <5.00 pH.

Tinkham Pond. Water pH at Tinkham Pond was highly acidic with none of the 90 measurements above the 6.5 threshold (**Figure 6B**). This resulted in an *Impaired* classification for pH with an exceedance rate of 100%. The average water pH for Tinkham Pond was only slightly lower than Snipatuit Pond at 5.69; however, the measurements were consistently low (SD = 0.253, vs 0.753 at Snipatuit Pond) with no measurements below 5.00 and only seven in the range of 6.00 to 6.50.

Dissolved Oxygen

Adequate DO concentrations are essential for the respiration and metabolism of aquatic life. Water DO is highly influenced by water temperature, as well as chemical and biological processes that influence seasonal and diurnal cycles. The QAPP adopted the *Mass*DEP criterion of ≥5.0 mg/L for DO as *Suitable* to support Aquatic Life.

Snipatuit Pond. Snipatuit Pond was classified as *Suitable* for DO with none of the 89 transect measurements below the ≥5.0 mg/L DO threshold (**Figure 5C**). As a shallow pond with no depth stratification, the bottom measurements of DO were only slightly lower than surface measurements. Additionally, no surface measurements were highly DO supersaturated; a typical symptom of eutrophied water bodies. The status of no DO exceedances and no surface DO supersaturation has not been observed during prior DMF river herring spawning and nursery habitat assessments.

Tinkham Pond. In contrast to Snipatuit Pond, Tinkham Pond was found to be severely degraded by low dissolved oxygen. Forty-seven of the 68 DO measurements were below the 5.0 mg/l threshold: resulting in an *Impaired* classification with an exceedance rate of 69% (**Figure**

6C). The mean DO concentration for all transect samples was 3.60 mg/l. This mean is depressed by numerous very low DO measurements: including anoxic surface measurements (<1.0 mg/l) collected in July and August of both years, and hypoxic surface measurements (1.0 to <4.0 mg/l) made in September of both years and June of 2014. Anoxic surface DO measurements in the daytime are unusual due to natural process of photosynthesis and surface wind action. The level of DO and pH impairment found at Tinkham Pond is uncommon in MA coastal ponds and a significant limitation for the concept of restoring river herring to Tinkham Pond.

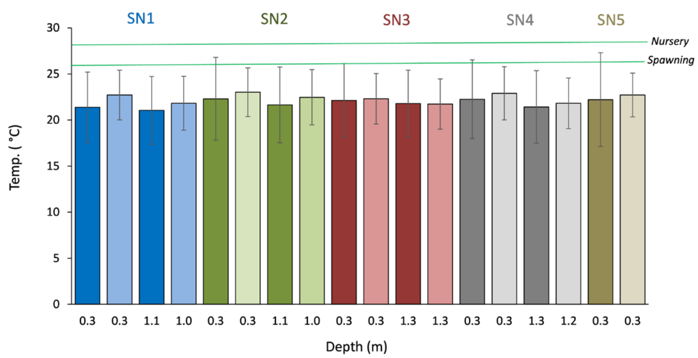
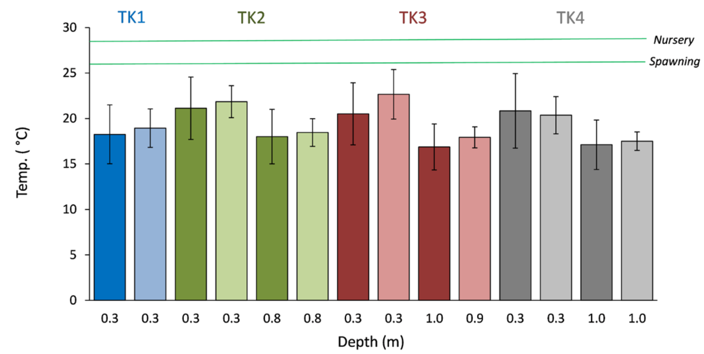


Figure 5A. Water temperature (°C) measurements taken at Snipatuit Pond, 2013-2014. Station averages are presented (+/- 2 SE) for 2013 (dark bars) and 2014 (light bars). Five samples were made at each depth interval per year.



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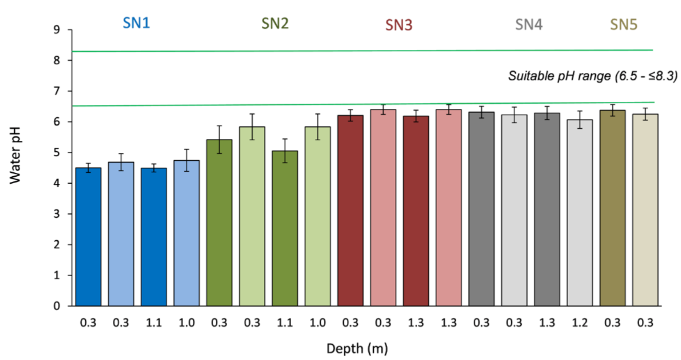

Figure 5B. Water pH measurements taken at Snipatuit Pond, 2013-2014. Station averages are presented (± 2 SE) for 2013 (dark bars) and 2014 (light bars). Five samples were made at each depth interval per year.

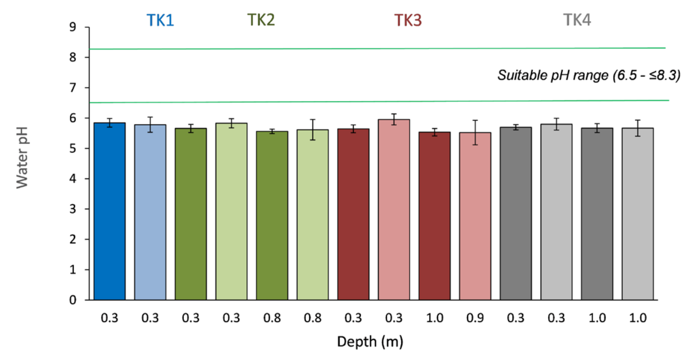

Figure 6B. Water pH measurements taken at Tinkham Pond, 2013-2014. Station averages are presented (+/- 2 SE) for 2013 (dark bars) and 2014 (light bars). Five samples were made at each depth per year.

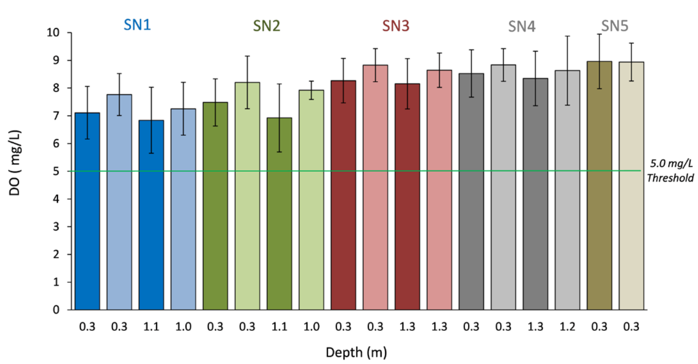

Figure 5C. Dissolved oxygen (mg/L) measurements taken at Snipatuit Pond, 2013-2014. Station averages are presented (+/- 2 SE) for 2013 (dark bars) and 2014 (light bars). Five samples were made at each depth per year.

