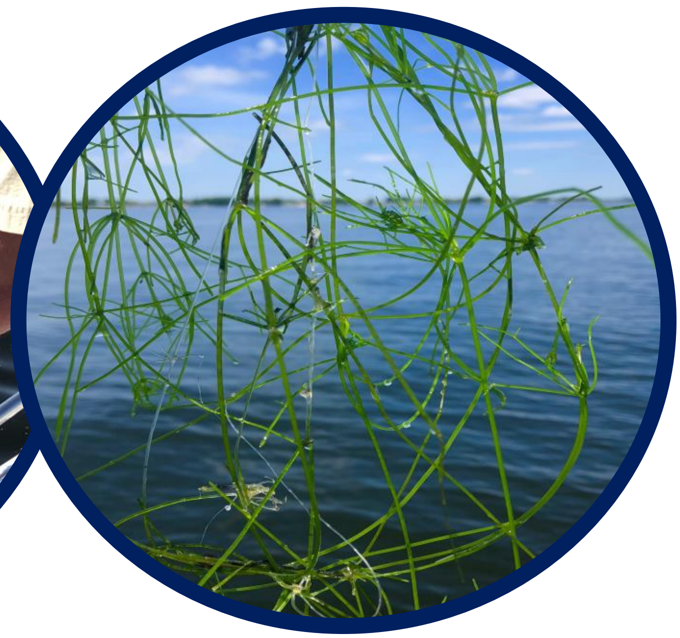
Houghton Lake 2019 Aquatic Vegetation, Water Quality, and 2020 Management Recommendations Annual Report



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Houghton Lake 2019 Aquatic Vegetation, Water Quality, and 2020 Management Recommendations Annual Report

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1

Houghton Lake 2019 Aquatic Vegetation, Water Quality, and 2020 Management Recommendations Annual Report

The following Houghton Lake report is a summary of key lake findings collected in 2019.

The overall condition of Houghton Lake has been improving over the past few years due to rigorous aquatic vegetation surveys and selective spot-treatments to control invasive aquatic plant species such as hybrid Eurasian Watermilfoil (EWM), and Starry Stonewort. Both of these species are declining in Houghton Lake and providing space for the 27 native aquatic plant species that are so important to the ecological balance of Houghton Lake.

The water quality of Houghton Lake and the canals continues to be at or below the eutrophic threshold relative to nutrients. The dissolved oxygen is abundant the pH is ideal for an inland lake. The specific conductivity is moderate and favorable. The water clarity is fair to good and the algal communities are diverse and a good source of primary productivity for the fishery. The sediment macroinvertebrate community is also showing some improvements relative to taxa and relative abundance and this may change annually.

RLS recommends continued intense aquatic vegetation community surveys of the entire lake and canals and spot-treatments as needed for management of invasive species only. The recent ProcellaCOR® herbicide treatments in 2018-2019 have proven to be very effective with reducing the density and abundance of milfoil. There were also numerous locations of Wild Rice found in the North Bay, Middle Grounds, and Muddy Bay during the 2019 whole-lake survey. Protection of this emergent plant is critical to the lake and migratory wildlife as well as the lake fishery.

Section

2

Houghton Lake Water Quality Data (2019)

Water Quality Parameters Measured

There are numerous water quality parameters that can be measured on an inland lake, but several are the most critical indicators of lake health. The parameters measured in Houghton Lake in 2019 and in previous years included: water temperature (measured in °C or °F), dissolved oxygen (measured in mg/L), pH (measured in standard units-SU), conductivity (measured in micro-Siemens per centimeter-µS/cm), total alkalinity or hardness (measured in mg of calcium carbonate per liter-mg $CaCO_3$/L), total dissolved solids (mg/L), secchi transparency (feet), total phosphorus, ortho-phosphorus, and total Kjeldahl nitrogen (all in mg/L), chlorophyll-*a* (in µg/L), and algal community composition. Graphs that show trends for some parameters of each year are displayed below. Water quality was measured in the deep basins of Houghton Lake in late-summer/fall of 2019 (Figure 1). Additional water quality samples were collected in the tributaries (Figure 2) and in the canals (Figure 3).

Trend data was calculated using mean values of each parameter over the sampling locations. Table 1 below demonstrates how lakes are classified based on key parameters. Houghton Lake would be considered meso-eutrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth but has good water clarity and moderately low planktonic algal growth. General water quality classification criteria are defined in Table 1. 2019 water quality data for Houghton Lake are shown below in Tables 2-7. Water quality data for the tributaries and canals are shown in Tables 8-12.

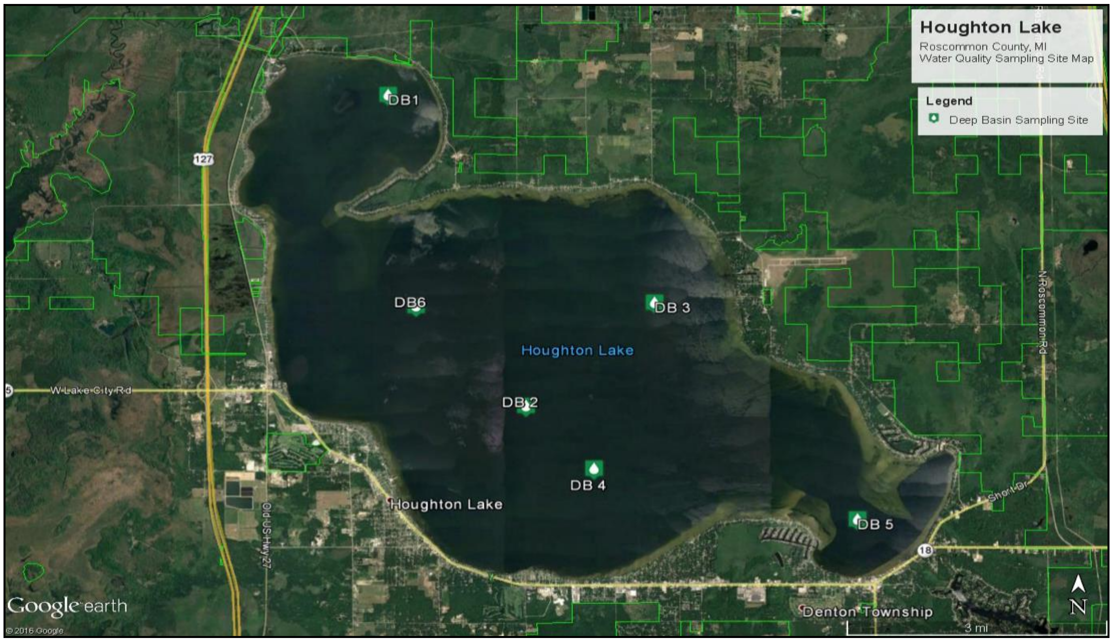

Figure 1. Deep basin water quality sampling locations in Houghton Lake (2016-2019).

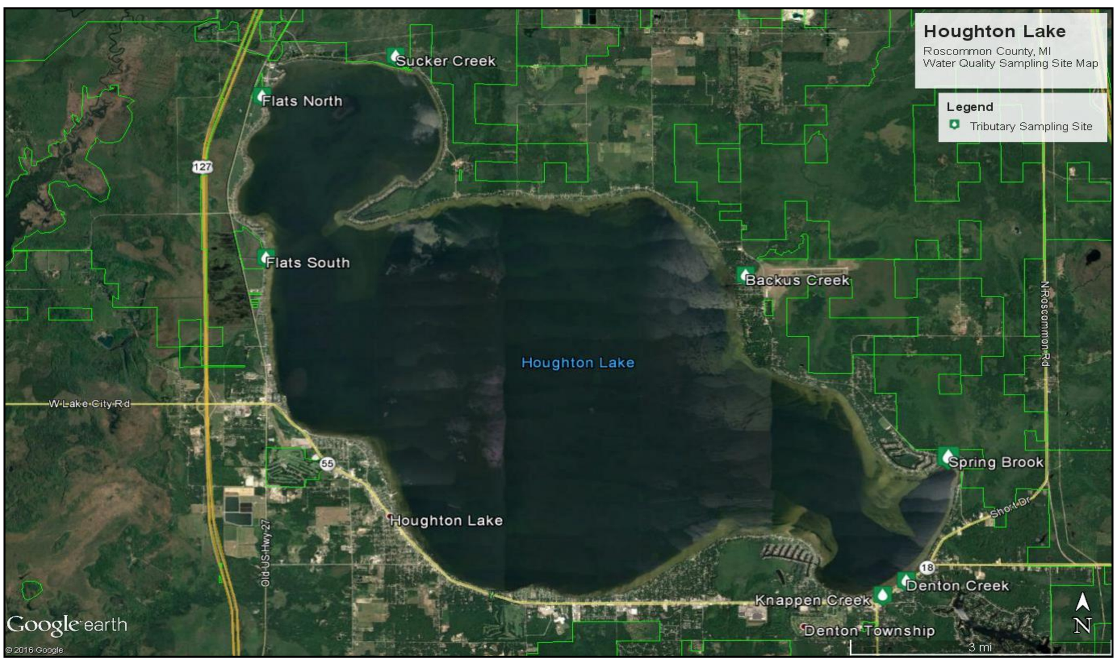

Figure 2. Tributary water quality sampling locations around Houghton Lake (2016-2019).