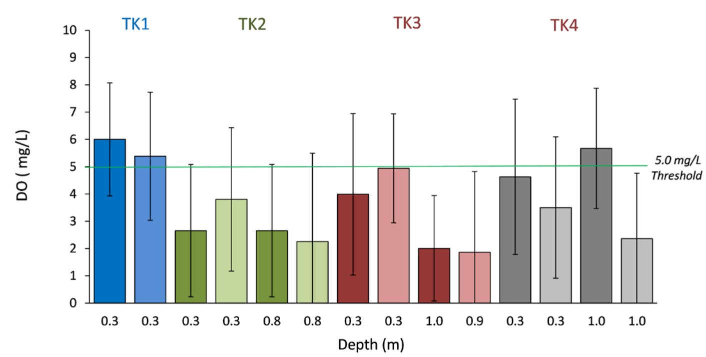

Figure 6C. Dissolved oxygen (mg/L) measurements taken at Tinkham Pond, 2013-2014. Station averages are presented (+/- 2 SE) for 2013 (dark bars) and 2014 (light bars). Five samples were made at each depth per year.

Nutrients

Total nitrogen and phosphorus are essential nutrients for plant metabolism and indicators of trophic status in water bodies. The QAPP adopted US EPA nutrient criteria of <0.32 mg/L for TN and <8.0 ug/L for TP as *Suitable* to support Aquatic Life.

Snipatuit Pond. Monthly surface samples of TN and TP were collected at SN2, SN3, and SN5 in Snipatuit Pond. These samples were pooled, resulting in an *Impaired* classification for TN and TP. All measurements exceeded the nutrient criteria with the exception of five TN measurements at SN3 and two at SN5. TP concentrations declined from the upgradient SN2 to the pond outlet SN5. The highest mean TN and TP were also found at SN2 (**Figures 7 and 8**).

Tinkham Pond. Monthly surface samples of TN and TP were collected at TK4 in Tinkham Pond. All measurements exceeded the nutrient criteria, resulting in an *Impaired* classification for TN and TP. Despite the impaired status, the mean TP at Tinkham Pond (26 ug/L) was well below that found at the Snipatuit Pond stations (37-48 ug/L; **Figure 7**) and relatively low for coastal MA ponds. Conversely, the TN mean for TK4 (0.73 mg/L) was well above the means for the Snipatuit Pond stations (0.40 to 0.51 mg/L; **Figure 8**).

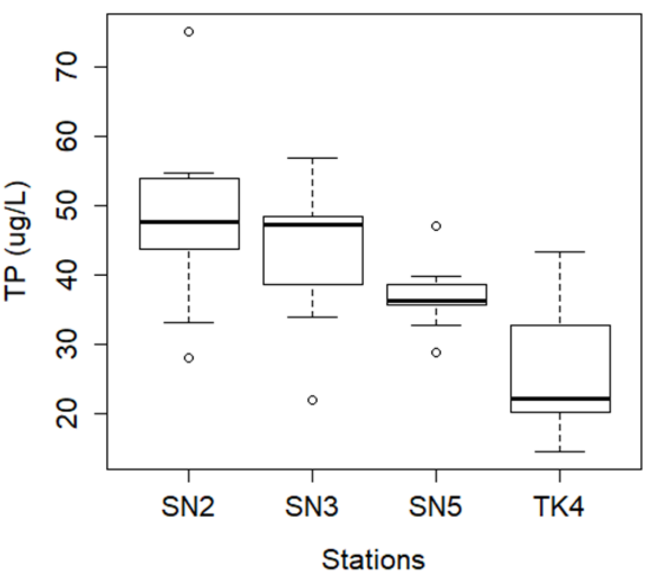

Figure 7. Total Phosphorus (TP) measurements at Snipatuit Pond (SN2, SN3, and SN5) and Tinkham Pond (TK4).

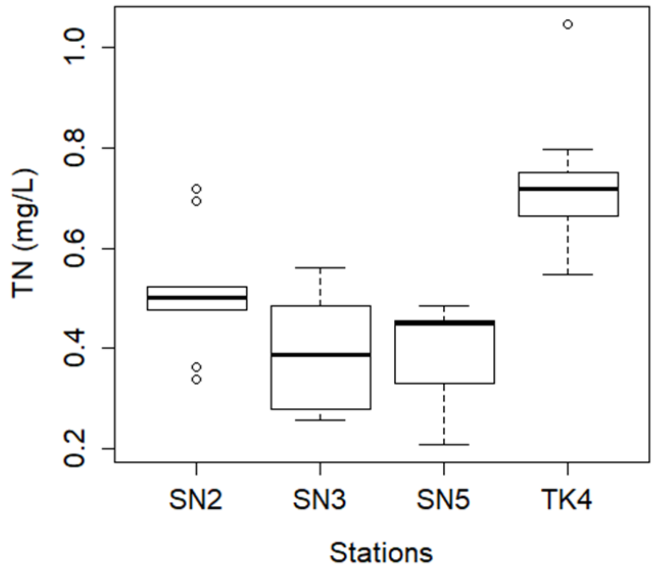

Figure 8. Total Nitrogen (TN) measurements at Snipatuit Pond (SN2, SN3, and SN5) and Tinkham Pond (TK4).

Secchi Disk

Secchi disk is an easily measured proxy for the transparency of water to light. There is little information that directly links Secchi disk depth to river herring life history, although it is widely accepted as an indicator of water quality. The US EPA Secchi disk criterion of ≥4.9 m for subecoregion #59 (Northeast Coastal) is higher than water clarity typically seen in Massachusetts coastal drainages, therefore the criterion for subecoregion #84 (Cape Cod) of ≥2.0 m Secchi disk depth was adopted by the QAPP as Suitable to support Aquatic Life.

Snipatuit Pond. None of the 38 Secchi disk measurements at four transect stations in Snipatuit Pond were above the criterion, resulting in an *Impaired* classification (**Figure 9**). Despite low measured turbidity and the lack of severe phytoplankton blooms the pond appeared naturally tannic and had very low visibility as measured by Secchi disk. The maximum Secchi disk measurement for all stations was only 1.45 m. The northern bay station SN1 had very low visibility with a mean of 0.5 m, and there was a gradient of gradually increasing Secchi disk depth moving downstream.

Tinkham Pond. None of the 30 Secchi disk measurements at three transect stations in Tinkham Pond were above the criterion, resulting in an *Impaired* classification (**Figure 10**). The measurements at all stations were consistently low, with none reaching 1.0 m in Secchi disk depth. The tannic conditions seen at Tinkham Pond were similar to that observed at SN1 in the northern bay of Snipatuit Pond.

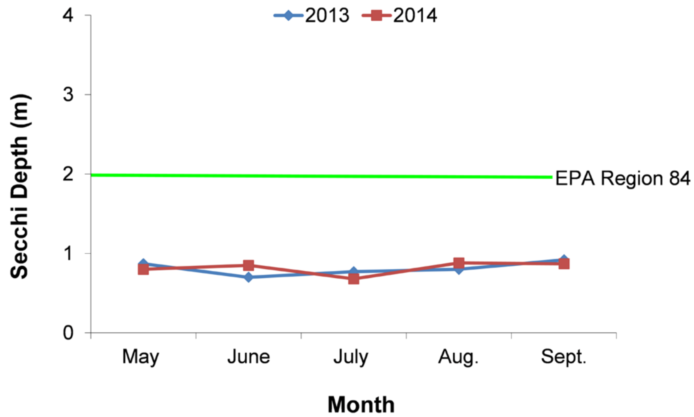

Figure 9. Secchi disk measurements taken at Snipatuit Pond, 2013-2014. Average monthly Secchi disk measured at stations SN1-SN4. Four samples were targeted each month.

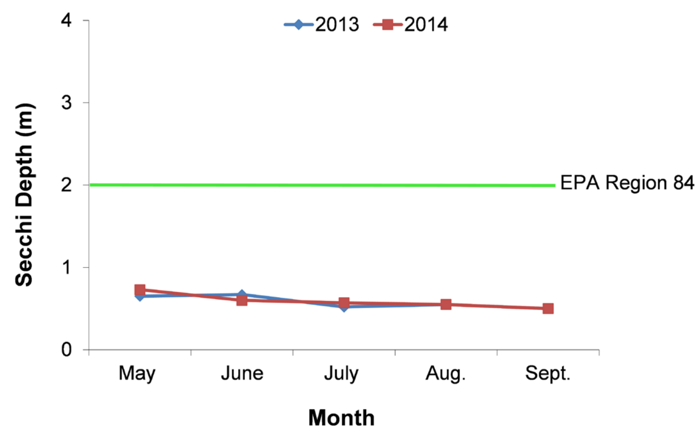

Figure 10. Secchi disk measurements taken at Tinkham Pond, 2013-2014. Average monthly Secchi disk measured at stations TK1-TK3. Three samples were targeted each month.

Best Professional Judgment

Fish Passage

The QAPP provides a process for using Best Professional Judgment (BPJ) to assess the potential of river herring to pass fishways and impediments. With each site visit, the type of impediment is documented and the potential for upstream passage of adult river herring and downstream passage of emigrating adults and juvenile river herring are assessed and classified as *Suitable*, *Impaired*, or *Unsuitable*. Because the Mattapoisett River has multiple locations that were assessed for fish passage, each location was classified separately below.

Mattapoisett River. Fish passage status was assessed at five stations from the Snipatuit Pond outlet to the Rt 6 fishway.

1.) Neck Road Culvert (SN01). The culvert at Neck Road conveys flow between the main body of Snipatuit Pond and the northern bay. This site was assessed due to uncertainty over water depth in the culvert during summer. All observations were *Suitable*, with no conditions found that would impede fish entering or exiting the northern bay.

2.) Snipatuit Pond Outlet (SN02). The fishway at the outlet of Snipatuit Pond is a concrete weir-pool fishway constructed by the DMF Fishway Crew in 1986. The design is very suitable for a flow-limited watershed with dual channels: one for fish passage and one for excess flows. Outflow was sufficient during spring of both years to pass adult river herring. Despite substantially lower outflow during July-September, the fishway operations are efficiently managed by the long-time Rochester Herring Warden, Dave Watling, to store and release water as needed for juvenile herring emigration. All assessments were *Suitable* for SN02 except for one *Impaired* in September 2013 when pond levels allowed almost no outflow.

3.) Fish Hatchery Fishway (MRF2). The former fish hatchery off Hartley Road is presently a MA DFW Wildlife Management Area that contains a bypass channel that serves as a fishway with 15 in-stream rock weirs. These weirs adequately raised water depth for fish passage under most conditions. The assessment for this site was *Suitable* for all months except for *Impaired* during very low flows in August/September 2014. A concrete dam with a 6-foot spillway height prevents fish from passing into what was formerly the main stem river channel at the hatchery and requires fish to use the bypass channel.

4.) Relic Mill at Rt 105 (MRF3). The ruins of a former mill at Rt 105 have previously impeded fish passage and required stop-log board management for the herring run. This station had the same monthly assessment as MRF2: *Suitable* conditions except for the low flow found late in 2014. The site has the potential to develop a velocity barrier for river herring as the channel constricts at the mill. Such conditions were not observed during 2013-2014. Site management over the years by the Rochester Herring Warden has groomed the channel slope and eliminated the need for board operations.

5.) Rt 6 Fishway (MRF1). The first obstruction on the Mattapoisett River is the dam at Rt 6 that contains a concrete Denil fishway rebuilt during a cooperative project in 1996. The dam contains two adjustable spillway gates next to the 58 ft fishway and a third gate at a bypass channel close to the fishway exit. The operation of the fishway depends on careful adjustment of the three gates. This station received an *Impaired* assessment for 4 visits and *Suitable* for the remaining 6 visits. Two of the *Impaired* classifications were due to improper gate adjustment (too much flow at fishway entrance and bypass gate open during spring migration). The other two *Impaired* assessments were during the late-2014 low flow period. DMF installed a staff gauge at the fishway for the assessment and developed a Fishway Operation and Maintenance (O&M) plan in 2014 in cooperation with the dam owner to provide guidance on fishway management. The working draft O&M plan was finalized in 2019.

Collectively, the Mattapoisett River stations received an *Impaired* classification for fish passage (9 of 50 visits were *Impaired*). However, all but two of the *Impaired* assessments were due to low flows experienced during August/September 2014. Adequate fish passage is attainable in the watershed with active management by the Rochester and Mattapoisett herring wardens during average flows. Fish passage concerns were demonstrated for below-average stream flows.