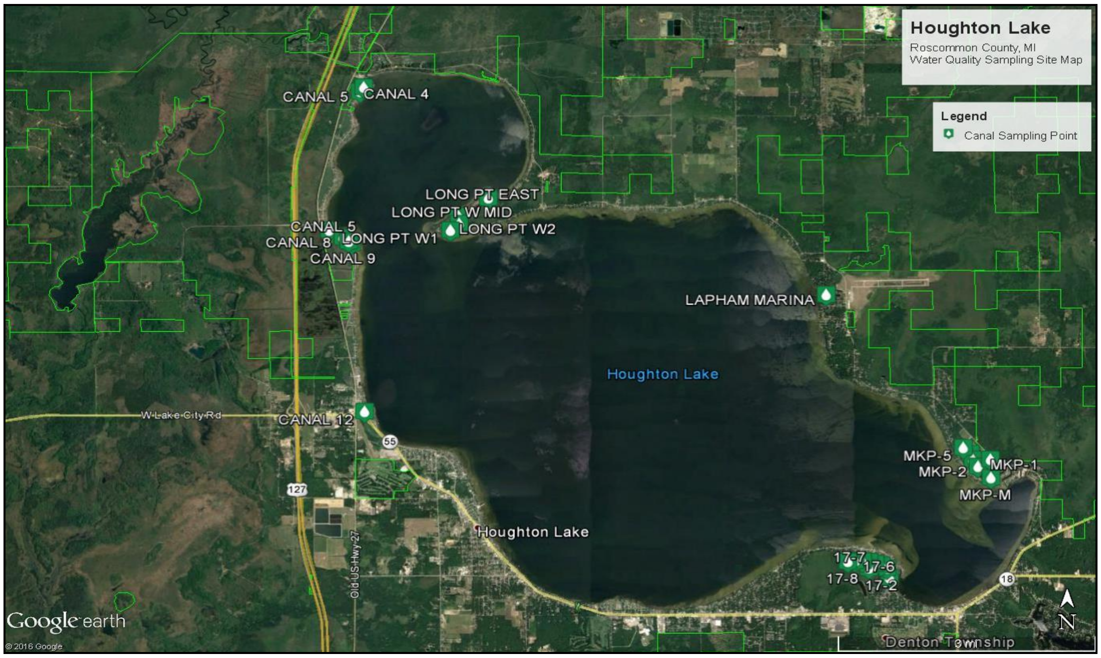

Figure 3. Houghton Lake canals water quality sampling locations (2016-2019).

Table 1. Lake trophic classification (MDNR).

Lake Trophic Status	*Total Phosphorus ($\mu g\ L^{-1}$)*	*Chlorophyll-a ($\mu g\ L^{-1}$)*	*Secchi Transparency (feet)*
Oligotrophic	**< 10.0**	**< 2.2**	**> 15.0**
Mesotrophic	**10.0 – 20.0**	**2.2 – 6.0**	**7.5 – 15.0**
Eutrophic	**> 20.0**	**> 6.0**	**< 7.5**

Houghton Lake Deep Basin Water Quality Data Tables:

Table 2. Houghton Lake water quality parameter data collected in deep basin #1 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	**7.8**	**11.4**	**8.0**	**217**	**1.6**	**139**	**0.016**	**<0.010**	**0.6**
2.5	**7.4**	**11.5**	**8.0**	**217**	**1.6**	**139**	**0.016**	**<0.010**	**0.6**
5.0	**7.4**	**11.4**	**8.0**	**217**	**1.6**	**139**	**0.016**	**<0.010**	**0.6**

Table 3. Houghton Lake water quality parameter data collected in deep basin #2 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	**7.9**	**11.2**	**8.5**	**223**	**1.3**	**142**	**0.021**	**<0.010**	**1.0**
8.0	**7.9**	**11.0**	**8.4**	**223**	**1.6**	**142**	**0.021**	**<0.000**	**1.0**
16.0	**7.8**	**11.0**	**8.3**	**222**	**1.6**	**142**	**0.021**	**<0.010**	**1.0**

Table 4. Houghton Lake water quality parameter data collected in deep basin #3 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	**8.8**	**11.0**	**8.4**	**221**	**1.0**	**142**	**0.025**	**<0.010**	**0.8**
8.0	**8.3**	**10.8**	**8.3**	**221**	**1.5**	**142**	**0.025**	**<0.000**	**0.8**
16.0	**8.2**	**10.8**	**8.3**	**221**	**1.9**	**142**	**0.025**	**<0.010**	**0.8**

Table 5. Houghton Lake water quality parameter data collected in deep basin #4 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	8.1	10.8	8.5	222	0.4	142	0.015	<0.010	0.8
10.0	8.0	10.8	8.4	222	1.2	142	0.023	<0.000	0.7
20.0	7.8	11.0	8.4	222	1.9	142	0.019	<0.010	1.0

Table 6. Houghton Lake water quality parameter data collected in deep basin #5 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	8.3	11.5	8.4	222	0.4	142	0.012	<0.010	0.7
10.0	8.1	10.9	8.3	222	1.0	142	0.012	<0.000	0.7
20.0	8.0	10.9	8.3	222	2.4	142	0.010	<0.010	0.7

Table 7. Houghton Lake water quality parameter data collected in deep basin #6 on October 18, 2019.

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Ortho-P mg L^{-1}*	*TKN mg L^{-1}*
0	8.4	10.8	8.3	223	0.7	143	0.015	<0.010	0.7
6.0	8.3	10.7	8.3	222	0.9	142	0.016	<0.000	0.7
12.0	8.2	10.6	8.3	222	1.6	142	0.016	<0.010	0.7

Houghton Lake Canal Water Quality Data Tables:

Table 8. Houghton Lake water quality parameter data collected in the Chippewa canals on October 18, 2019. Note: All samples were collected at a mid-depth of 3.0 feet. Site CM refers to the middle of the canal series.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
C1	8.3	8.6	7.6	548	2.2	350	0.031
C2	8.3	8.1	7.7	548	1.3	350	0.030
C3	8.2	8.2	7.6	544	1.8	348	0.031
C4	8.1	8.0	7.6	547	1.7	348	0.031
C5	8.1	8.1	7.9	544	2.0	348	0.040
C6	8.3	8.0	7.8	544	1.6	348	0.040
C7	8.3	7.8	7.9	543	1.9	349	0.030
C8	8.1	7.5	8.0	544	2.0	351	0.030
CM	8.2	8.1	7.6	544	1.7	350	0.030

Table 9. Houghton Lake water quality parameter data collected in the McKinley Park (MPK) canals on October 18, 2019. Note: All samples were collected at mid-depth of 3.0 feet. Site MPK M refers to the middle of the canal series.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
MPK 1	**9.3**	**9.9**	**8.3**	**337**	**2.1**	**216**	**0.020**
MPK 2	**9.3**	**9.5**	**8.3**	**337**	**2.3**	**216**	**0.021**
MPK 3	**9.1**	**9.5**	**8.3**	**337**	**1.8**	**216**	**0.021**
MPK 4	**9.1**	**9.7**	**8.1**	**337**	**1.9**	**217**	**0.020**
MPK 5	**9.1**	**9.4**	**8.4**	**336**	**2.1**	**216**	**0.020**
MPK M	**9.3**	**9.7**	**8.4**	**336**	**2.7**	**216**	**0.020**

Table 10. Houghton Lake water quality parameter data collected in the Lapham and Long Point canals on October 18, 2019. Note: All samples were collected at mid-depth of 3.0 feet.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
LAPHAM	**9.2**	**10.2**	**8.3**	**320**	**1.7**	**211**	**0.010**
L POINT MID	**9.2**	**10.0**	**8.3**	**320**	**1.4**	**211**	**0.010**
L POINT W1	**9.0**	**9.9**	**8.4**	**320**	**1.8**	**216**	**0.010**
L POINT W2	**9.2**	**10.2**	**8.4**	**326**	**1.2**	**213**	**0.015**
L POINT E	**9.0**	**10.4**	**8.4**	**331**	**1.9**	**213**	**0.012**

Table 11. Houghton Lake water quality parameter data collected in the canals north and west of Long Point canals #4-12 on October 18, 2019. Note: All samples were collected at mid-depth of 3.0 feet.