Tinkham Pond. Tinkham Pond discharges to a tributary of the Mattapoisett River at the Tinkham Pond Dam (TK5) which is also called Tripps Mill Dam just upstream of Acushnet Road. This dam has no fishway and was readily classified as *Unsuitable* for fish passage with each visit. At approximately 350 m downstream from Acushnet Road a bog flume directs stream flow to either a dug channel to the former Decas cranberry bogs or the natural channel that bends east to meet the Mattapoisett River. The bog flume (TK6) also has no fishway and was readily classified as *Unsuitable* for fish passage with each visit. The third assessment site (TK7) was a culvert further downstream at Acushnet Road that conveys the natural stream channel. This site has a rock weir that was *Suitable* for fish passage during May and June of 2013 when flows were high but was assessed as *Impaired* or *Unsuitable* during all other visits. The final site was a 3rd culvert crossing (TK8) at Acushnet Road that discharged flow from the former bog to the Mattapoisett River. This site was assessed as *Impaired* or *Unsuitable* for 9 of 10 visits due to a combination of an elevation change and low flow.

Overall, passage for river herring to Tinkham Pond was not possible due to two impassible locations. Even if fish passage was provided at the dams, low flows at the two lower Acushnet Road culverts would have prevented passage for all but two months during the assessment.

Stream Flow

Stream flow is a separate classification from fish passage because in some cases, stream flow can influence passage and habitat quality independently of a structural impediment. A common example is a situation where stream flow would be adequate to provide upstream passage for spawning adult river herring or downstream passage of juveniles if an obstruction was not present. In that example, the station would be classified as *Impaired* or *Unsuitable* for fish passage and *Suitable* for stream flow. In other cases, stream flow can be too low to support river herring passage independent of channel dimensions or the presence of obstructions.

A US Geological Survey streamflow gage is located on the Mattapoisett River (No. 01105917) less than 1 km north of the Rt 6 fishway. However, the gage was offline during the 2013-2014 habitat assessment. The gage was recording during 2006-2010, and from 2015 to the present. During this period of operation, the highest monthly mean discharge occurred in March (94 cfs) and the lowest in August (6.9 cfs). Low flows also commonly occur in September (monthly mean = 7.4 cfs). Both August and September had three years in the 10-year time series with monthly mean flows under 1 cfs. These low flow conditions are expected to be challenging for emigrating juvenile river herring.

Mattapoisett River. Stream flow is a significant concern in this long, coastal river (18 km) with limited outflow from Snipatuit Pond. The ability of juvenile river herring to emigrate to tidal waters during drought years has long been a concern for the Mattapoisett River. The following locations were visited monthly during the assessment to observe flow conditions, including the recording of water surface elevation data at Neck Road, the Snipatuit Pond outlet fishway and the Rt 6 fishway.

1.) Neck Road Culvert (SN01). No issues were observed on limited outflow at SN01 during both years with all visits having *Suitable* conditions for Stream Flow.

2.) Snipatuit Pond Outlet (SN02). Similar to the Fish Passage assessment at SN02, the low outflow conditions are well-managed by the Rochester Herring Warden with stop-log board operations. All visits had *Suitable* conditions for Stream Flow except September 2014 which was *Impaired* due to low pond outflow.

3.) Fish Hatchery Fishway (MRF2). This station suffered from low water depth and debris jams in the shallow water that could impede and impinge juvenile herring. The station had seven *Suitable* assessments but received *Impaired* or *Unsuitable* for 3 of the 4 trips in August/September.

4.) Relic Mill at Rt 105 (MRF3). This station had similar concerns as MRF2 and the same assessment for Stream Flow with the exception of three *Impaired* assessments in August/September and no *Unsuitable* assessments.

5.) Rt 6 Fishway (MRF1). Stream flow conditions were sufficient to allow passage in the Rt 6 fishway at MRF1, with *Suitable* conditions for all dates except for *Impaired* during August/September 2014 related to very low flows in the Mattapoisett River.

Collectively, the Mattapoisett River stations received an *Impaired* classification for Stream Flow (9 of 50 visits were *Impaired*). Most of the *Impaired* assessments occurred during the dry period of August/September 2014.

Tinkham Pond. Higher flows present in 2013 allowed an assessment of *Suitable* stream flow at all four BPJ stations (TK5-TK8) in May and June. This was repeated in May 2014 and for one station in June 2014 (TK6); however, all remaining monthly assessments were *Impaired* or *Unsuitable*. Low flow or no flow was a persistent problem during July-September at all stations that would hamper juvenile river herring emigration. Overall, the stream flow classification for Tinkham Pond was *Impaired*.

Water Level Gauges. Relative water levels were monitored with each assessment visit at Snipatuit Pond (SNO2), Tinkham Pond (TK5), and the Rt. 6 fishway (MRF1). These relative measurements of water surface elevations are useful proxies for pond volume and river flow and can provide valuable thresholds for fishway operations with larger sample sizes. The seasonal decline of Snipatuit Pond elevation was similar in both 2013 and 2014 (**Figure 11**). Although 2014 had a larger decline from May to September (37 cm) than in 2013 (21 cm), September 2014 was the only month in the assessment where this station received an *Impaired* classification for both Fish Passage and Stream Flow.

Tinkham Pond water elevation showed more fluctuation between the two years than Snipatuit Pond (**Figure 12**). The drop in pond elevation from May to September was only 10 cm in both years; however, there was a sharp 44 cm drop from July to August in 2014 that coincided with no outflow in August and September. The low pond level recorded for May 2014 at the gauge is not consistent with the *Suitable* Stream Flow classification for that visit, and may suggest a field sampling error or marginal BPJ classification.

The water level measurements at the Rt. 6 fishway (MRF1) were made at a staff gauge placed by DMF at the fishway exit. The intention of the gauge was to determine the appropriate range of water depth for the Denil fishway baffles. The gauge data showed a decline in fishway water level from May to September of 1.8 ft in 2013 and 1.3 ft in 2014 (**Figure 13**). These data and subsequent gauge measurements have allowed the inclusion of a target depth range of 2.5 to 3.2 ft during the spring river herring migration in the fishway's final O&M plan.

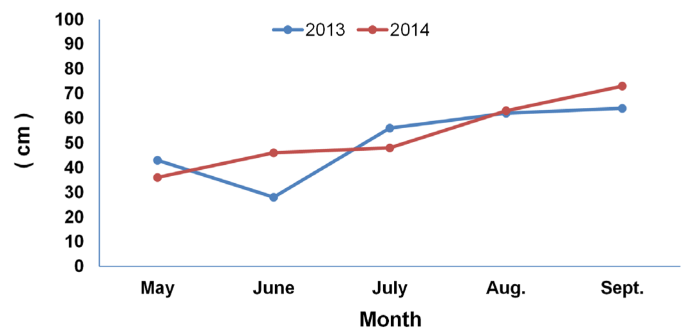

Figure 11. Pond level staff gauge at Snipatuit Pond, Rochester. Staff gauge is located next to fishway. The data indicated decreasing pond water surface elevation with increasing staff gauge height.