Canal Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*
CANAL 4	8.9	8.9	8.3	279	1.7	192	<0.020
CANAL 5	8.8	9.7	8.3	279	1.3	194	<0.020
CANAL 6	8.9	10.2	8.1	276	1.7	193	<0.020
CANAL 8	9.1	9.9	8.1	282	1.9	193	0.020
CANAL 9	9.1	10.1	7.9	284	1.4	195	<0.010
CANAL 10	9.1	9.8	8.2	277	1.1	189	<0.020
CANAL 12	9.0	9.9	8.4	279	1.9	189	<0.020

Houghton Lake Tributary Water Quality Data Table:

Table 12. Houghton Lake water quality parameter data collected in the tributaries and flats on October 18, 2019.

Trib Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. mS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TSS mg L^{-1}*	*TP mg L^{-1}*	*TKN mg L^{-1}*
DENTON CRK	10.2	10.5	8.4	213	1.4	136	<10	0.031	0.8
SPRING BROOK	10.5	10.2	8.4	226	1.9	143	<10	0.015	<0.50
BACKUS CRK	9.8	10.6	8.4	262	1.6	152	<10	0.010	<0.50
FLATS N	8.4	8.6	8.3	460	2.2	296	<10	0.033	1.0
FLATS S	14.0	9.4	8.3	232	2.5	147	<10	0.041	1.1
SUCKER CRK	7.2	8.0	8.4	126	1.6	79	<10	0.027	1.2
KNAPPEN CRK	7.5	11.5	8.4	128	1.9	200	20	0.014	0.5

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen was measured in milligrams per liter (mg L^{-1}) with the use of a calibrated Eureka Manta II® dissolved oxygen meter. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. Dissolved oxygen concentrations during the October 18, 2019 sampling event averaged 11.0 mg L^{-1}. All of these concentrations are likely higher due to cooler water temperatures in fall which hold more oxygen. Figure 4 below shows the changes in mean DO with time in Houghton Lake.

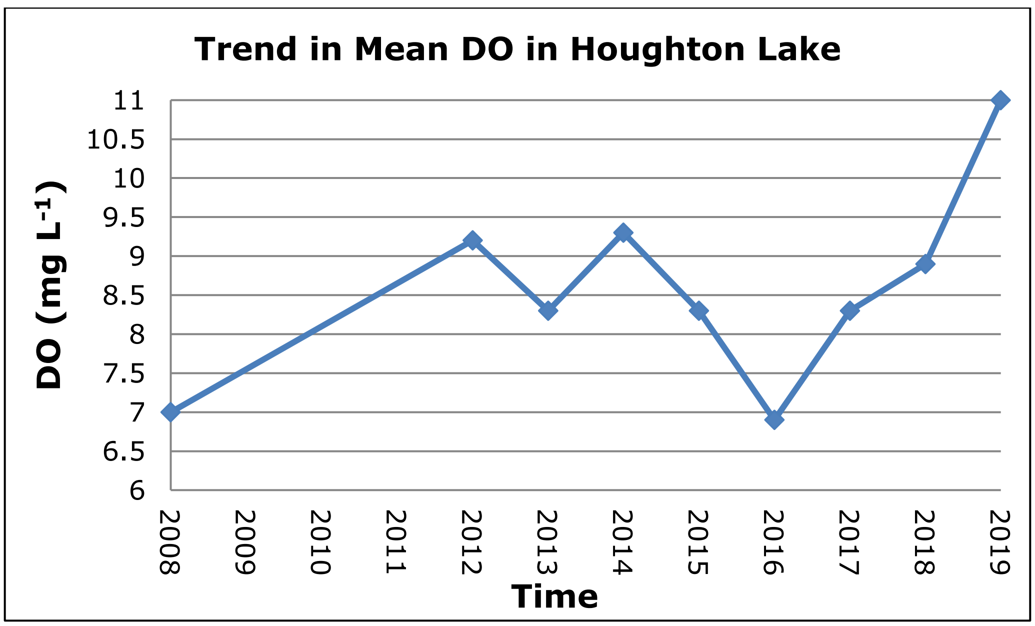

Figure 4. Changes in mean DO with time in Houghton Lake.

Water Clarity (Transparency)

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Houghton Lake was adequate in mid-October of 2019 (mean of 5.8 feet; Figure 5) to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake. Secchi transparency is variable and depends on the number of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement. Other parameters such as turbidity (measured in NTU's) and Total Dissolved Solids (measured in mg/L) are correlated with water clarity and show an increase as clarity decreases.

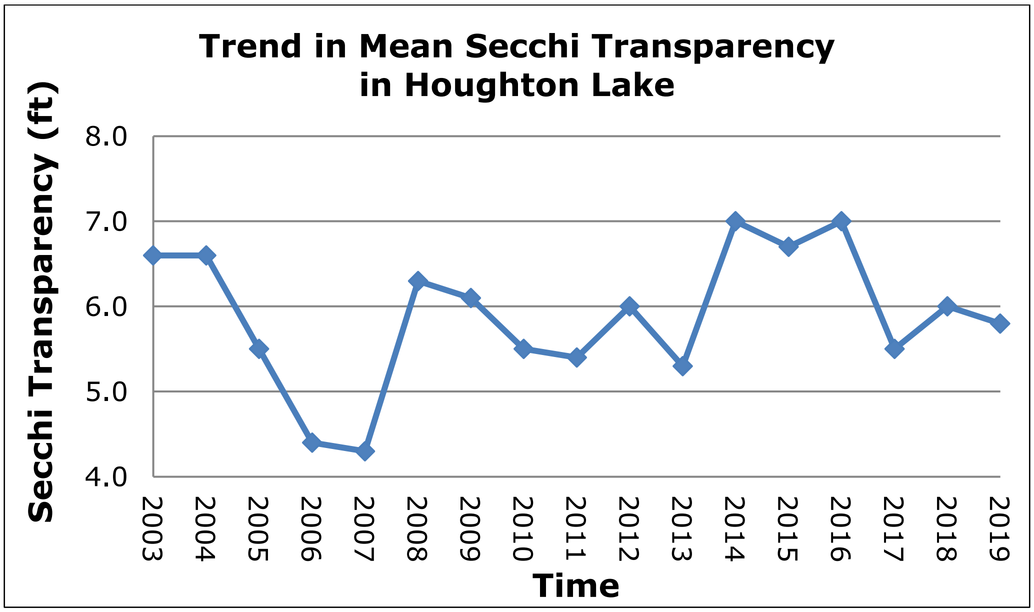

Figure 5. Changes in mean Secchi Transparency with time in Houghton Lake.

Total Phosphorus & Ortho-Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP concentrations are usually higher at increased depths due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Fortunately, even though the TP levels in Houghton Lake are moderate, the dissolved oxygen levels are high enough at the bottom to not result in the release of phosphorus from the bottom. The mean TP concentration in mid-October 2019 was 0.018 mg L^{-1} (Figure 6), which is favorable and below the eutrophic threshold. Ortho-phosphorus or "soluble reactive phosphorus" refers to the proportion of phosphorus that is bioavailable to aquatic life. Higher concentrations of ortho-phosphorus concentrations in the lake result in increased uptake of the nutrient by aquatic plants and algae. The ortho-phosphorus concentrations in the deep basins of Houghton Lake were all ≤ 0.010 mg L^{-1}, which were quite low. The mean TP in the canals was higher at 0.023 mg L^{-1}. The mean TP in the tributaries was even higher at 0.024 mg L^{-1}.