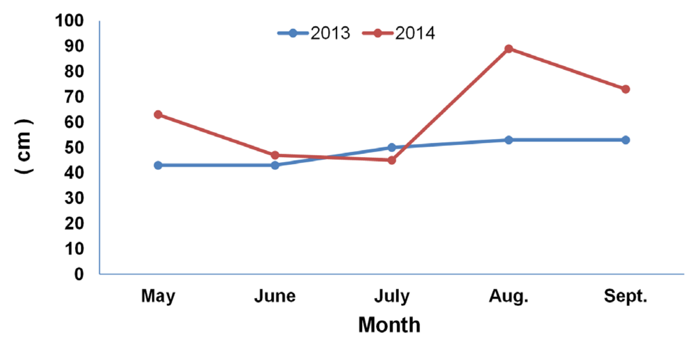

Figure 12. Pond level staff gauge at Tinkham Pond, Mattapoisett. Staff gauge is located at the pond headwall of Tinkham Pond Dam. The data indicated decreasing pond water surface elevation with increasing staff gauge height.

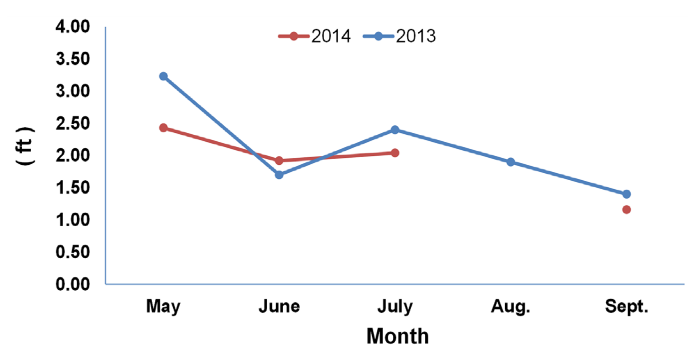

Figure 13. Fishway staff gauge at the Route 6 fishway on the Mattapoisett River. The gauge data reflect the depth of water in the Denil fishway. The target depth range for suitable fish passage during the spring river herring migration is presently considered 2.5 to 3.0 ft.

Spawning Substrate

River herring deposit demersal, adhesive eggs. After one day, the eggs become non-adhesive and hatch in an additional 3 to 4 days. No spawning substrate classification was provided in the QAPP due to the wide variety of substrate used by river herring and the lack of consensus in the scientific literature on optimal or preferred substrate. Instead, the QAPP provides a qualitative protocol for assessing the percent composition of major substrate cover. To date, habitat monitoring during DMF's QAPP assessments supports the view that clean gravel is a better surface for egg survival than fine silt or dense periphyton growth.

Snipatuit Pond. The observations recorded on substrate conditions at Snipatuit Pond were collected at SN-1, 2, 5, and 6. The substrate at SN1 in the northern bay was 100% silt for all observations. Despite a maximum depth of only 1.5 m, there was no light penetration through the highly tannic water, resulting in no plant growth at this station. The station off the Neck Road culvert (SN2) was not a representative station for spawning substrate as it was scoured by culvert flow. Stations SN5 and SN6, located on the south fringe of the pond, had suitable substrate for river herring spawning with a mix of sand, gravel, and vascular plants. Both stations had natural conditions of native plants growing on sand/gravel with low percentages of silt, periphyton, and invasive fanwort. The highest percentage of fanwort (80% substrate coverage – Aug. 2013) was found at the off-transect station SN8 on the west side of Snipatuit Pond. Overall, fanwort and bladderwort had the highest percent occurrence and estimated biomass among vascular plants in Snipatuit Pond.

Tinkham Pond. Tinkham Pond is a flooded stream channel that transitions back to a meandering stream less than 0.5 km upstream of Tinkham Pond Dam. This artificial mill pond status with minor stream flow has caused the substrate to be dominated by dense silt. Station TK1 was the furthest upstream station with 100% silt for all observations. Station TK2 is at the upper pond near the extent of the dam's backwatering effect. This station had 90% silt substrate with minor growth of aquatic moss and lily pads. The other Tinkham Pond stations, TK3 and TK4, were deep enough and highly tannic to make substrate observations challenging. Although substrate was not routinely sampled at those stations, it appeared their status was similar to TK1 and SN1 and substrates consisted of 100% silt with plant growth inhibited by poor light penetration in the highly tannic water.

Additional Water Quality Data

Turbidity. Turbidity in water is caused by suspended inorganic and organic matter. Concentrations of organic material can relate to productivity and high levels of inorganic particulates can threaten aquatic life, especially filter feeders. No *Mass*DEP or US EPA reference conditions are provided for turbidity in lakes and ponds, therefore the QAPP does not have a turbidity criterion. The US EPA turbidity reference condition for rivers in subecoregion #59 is ≤ 1.7 NTU (US EPA 2001).

The average turbidity for all transect stations in Snipatuit Pond was 1.6 NTU (N = 86, SE = 0.130). The average turbidity for all transect stations in Tinkham Pond was 1.1 NTU (N = 62, SE = 0.097). In both ponds, the poor visibility from the tannic water that was reflected in the low Secchi disk depth measurements did not correlate well with the low turbidity values. This may be due to the low presence of particulate matter or phytoplankton that can increase turbidity concentrations. The turbidity sensor does not respond to coloration differences in the water.

Specific Conductivity. Conductivity is proportional to the concentration of major ions in solution. Specific conductivity is a measure of the resistance in a solution to electrical current that has been corrected to the international standard of 25°C. The ionic composition of fresh water is usually dominated by dilute solutions of natural compounds of bicarbonates, carbonates, sulfates, and chlorides. No *Mass*DEP or US EPA reference conditions are provided for conductivity, therefore the QAPP does not have a conductivity criterion. High conductance in fresh water can indicate watershed contributions of natural alkaline compounds or ionic contributions from pollution sources.

Specific conductivity at Snipatuit Pond was low and consistent among stations and depth strata. The mean for all transect measurements was 0.049 mS/cm (N = 90, SE = 0.0003). The specific conductivity at Tinkham Pond was also low and stable (mean = 0.102 mS/cm, N = 68, SE = 0.003) although not to the degree observed at Snipatuit Pond. The specific conductivity measured at Snipatuit Pond was uncommonly low and lacking variability for a large coastal pond in Massachusetts.

Carlson Trophic State Index. The Carlson Trophic State Index (TSI) (Carlson 1977) is a commonly used classification that relates water chemistry indicators associated with algal biomass to an expected range of trophic conditions.