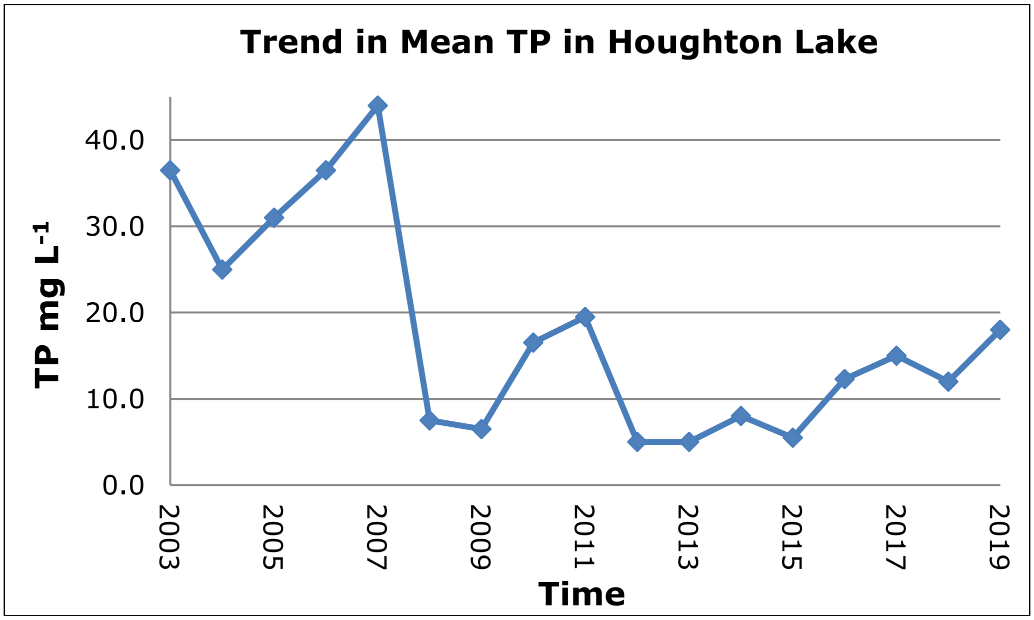

Figure 6. Changes in mean TP with time in Houghton Lake.

Total Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning of fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through ground or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic. The mean TKN concentration in Houghton Lake in mid-October of 2019 averaged 0.8 mg L^{-1}, which is moderately low for an inland lake. The TKN in the tributaries ranged from <0.5-1.2 mg L^{-1}.

Total Alkalinity

Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" water. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water. The alkalinity of Houghton Lake was moderately low in mid-October of 2019 (mean of 86 mg L^{-1} of $CaCO_3$) and indicates a slightly soft-water lake.

Turbidity, Total Dissolved & Suspended Solids

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, storm water discharge, urban runoff, re-suspension of bottom sediments, and in smaller lakes by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity is measured in Nephelometric Turbidity Units (NTU's) with the use of a turbidimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that.

The turbidity of Houghton Lake was quite low and was ≤2.4 NTU's during the sampling event. Spring values may be higher due to increased watershed inputs from spring runoff and/or from increased algal blooms in the water column from resultant runoff contributions. The turbidity of the canals was ≤2.7 NTU's and is favorable due to less wind and sediment re-suspension. The turbidity of the tributaries was ≤2.5 NTU's which is favorable.

Total dissolved solids (TDS) is a measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. TDS was measured with the use of a calibrated Eureka Manta II® TDS probe in mg L^{-1}. Spring values may be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS in Houghton Lake was ≤143 mg L^{-1} for the deep basins in mid-October of 2019, which is moderate for an inland lake.

The preferred range for TDS in surface waters is between 0-1,000 mg L^{-1} but the lower values are most favorable. The TDS in the canals was ≤351 mg L^{-1} which is higher than the lake and likely due to the presence of tannins from the forests and wetlands near the canals and increased rainfall and runoff in 2019. The TDS of the tributaries was ≤296 mg L^{-1} which is similar to the canals for the same reason.

Total Suspended Solids

Total suspended solids (TSS) refers to the quantity of solid particles detected in the water that reduce light penetration and create turbidity in the water. The TSS samples measured in the Houghton Lake tributaries ranged from ≤10-20 mg L^{-1}, which is low and favorable. The Knappen Creek had the highest concentration, but this was still favorable. The ideal concentration for TSS in inland lakes and streams is ≤ 20 mg L^{-1}.

pH

Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). Houghton Lake is considered “slightly basic” on the pH scale. The pH of Houghton Lake averaged 8.3 S.U. (Figure 7) in mid-October of 2019 which is ideal for an inland lake. The pH of the canals ranged from 7.6-8.4 S.U. and the pH of the tributaries ranged from 8.3-8.4 S.U. All of these values are normal and favorable for aquatic environments.

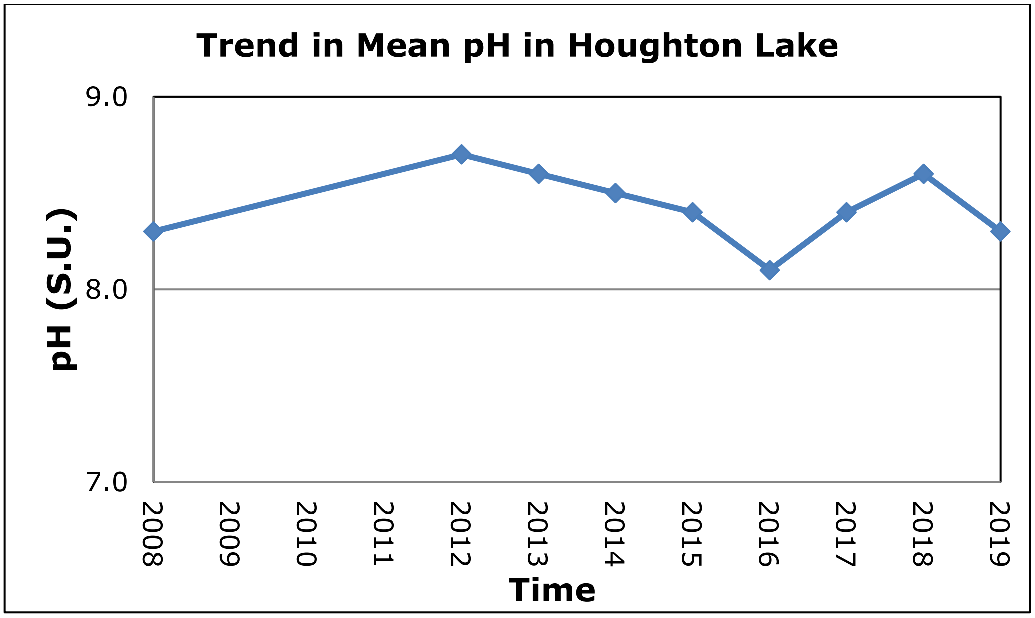

Figure 7. Changes in mean pH with time in Houghton Lake.

Conductivity

Conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances and was measured with a calibrated Eureka Manta II® probe. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The conductivity in Houghton Lake ranged from 217-223 µS/cm in mid-October of 2019. The conductivity of the canals ranged from 276-548 µS/cm and the conductivity in the tributaries ranged from 126-460 µS/cm. Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.

Chlorophyll-*a* and Algal Species Composition

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L are found in nutrient-poor or oligotrophic lakes. The mean chlorophyll-*a* concentration measured in mid-October of 2019 (Figure 8) was 2.0 µg L^{-1}.

The algal genera were determined from composite water samples collected over the deep basins of Houghton Lake in 2019 were analyzed with a compound Zeiss® bright field microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Mougeotia* sp., *Cladophora* sp., *Scenedesmus* sp., *Spirogyra* sp., *Haematococcus* sp., *Radiococcus* sp., *Gleocystis* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): *Oscillatoria* sp., and the Bascillariophyta (diatoms): *Navicula* sp., *Fragillaria* sp., *Cymbella* sp., *Synedra* sp., *Navicula* sp., and *Tabellaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of algae with an abundance of diatoms that are indicative of great water quality.

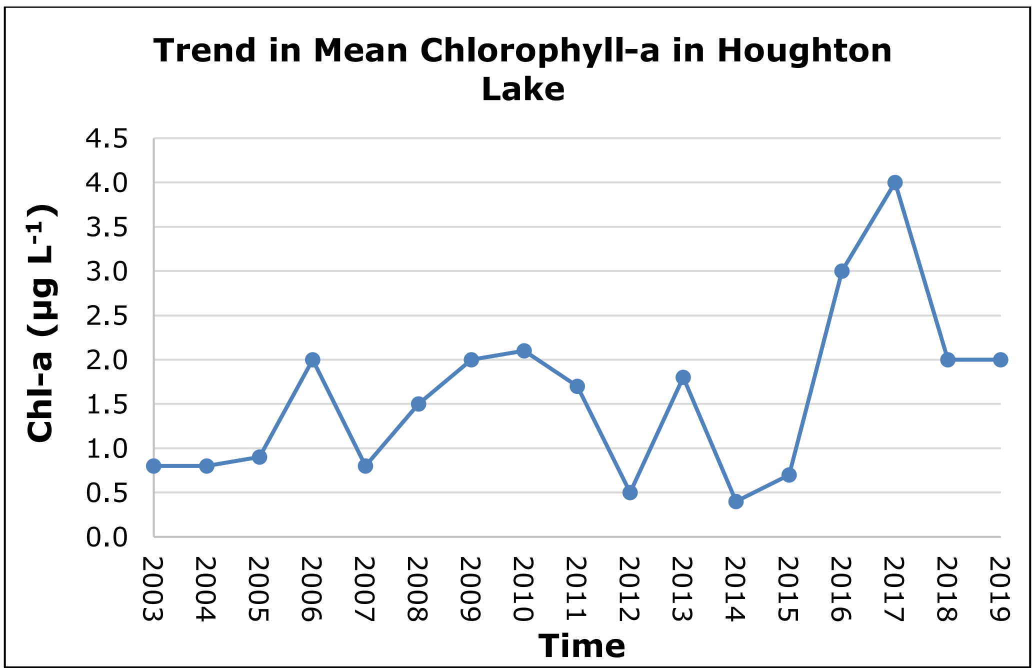

Figure 8. Changes in mean chl-*a* with time in Houghton Lake.

Section

3

Aquatic Vegetation Data (2019)

Status of Native Aquatic Vegetation in Houghton Lake

The native aquatic vegetation present in Houghton Lake is essential for the overall health of the lake and the support of the lake fishery. The June/July 2019 whole-lake survey using the GPS Point-Intercept method as in Figure 9 below determined that there were a total of 27 native aquatic plant species in Houghton Lake. These included 18 submersed species, 3 floating-leaved species, and 6 emergent species. This indicates a very high biodiversity of aquatic vegetation in Houghton Lake that may change each year due to climate and germination conditions. The overall % cover of the lake by native aquatic plants is low relative to the lake size due to the great mean depth and thus these plants should be protected. A list of all current aquatic plant species and their % cover before and after the ProcellaCOR® treatment in Middle Grounds is shown below in Table 13. The aquatic plant species found in the main open waters of the lake (excluding Middle Grounds) is shown below in Table 14. Aquatic vegetation biovolume is displayed in Figure 10 below.

The EWM was significantly reduced in the Middle Grounds after the ProcellaCOR® treatment and this number could continue to decline after another survey is conducted in 2020 since many plants treated in June/July need more time for evaluation of death beyond a 3-4 month period which was observed in October, 2019. The ProcellaCOR® has resulted in an increase in fish cover species such as pondweeds and Elodea which continue to occupy the niche once taken by EWM. In addition, the Wild Rice population in the Middle Grounds is showing signs of improvement relative to re-colonization and has not been negatively impacted by the herbicide treatments in the Middle Grounds.

The open waters of the lake are also quite diverse but have much less relative abundance than Middle Grounds. The most vegetated areas of open water in the lake include the southwest corner and Muddy Bay with some areas of density in North Bay. RLS will re-evaluate North Bay in 2020 to determine if native aquatic plant species are occupying the area once colonized by EWM.

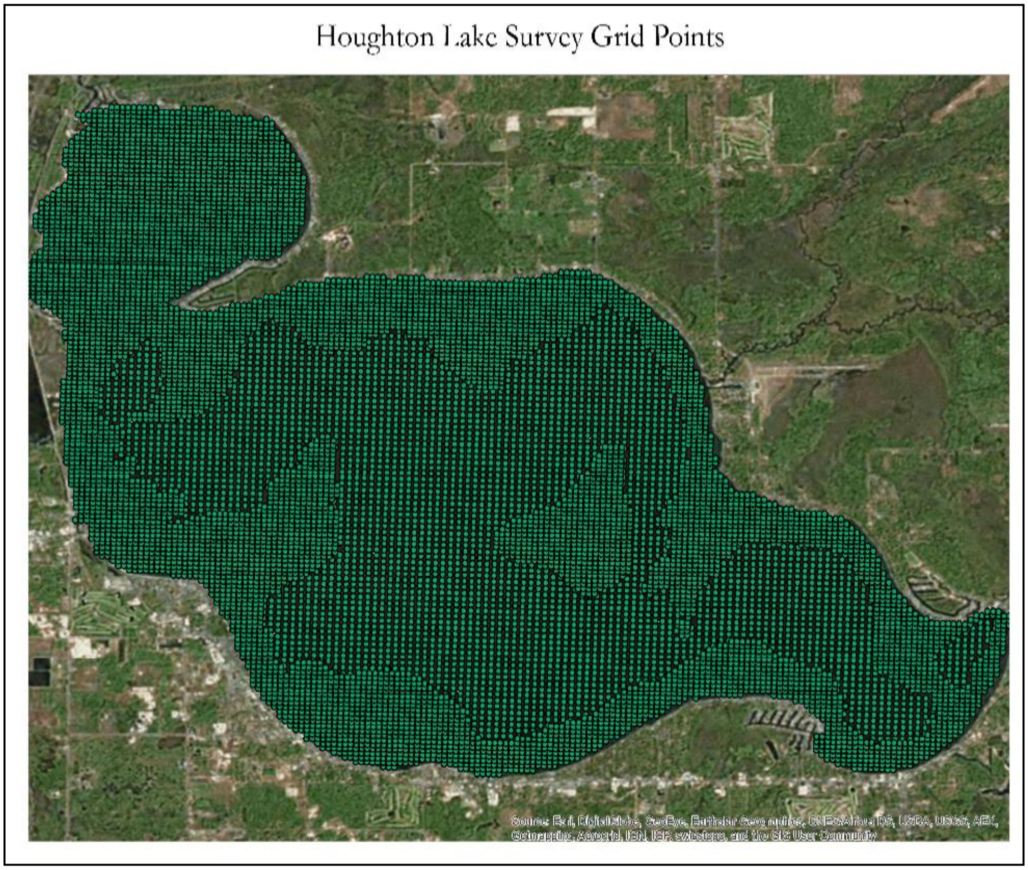

Figure 9. GPS Sampling Points in Houghton Lake (RLS).

Table 13. Changes in relative abundance (frequency) of native and invasive aquatic plants in the Middle Grounds before and after ProcellaCOR® herbicide treatment in 2019.

Aquatic Plant Species	June 2019 (Pre-ProcellaCOR®)	October 2019 (Post-ProcellaCOR®)
Hybrid EWM	45.3	17.2
Curly-leaf Pondweed	6.9	2.0
Chara	35.2	70.7
Thin-leaf Pondweed	0	0.5
Flat-stem Pondweed	0.5	0
White-stem Pondweed	3.9	11.8
Clasping-leaf Pondweed	0.2	0
Large-leaf Pondweed	0.2	0
Wild Celery	27.6	27.6
Coontail	1.7	2.7
Elodea	17.2	49.5
Slender Naiad	30.3	25.1
Starry Stonewort	6.4	7.4
Wild Rice	2.2	2.2

Table 14. Aquatic plant species relative abundance (frequency) in the main portion of the lake (open water that did not include Middle Grounds or canals; July 15-20, 2019).