The TSI established relationships for TP, chlorophyll a, and Secchi disk depth with scores ranging from 0 to 100. Scores near zero indicate uncommonly nutrient-poor and low productivity conditions, while scores near 100 indicate extremely degraded and highly productive conditions. The TSIs for these parameters are connected by the concept that increasing nutrients elevate plant productivity and result in reduced water clarity.

The mean Secchi disk measurements for all transect measurements at Snipatuit Pond and Tinkham Pond resulted in TSI scores of 61.5 (Secchi: N = 39; mean = 0.90 m) and 67.8 (Secchi: N = 29; mean = 0.58 m), respectively. The mean TP measurements for all transect measurements at Snipatuit Pond and Tinkham Pond resulted in TSI scores of 58.4 (TP: N = 30; mean = 43.1 ug/L) and 51.2 (TP: N = 10; mean = 26.1 ug/L), respectively.

All these scores are in the index range for eutrophy (Carlson 1977). The index attributes for scores in the 50-60s include anoxic hypolimnia, macrophyte problems, and reduced water clarity. Scores in the 60s can indicate advanced eutrophic symptoms. In the case of these two ponds, the low water clarity may have been more related to tannic water coloration than the density of phytoplankton.

Shallow Off-Transect Stations. Several shallow stations were visited to collect information on habitat quality at different locations in Snipatuit Pond and the Mattapoisett River. Station SN6 was visited on all 10 trips during the assessment but the data were not included in the classification because two other shallow transect stations were selected initially. Station SN7 was located on the east side of Long Pond and visited twice. Station SN8 was located at a west side cove and was visited three times. The water chemistry measured at the three Snipatuit Pond off-transect stations did not vary from that measured at the transect stations. Both SN6 and SN7 were adjacent to unaltered shoreline and had suitable spawning substrate with gravel, sand, and native vascular plants. Only traces of the invasive fanwort were found at these stations. Station SN8 had dense fanwort growth in the shallow cove with silt-dominated substrate.

Station MRF1 was located in the impoundment upstream of the Rt 6 dam and fishway. Water chemistry was measured eight times at MRF1 to determine if differences occurred at this Mattapoisett River location 18 km downstream from Snipatuit Pond. There were no water quality exceedances for temperature and DO at MRF1, and all eight pH measurements were below the 6.5 criterion. The low specific conductivity and acidic pH found at Snipatuit Pond were repeated at MRF1, although at higher mean values: 0.090 uS/cm and 6.04 pH at MRF1 vs. 0.049 uS/cm and 5.74 pH at the Snipatuit Pond transect stations.

QA/QC Summary

Field and laboratory measurements conducted for the habitat assessment are guided by sampling protocols and data quality objectives from the project's QAPP (Chase 2010) that rely on parameter-based precision and accuracy indicators. Data are classified as *Final*, *Conditional*, or *Censored* based on calibration performance, agreement of precision and accuracy checks to QAPP criteria, and the relation of outliers to data distributions. All laboratory calibration and laboratory and field precision checks for 2013–2014 were acceptable. Tinkham Pond did have one turbidity and three DO field precision checks that exceeded low-value exceptions but were accepted due to the fine spatial variability noted in the measurements of this eutrophied pond. Laboratory sonde calibration exceedances in 2014 caused DO data for July and September and turbidity data for June and July to be classified as *Conditional*.

Nutrient QA/QC checks were acceptable for all TN and TP field duplicates and blanks. The average TN duplicate relative percent difference (RPD) was 5.0% and the average TP duplicate was 10.9%. None of the duplicates exceeded 18%, well below the acceptable criteria of <35%. A single TP sample of 368 ug/L from June 2013 in Snipatuit Pond required outlier review. This sample was *Censored* for greatly exceeding the mean of all TP samples by >3 SD with no explanation.

Diadromous Fish Observations

Few direct observations of diadromous fish were made during the 10 assessment trips. Adult river herring were observed at SN2 during both May visits schooling at the fishway exit, in apparent preparation to migrate downstream. Young-of-year river herring were observed at SN2 in June 2014 and a large school of unidentified fry fish was seen at SN8 on the same trip schooling near the surface. Juvenile American eel (glass eels) were observed below the Rt 6 bridge during May each year of the assessment. Illegal poaching of glass eels during their spring migration has been known to occur at this location. Large numbers of glass eels were also seen during May each year climbing the metal bog flume below Tinkham Pond (TK6).

Conclusion

River herring runs have declined in many Massachusetts rivers in the last 30 years. The decline in the Mattapoisett River is particularly concerning as it appears sharper than most other runs in the region and because of the magnitude of the spawning run reduction compared to historical harvests. The river herring habitat assessment conducted during 2013-2014 resulted in *Impaired* classifications for pH, Secchi disk depth, TN, and TP at Snipatuit Pond, the primary spawning and nursery habitat in the Mattapoisett River watershed. Despite these exceedances to DMF's Program QAPP criteria, the water quality conditions were not in a range that would cause obvious population level concerns. Favorably, Snipatuit Pond was found to be *Suitable* for DO, without conditions of anoxia/hypoxia that have been common in the coastal ponds assessed to date. Overall, the 710-acre Snipatuit Pond had water quality conditions that should be supportive of river herring early life stages. Two potential negative influences on population recruitment identified during the assessment were the habitat alteration that comes with the recent proliferation of the invasive fanwort, and the low river flow conditions seen in late summer and early fall that could impact the emigration of juvenile river herring to marine waters.

The impairments found at Snipatuit Pond were also found at Tinkham Pond, a 17-acre tributary headpond with no present passage at the Tripp Mill Dam. However, the degraded conditions of this eutrophied, artificial impoundment were more pronounced than in Snipatuit Pond. Tinkham Pond was also *Impaired* for DO with hypoxia influencing most of the water column. The combination of low outflow, no passage, and poor water quality at Tinkham Pond greatly reduces the potential for river herring restoration in this tributary.

Recommendations

1.) *Mass*DEP *Assessments*. The river herring spawning and nursery habitat assessment data should be provided to *Mass*DEP to support 305(b) reporting, their ongoing watershed assessments, and to assist local water quality remediation.

2.) *Invasive Plant Management*. The proliferation of the invasive fanwort may be having adverse impacts on native species of plants and animals; however, little is known about the long-term ecological effects of invasive plants in the watershed. Related to river herring, there is concern that the shallow fringes typically used for river herring spawning may be negatively altered as coarse substrate is buried by the silt produced during annual decomposition of the dense plant beds. Investigations on the causes and effects of invasive plants on the health of Snipatuit Pond and river herring spawning and nursery habitat that contribute to management actions are needed.