Aquatic Plant Species	Main Lake Frequency	Aquatic Plant Species	Main Lake Frequency
Hybrid EWM	2.1	Bladderwort	0.03
Curly-leaf Pondweed	0.1	Slender Naiad	4.2
Chara	10.7	Sago Pondweed	0.2
Thin-leaf Pondweed	0.03	Starry Stonewort	2.9
Water Stargrass	0.03	Variable-leaf Pondweed	0.2
Flat-stem Pondweed	0.03	White Waterlily	0.03
White-stem Pondweed	3.6	Yellow Waterlily	0.04
Clasping-leaf Pondweed	0.8	Duckweed	0.03
Fern-leaf Pondweed	0.03	Bulrushes	0.08
Illinois Pondweed	0.3	Cattails	0.03
Large-leaf Pondweed	0.5	Pickerelweed	0.03
American Pondweed	0.03	Arrowhead	0.03
Floating-leaf Pondweed	0.03	Wild Rice	0.01
Wild Celery	0.3	Iris	0.03
Coontail	0.03		
Elodea	1.2		

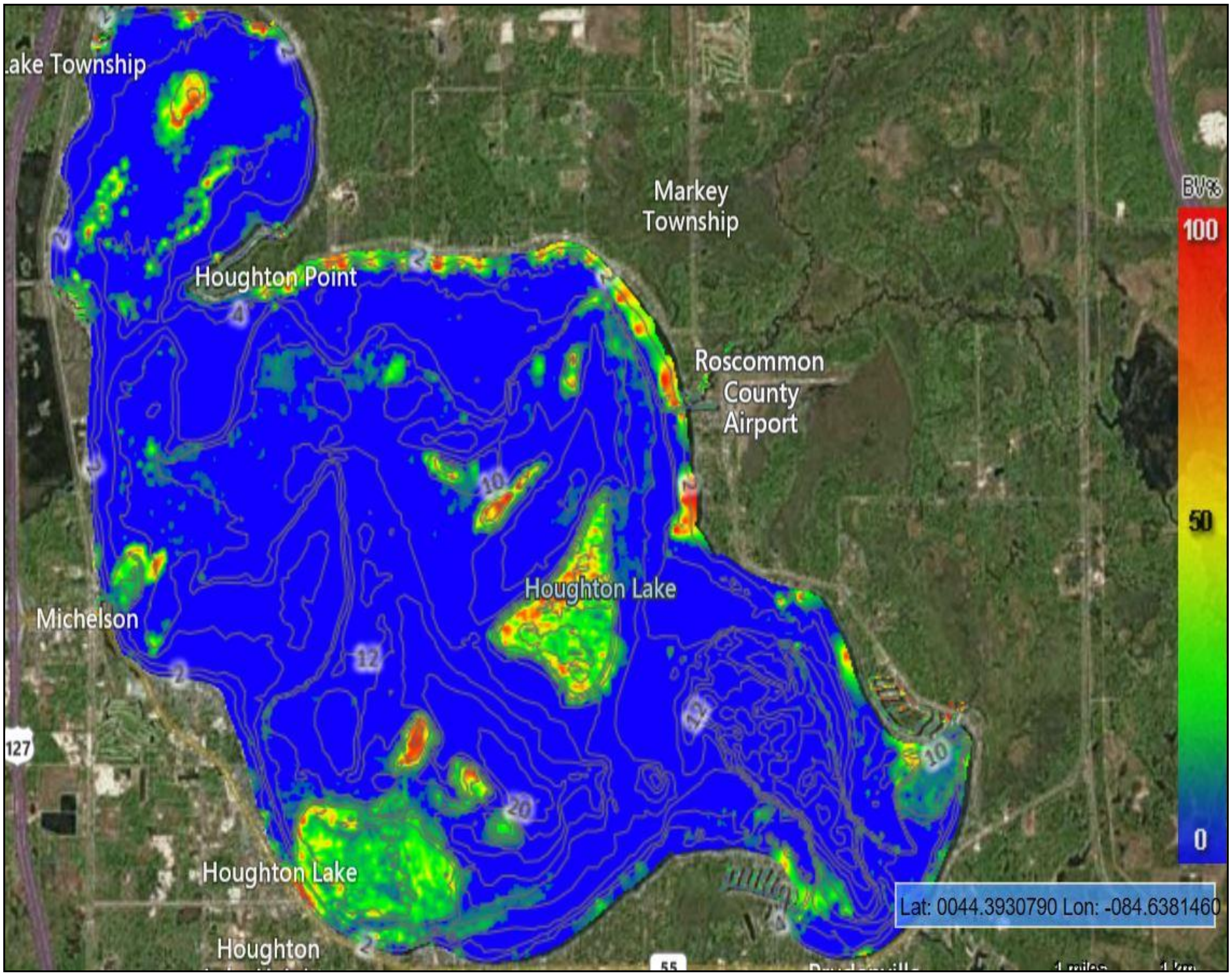

Figure 10. Aquatic vegetation biovolume scan and map of Houghton Lake in June/July, 2019 (RLS). NOTE: The blue color represents no vegetation present (previously this was displayed as blue and will be in the future); Red color represent tall, high-growing aquatic plants; Green color represents low-growing vegetation on the lake bottom such as Chara.

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 11) present in Houghton Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. There were intense rainfall events in 2018-2019 that resulted in increased runoff and many lakes experienced nuisance milfoil and algal outbreaks. The June 2019 survey revealed that approximately 625 acres of milfoil was found throughout the entire lake. This included area of sparse milfoil that were also treated to avoid spread in future years. These areas were treated on June 26, 2019 by PLM with systemic herbicides such as ProcellaCOR® at a dose of 5 PDU and Sculpin G® at a dose of 240 lbs./acre. An additional 109 acres were found to be late-season growth and were treated by PLM on July 31, 2019 with Sculpin G® at a dose of 200 lbs. /acre. Some canals were treated on June 20, 2019 with Clipper® at 200 ppb for a total of 7.7 acres of nuisance milfoil and again on July 31, 2019 for 3.8 acres with Clipper® at 200 ppb for nuisance milfoil. Figures 12-16 display areas of critical milfoil treatment in 2019.

Table 15 below shows the history to date on the amounts of contact and systemic herbicides used in Houghton Lake for milfoil treatments and in some canals the use of contacts for extremely dense vegetation.

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Figure 11. Eurasian Watermilfoil

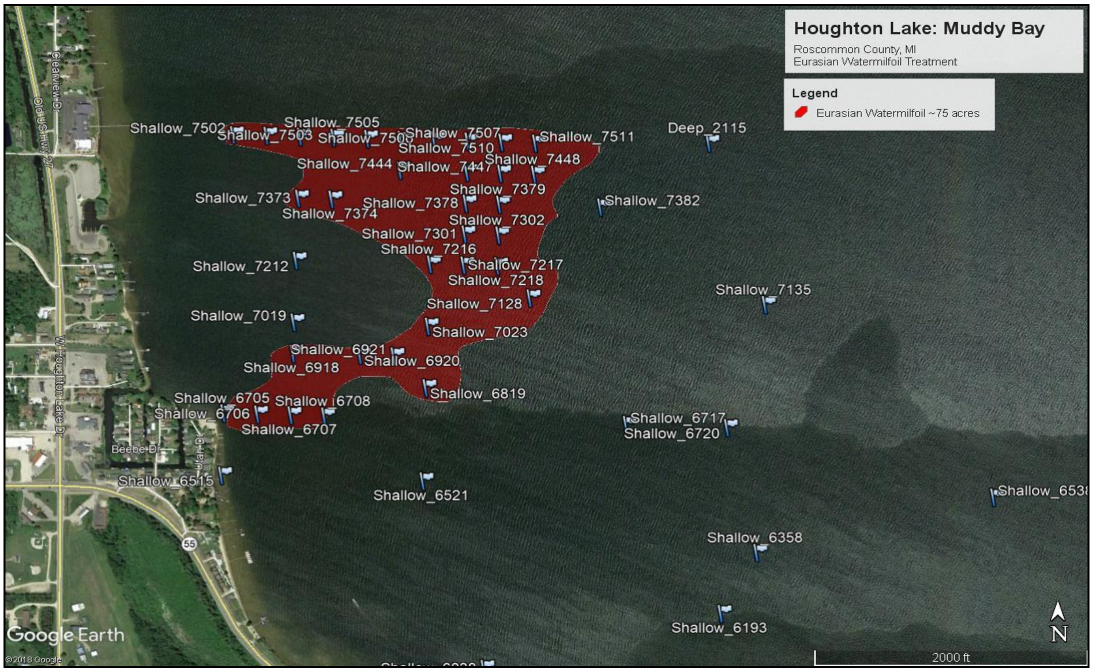

Figure 12. EWM in Houghton Lake Muddy Bay (June, 2019).

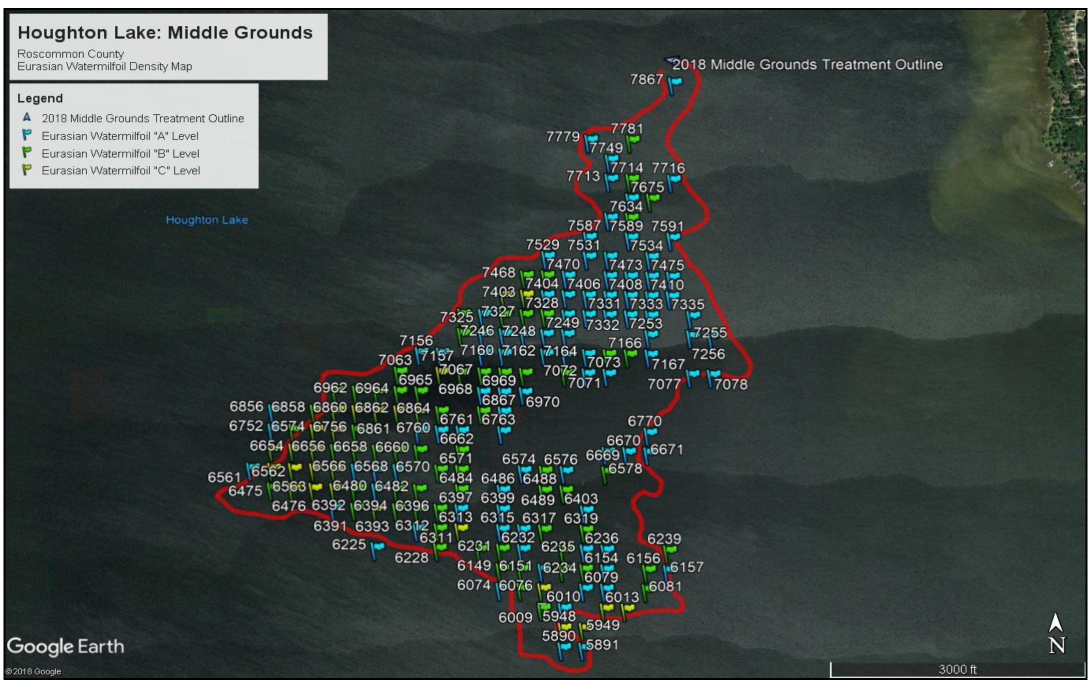

Figure 13. EWM in Houghton Lake Middle Grounds (June, 2019).

Figure 14. EWM in Houghton Lake Middle Grounds (October, 2019).

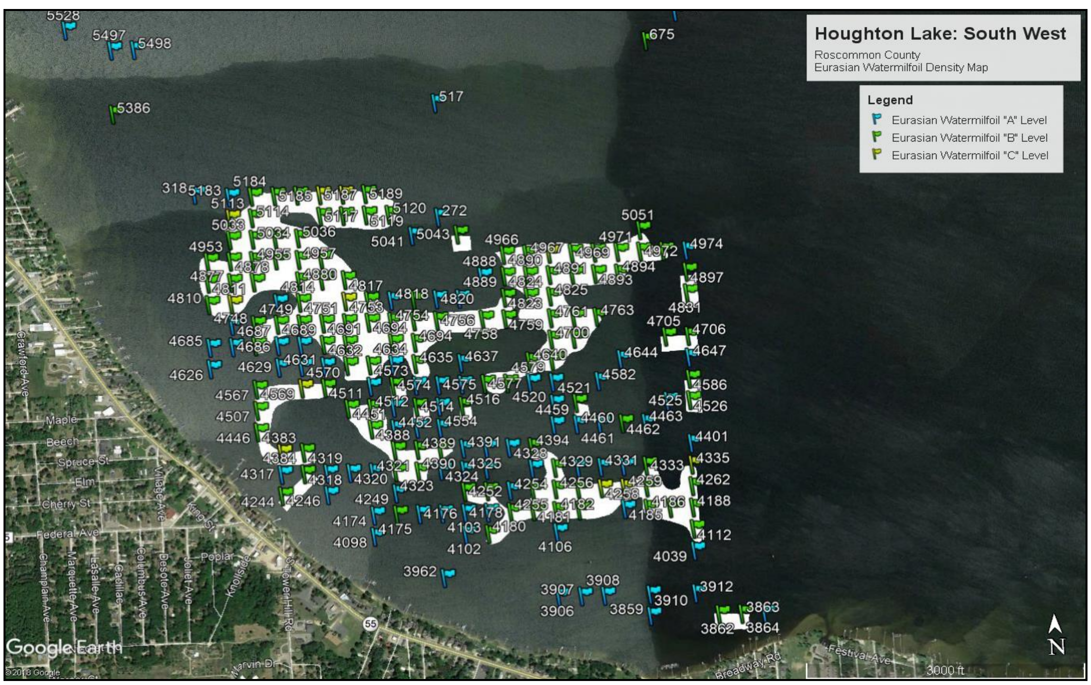

Figure 15. EWM in Southwest Houghton Lake (2019).

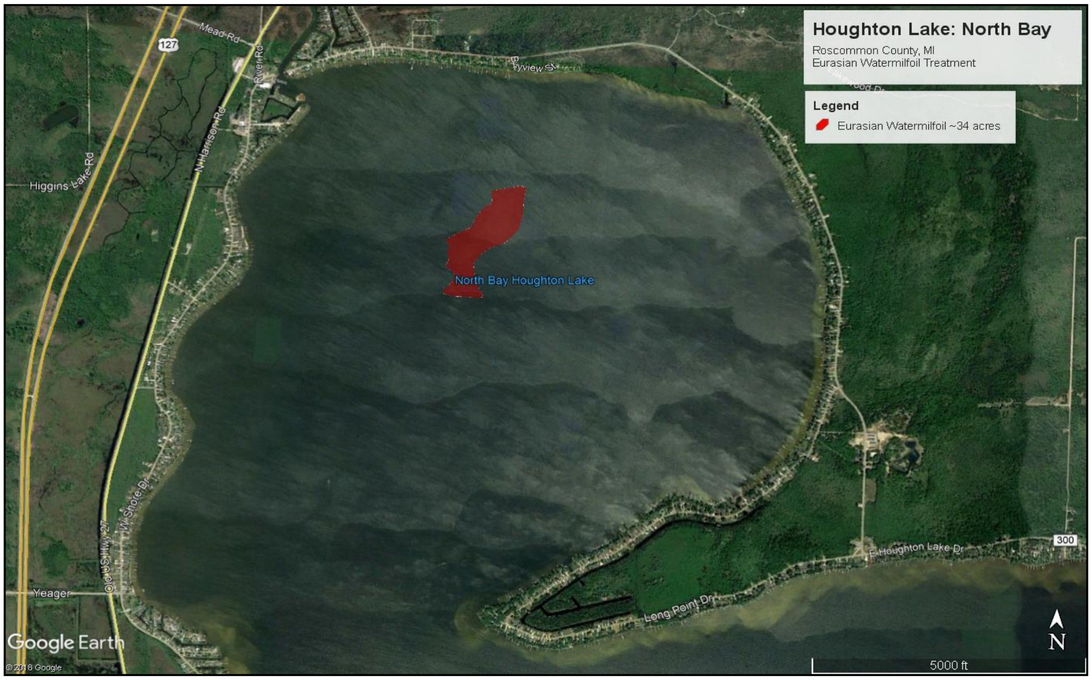

Figure 16. EWM in Houghton Lake North Bay (June, 2019).

Table 15. Houghton Lake invasive aquatic plant treatment history to date (2002-2019). Note: This includes treatments in all canals.

Year	# Acres Sonar	# Acres Contacts	# Acres Systemic	# Acres Harvested	# Milfoil Weevils Stocked
2002	20,044	17	--	--	--
2003	--	--	32	--	--
2004	--	--	44	81	5,000
2005	--	50	395	84	28,000
2006	--	59	444	105	--
2007	--	106	660	--	30,000
2008	--	20	1,310	35	--
2009	--	40	1,751	--	--
2010	--	39	558	--	--
2011	--	42	1,747	--	--
2012	--	84	1,237	--	--
2013	--	49	1,902	--	--
2014	--	51	1,054	--	--
2015	--	65	600	--	--
2016	--	450	499	--	--
2017	--	0.3	434	8.75	--
2018	--	16.7	875	8.75	--
2019	--	13.9	734	--	--

Section

4

Houghton Lake Sediment Aquatic Macroinvertebrates

RLS scientists collected sediment macroinvertebrate communities from the North Bay, Central Basin, and South Bay on October 18, 2019 so they may be compared to earlier sample data and also determine the existing biodiversity of taxa that contribute to the ecological balance of Houghton Lake. Tables 16-18 list all of the aquatic macroinvertebrates found during the sampling.