3.) *Nutrient Management*. Elevated concentrations of TN and TP were documented in the habitat assessment. These nutrient levels may be contributing to the high growth of invasive plants in each water body. A multi-jurisdictional effort should be initiated to identify point sources and stormwater sources of nutrient loading and to develop management plans for remediation.

4. *Mattapoisett River flow*. Low flow and drought years have the potential to cause significant impacts to the aquatic health of the Mattapoisett River. It is possible that even average river flows are creating difficult conditions for young-of-year river herring to travel the 18 km of river channel to marine waters. A multi-agency, cooperative review is needed to determine possible impacts to the river from human water supply and farm water withdrawals and what measures can be enacted to mitigate surface flow reductions.

5. *Stream Channel Maintenance*. Given the reduced river flows, there is enhanced potential for the Mattapoisett River channel to become blocked from tree falls, debris jams, and wetland plant overgrowth. The Herring Wardens of the three towns are aware of this issue and are diligent to conduct annual work. Their efforts should be supported with the drafting of a DMF Stream Maintenance Plan and a contribution of labor from a wider source of participants.

6. *Tinkham Pond Restoration*. The lack of passage into Tinkham Pond is one hurdle to be overcome in order to allow river herring access to Tinkham Pond. However, we don't recommend this action given the severe water quality degradation found during the habitat assessment in the pond. The pond is slowly advancing towards later stages of eutrophy. Public restoration funds targeting diadromous fish would be better spent on Snipatuit Pond and the main stem Mattapoisett River.

Acknowledgements

The Mattapoisett River watershed habitat assessment was conducted entirely by DMF staff. The knowledge and advice of Rochester Herring Warden, Dave Watling, contributed to the assessment design and field reconnaissance. All river herring habitat assessments conducted by DMF are supported through staff time and equipment reimbursements from the Sportfish Restoration Act, and through staff time funded by the Massachusetts Saltwater Sportfish License.

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Appendix Tables (A.1 - A.12)

Table A.1. Station locations sampled during the Mattapoisett River watershed habitat assessment, 2013-2104.

No.	Latitude	Longitude	Station Type	Depth Strata	Max. Depth (m)	Sample (No.)	Location
SN1	41.78928	70.86015	transect	Mid	1.5	10	northern pond
SN2	41.78582	70.85882	transect	Shallow	1.4	10	20 m off Neck Rd culvert
SN3	41.77789	70.86072	transect	Mid	1.8	10	northern mid-pond
SN4	41.76927	70.86453	transect	Mid	1.8	10	southern mid-pond
SN5	41.76295	70.86910	transect	Shallow	1	9	50 m off fishway outlet
SN6	41.76431	70.86416	off-transect	Shallow	1.1	7	off kayak launch
SN7	41.76745	70.85842	off-transect	Shallow	1	2	near Long Pond
SN8	41.77254	70.87270	off-transect	Shallow	1.3	2	west side fanwort
MRF1	41.65708	70.83421	outlet	Shallow	*NA*	8	Rt 6 Fishway
TK1	41.68545	70.86280	transect	Shallow	0.8	10	upper stream channel
TK2	41.68443	70.85885	transect	Shallow	1.3	10	stream/pond transition
TK3	41.68326	70.85726	transect	Mid	1.4	10	mid-pond
TK4	41.68198	70.85748	transect	Mid	1.5	10	off pond outlet

Table A.2. Summary water chemistry data collected at station MRF1, Mattapoisett River, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	8	19.90	1.37	19.09	≤26.0 / ≤28.3	100
pH	(SU)	8	6.04	0.11	6.10	≥6.5, ≤8.3	20
DO	(mg/L)	8	8.02	0.48	7.94	≥5.0	100
DO sat.	%	8	87.8	5.00	81.6	NA	
Turbidity	(NTU)	8	1.6	0.20	1.7	NA	
Sp. Cond.	(mS/cm)	8	0.090	0.01	0.089	NA	

Note: Temperature criterion is ≤ 26.0 ˚C for May/June and ≤ 28.3 ˚C for July-September.

Table A.3. Summary water chemistry data collected at station SN1, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.05	1.13	22.16	≤26.0 / ≤28.3	100
pH	(SU)	10	4.59	0.08	4.59	≥6.5, ≤8.3	0
DO	(mg/L)	10	7.44	0.31	7.38	≥5.0	100
DO sat.	%	10	84.71	2.50	85.05	NA	
Turbidity	(NTU)	10	0.1	0.08	0.2	NA	
Sp. Cond.	(mS/cm)	10	0.051	0.00	0.052	NA	
Secchi	(m)	10	0.5	0.45	0.5	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	21.43	1.12	21.78	≤26.0 / ≤28.3	100
pH	(SU)	10	4.62	0.10	4.57	≥6.5, ≤8.3	0
DO	(mg/L)	10	7.05	0.37	6.96	≥5.0	100
DO sat.	%	10	78.79	3.01	78.50	NA	
Turbidity	(NTU)	9	0.2	0.17	0.2	NA	
Sp. Cond.	(mS/cm)	10	0.051	0.00	0.052	NA	

Table A.4. Summary water chemistry data collected at station SN2, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.66	1.24	22.79	≤26.0 / ≤28.3	90
pH	(SU)	10	5.62	0.16	5.60	≥6.5, ≤8.3	0
DO	(mg/L)	10	7.84	0.32	7.80	≥5.0	100
DO sat.	%	10	90.42	2.61	88.35	NA	
Turbidity	(NTU)	10	1.6	0.30	1.7	NA	
Sp. Cond.	(mS/cm)	10	0.048	0.00	0.049	NA	
TN	(mg/L)	10	0.511	0.04	0.500	0.32	0
TP	(ug/L)	10	47.9	4.05	47.7	8.00	0
Secchi	(m)	10	0.8	0.05	0.8	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.06	1.21	22.62	≤26.0 / ≤28.3	100
pH	(SU)	10	5.45	0.19	5.47	≥6.5, ≤8.3	0
DO	(mg/L)	10	7.42	0.34	7.73	≥5.0	100
DO sat.	%	10	84.45	3.24	85.85	NA	
Turbidity	(NTU)	10	1.5	0.34	1.6	NA	
Sp. Cond.	(mS/cm)	10	0.048	0.00	0.049	NA	

Table A.5. Summary water chemistry data collected at station SN3, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.22	1.14	22.96	≤26.0 / ≤28.3	90
pH	(SU)	10	6.32	0.07	6.37	≥6.5, ≤8.3	20
DO	(mg/L)	10	8.55	0.25	8.67	≥5.0	100
DO sat.	%	10	97.68	1.87	97.65	NA	
Turbidity	(NTU)	10	2.4	0.33	2.4	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.050	NA	
TN	(mg/L)	10	0.396	0.04	0.387	0.32	50
TP	(ug/L)	10	43.7	3.34	47.1	8.00	0
Secchi	(m)	10	1.1	0.06	1.2	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	21.76	1.07	22.74	≤26.0 / ≤28.3	100
pH	(SU)	10	6.29	0.07	6.33	≥6.5, ≤8.3	20
DO	(mg/L)	10	8.40	0.27	8.48	≥5.0	100
DO sat.	%	10	95.20	2.05	96.20	NA	
Turbidity	(NTU)	10	2.4	0.31	2.4	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.050	NA	

Table A.6. Summary water chemistry data collected at station SN4, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.58	1.22	23.04	≤26.0 / ≤28.3	90
pH	(SU)	10	6.27	0.08	6.29	≥6.5, ≤8.3	20
DO	(mg/L)	10	8.68	0.25	8.75	≥5.0	100
DO sat.	%	10	99.98	1.88	99.95	NA	
Turbidity	(NTU)	10	2.1	0.30	2.1	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.049	NA	
Secchi	(m)	9	1.2	0.05	1.2	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	21.62	1.14	22.54	≤26.0 / ≤28.3	100
pH	(SU)	10	6.18	0.09	6.20	≥6.5, ≤8.3	20
DO	(mg/L)	10	8.49	0.38	8.49	≥5.0	100
DO sat.	%	10	95.95	3.29	96.15	NA	
Turbidity	(NTU)	7	2.3	0.31	2.0	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.049	NA	

Table A.7. Summary water chemistry data collected at station SN5, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	22.47	1.33	22.99	≤26.0 / ≤28.3	90
pH	(SU)	10	6.31	0.06	6.34	≥6.5, ≤8.3	30
DO	(mg/L)	9	8.95	0.27	9.29	≥5.0	100
DO sat.	%	9	102.2	2.02	100.2	NA	
Turbidity	(NTU)	10	1.8	0.33	1.8	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.050	NA	
TN	(mg/L)	10	0.401	0.03	0.449	0.32	10
TP	(ug/L)	9	37.01	1.68	36.2	8.00	20

Table A.8. Summary water chemistry data collected at station SN6, Snipatuit Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	23.31	1.41	24.12	≤26.0 / ≤28.3	90
pH	(SU)	10	6.28	0.08	6.33	≥6.5, ≤8.3	20
DO	(mg/L)	9	8.71	0.30	8.59	≥5.0	100
DO sat.	%	9	101.0	2.92	101.9	NA	
Turbidity	(NTU)	10	2.2	0.40	2.0	NA	
Sp. Cond.	(mS/cm)	10	0.049	0.00	0.049	NA	

Table A.9. Summary water chemistry data collected at station TK1, Tinkham Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	18.60	0.92	19.50	≤26.0 / ≤28.3	100
pH	(SU)	10	5.81	0.07	5.80	≥6.5, ≤8.3	10
DO	(mg/L)	10	5.69	0.75	5.42	≥5.0	50
DO sat.	%	10	60.6	7.66	56.5	NA	
Turbidity	(NTU)	10	1.4	0.29	1.1	NA	
Sp. Cond.	(mS/cm)	10	0.127	0.01	0.119	NA	

Table A.10. Summary water chemistry data collected at station TK2, Tinkham Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	21.49	0.92	21.33	≤26.0 / ≤28.3	100
pH	(SU)	10	5.75	0.06	5.76	≥6.5, ≤8.3	0
DO	(mg/L)	10	3.84	0.87	2.96	≥5.0	20
DO sat.	%	10	42.3	9.2	32.9	NA	
Turbidity	(NTU)	10	0.68	0.07	0.70	NA	
Sp. Cond.	(mS/cm)	10	0.10	0.007	0.093	NA	0
Secchi	(m)	10	0.6	0.03	0.6	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	9	18.21	0.85	18.83	≤26.0 / ≤28.3	100
pH	(SU)	9	5.59	0.07	5.60	≥6.5, ≤8.3	10
DO	(mg/L)	9	2.48	0.92	0.89	≥5.0	30
DO sat.	%	9	25.3	9.28	9.7	NA	
Turbidity	(NTU)	8	1.4	0.31	1.1	NA	
Sp. Cond.	(mS/cm)	9	0.103	0.01	0.102	NA	

Table A.11. Summary water chemistry data collected at station TK3, Tinkham Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	21.59	1.09	20.86	≤26.0 / ≤28.3	90
pH	(SU)	10	5.80	0.07	5.77	≥6.5, ≤8.3	10
DO	(mg/L)	10	4.47	0.86	4.49	≥5.0	40
DO sat.	%	10	49.72	9.18	49.75	NA	
Turbidity	(NTU)	10	0.5	0.08	0.5	NA	
Sp. Cond.	(mS/cm)	10	0.096	0.01	0.093	NA	
Secchi	(m)	9	0.6	0.03	0.6	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	9	17.34	0.73	17.68	≤26.0 / ≤28.3	100
pH	(SU)	9	5.53	0.09	5.57	≥6.5, ≤8.3	10
DO	(mg/L)	9	1.94	0.79	0.42	≥5.0	30
DO sat.	%	9	19.7	7.83	4.9	NA	
Turbidity	(NTU)	7	1.7	0.29	1.3	NA	
Sp. Cond.	(mS/cm)	9	0.097	0.01	0.098	NA	

Table A.12. Summary water chemistry data collected at station TK4, Tinkham Pond, 2013-2104.

Surface (0.3 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	20.60	1.08	21.07	≤26.0 / ≤28.3	100
pH	(SU)	10	5.75	0.05	5.73	≥6.5, ≤8.3	10
DO	(mg/L)	10	4.07	0.93	3.27	≥5.0	40
DO sat.	%	10	43.8	9.72	35.1	NA	
Turbidity	(NTU)	10	0.6	0.07	0.7	NA	
Sp. Cond.	(mS/cm)	10	0.096	0.01	0.093	NA	
TP	(ug/L)	10	26.13	2.98	22.0	8.00	0
TN	(mg/L)	10	0.730	0.04	0.718	0.32	0
Secchi	(m)	10	0.6	0.02	0.6	≥2.0	0

Bottom-water (1.0 m average sample depth)

Parameter	Unit	N	Mean	SE	Median	WQ Criterion	Meeting Criterion (%)
Temp.	(°C)	10	17.31	0.69	17.25	≤26.0 / ≤28.3	100
pH	(SU)	10	5.61	0.07	5.60	≥6.5, ≤8.3	0
DO	(mg/L)	10	2.45	0.77	1.53	≥5.0	20
DO sat.	%	10	24.7	7.65	15.4	NA	
Turbidity	(NTU)	7	1.6	0.32	1.6	NA	
Sp. Cond.	(mS/cm)	10	0.099	0.01	0.095	NA	