A previous study on the Houghton Lake macroinvertebrate community determined that the total number of macroinvertebrate taxa declined from 19 in 1973 to 9 by 1995-1996. The October 2019 samples demonstrated 14 different taxa in the lake sediments and the numbers increased since 2018. Thus, future preservation is important since these organisms support the lake food chain and fishery. The Central Basin had the highest macroinvertebrate count followed by the South Basin. Taxa found in the samples included:

1. Pond snails
2. Mayfly larvae
3. Sow bugs
4. Fingernail clams
5. Wheel snails
6. Freshwater shrimp
7. Dragonfly larvae
8. Midge larvae
9. Caddisfly larvae
10. Flatworms
11. Crane fly larvae
12. Damselfly larvae
13. Predaceous water beetles
14. Water mites

Mayflies on a home near Houghton Lake in 2019.

Table 16. Houghton Lake sediment macroinvertebrate sampling data from the North Bay (October 18, 2019).

Sample 1	**Grab**	**Order**	**Family/Genus**	**Number**	**Common name**
		Diptera	Tipulidae	3	Crane fly larvae
		Ephemeroptera	Ephemerillidae	5	Mayfly larvae
		Planaria	Planariidae	3	Flatworms
		Diptera	Chironomidae	9	Midge larvae
		Gastropoda	Physidae	3	Pond snails
		Trichoptera	Phryganeidae	2	Caddisfly larvae
		Arachnida	Hydrachnidiae	1	Water mites
		Coleoptera	Dytiscidae	1	Predaceous water beetle
		Gastropoda	Planorbidae	9	Wheel Snails
			Total	**36**	
Sample 2	**Grab**	**Order**	**Family/Genus**	**Number**	**Common Name**
		Gastropoda	Physidae	1	Pond snails
		Ephemeroptera	Ephemerillidae	3	Mayfly larvae
		Isopoda	Asellidae	1	Sow bugs
		Bivalvia	Sphaeriidae	2	Fingernail clams
		Gastropoda	Planorbidae	11	Wheel snail
		Odonata	Calopterygidae	1	Damselfly larvae
		Planaria	Planariidae	5	Flatworm
		Amphipoda	Gammaridae	1	Freshwater shrimp
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	9	Midge larvae
			Total	**36**	

Table 17. Houghton Lake sediment macroinvertebrate sampling data from the Central Basin (October 18, 2019).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	3	Crane fly larvae
		Ephemeroptera	Ephemerillidae	4	Mayfly larvae
		Bivalvia	Sphaeriidae	1	Fingernail Clams
		Planaria	Planariidae	1	Flatworms
		Diptera	Chironomidae	9	Midge larvae
		Gastropoda	Physidae	4	Pond snails
		Trichoptera	Phryganeidae	2	Caddis fly larvae
		Gastropoda		10	Wheel Snails
		Coleoptera	Dytiscidae	1	Predaceous water beetle
			Total	**35**	
Sample 2	**Grab**				
		Gastropoda	Physidae	4	Pond snails
		Ephemeroptera	Ephemerillidae	3	Mayfly larvae
		Isopoda	Asellidae	2	Sow bugs
		Bivalvia	Sphaeriidae	3	Fingernail clams
		Gastropoda	Planorbidae	9	Wheel snail
		Odonata	Calopterygidae	1	Damselfly larvae
		Planaria	Planariidae	2	Flatworm
		Amphipoda	Gammaridae	4	Freshwater shrimp
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	9	Midge larvae
			Total	**39**	

Table 18. Houghton Lake sediment macroinvertebrate sampling data from the South Basin (October 18, 2019).

Sample 1	**Grab**	**Order**	**Family/Genus**	**Number**	**Common name**
		Diptera	Tipulidae	1	Crane fly larvae
		Ephemeroptera	Ephemerillidae	5	Mayfly larvae
		Gastropoda		13	Wheel Snails
		Planaria	Planariidae	1	Flatworms
		Diptera	Chironomidae	8	Midge larvae
		Gastropoda	Physidae	4	Pond snails
		Trichoptera	Phryganeidae	2	Caddis fly larvae
		Isopoda	Asellidae	5	Sow Bugs
			Total	**39**	
Sample 2	**Grab**				
		Gastropoda	Physidae	5	Pond snails
		Ephemeroptera	Ephemerillidae	1	Mayfly larvae
		Isopoda	Asellidae	2	Sow bugs
		Bivalvia	Sphaeriidae	1	Fingernail clams
		Gastropoda	Planorbidae	11	Wheel snail
		Amphipoda	Gammaridae	1	Freshwater shrimp
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	2	Midge larvae
			Total	**25**	

Section

5

Management Recommendations for 2020

1. Whole-lake Aquatic Vegetation Surveys:

Continued aquatic vegetation surveys are needed to determine the precise locations of Eurasian Watermilfoil (EWM) Curly-leaf Pondweed (CLP), Starry Stonewort, or other problematic invasives in or around Houghton Lake. These surveys should include a whole lake inventory in late June-early July 2020 and partial surveys post-treatment as needed in 2020. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2020 as in previous years. Treatment results will then be compared with previous years in the 2020 annual lake report.

2. Aquatic Herbicide Treatments:

Due to the relative scarcity of native aquatic vegetation in Houghton Lake, the treatment of these species with aquatic herbicides is not recommended and re-colonization of the lake by these species is a major goal for the current Houghton Lake management plan. The plan for 2020 includes the use of higher doses of systemic aquatic herbicides (such as triclopyr nearshore and 2, 4-D offshore) for the milfoil that may be present. Doses will be dependent upon the permit requirements as well as the size and density of the weed beds. Lower doses are used in the sensitive Middle Grounds area and in any areas where RLS finds Wild Rice during the whole-lake survey. Additionally, RLS will continue to individually evaluate previously treated ProcellaCOR® treatment areas and any new areas that may be added with that product. Thus far, the ProcellaCOR® product has proven to be a very effective herbicide for controlling the density and relative abundance of EWM without reducing favorable native aquatic plant species.

3. Wild Rice Re-colonization:

One of the objectives in the current Houghton Lake management plan was to re-colonize the North Bay with a healthy, viable population of Wild Rice (*Zizania aquatica*). However, previous presentations from Dr. Scott Herron from Ferris State University recommended that Muddy Bay would also be a favorable area for planting. This will help the lake fishery and wildlife and add biodiversity to the aquatic vegetation communities. RLS will work closely with Dr. Herron and the HLIB to make this recolonization effort possible upon request of the HLIB.

4. Water Quality Monitoring:

Water quality parameters from the lake will also be monitored and graphed with historical data to observe long-term trends. In addition, water quality from the canals and tributaries will also be sampled. RLS will use that data to make any necessary recommendations for additional BMPs (best management practices) if needed. The data collected to date have provided RLS and the HLIB with assurance that the lake is in overall good health.

5. Educational Outreach for Houghton Lake:

RLS continues to assist the HLIB with an educational strategy to assist the Houghton Lake community with learning how to preserve and protect Houghton Lake. In 2019, an educational ad campaign was released with the assistance of Spectrum which was broadcast on local channels. RLS received feedback from many residents that the campaign was effective at raising awareness. RLS will continue to assist the HLIB with other educational opportunities.

Glossary of Scientific Terms used in this Report

1) Biodiversity- The relative abundance or amount of unique and different biological life forms found in a given aquatic ecosystem. A more diverse ecosystem will have many different life forms such as species.

2) $CaCO_3$- The molecular acronym for calcium carbonate; also referred to as “marl” or mineral sediment content.

3) Eutrophic- Meaning “nutrient-rich” refers to a lake condition that consists of high nutrients in the water column, low water clarity, and an over-abundance of algae and aquatic plants.

4) Mesotrophic- Meaning “moderate nutrients” refers to a lake with a moderate quantity of nutrients that allows the lake to have some eutrophic qualities while still having some nutrient-poor characteristics

5) Oligotrophic- Meaning “low in nutrients or nutrient-poor” refers to a lake with minimal nutrients to allow for only scarce growth of aquatic plant and algae life. Also associated with very clear waters.

6) Sedimentary Deposits- refers to the type of lake bottom sediments that are present. In some lakes, gravel and sand are prevalent. In others, organic muck, peat, and silt are more common.