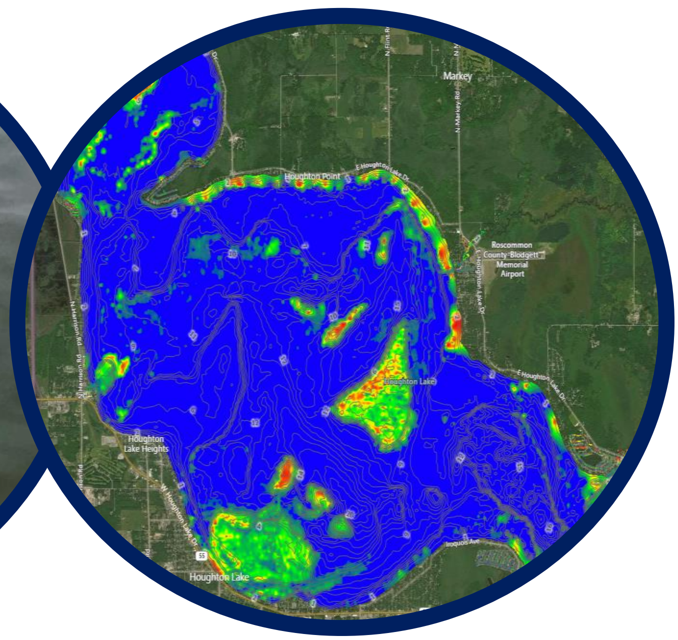
Houghton Lake 2020 Aquatic Vegetation, Water Quality, and 2021 Management Recommendations Annual Report



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Houghton Lake 2020 Aquatic Vegetation, Water Quality, and 2021 Management Recommendations Annual Report

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1

Houghton Lake 2020 Aquatic Vegetation, Water Quality, and 2021 Management Recommendations Annual Report

The following Houghton Lake report is a summary of key lake findings collected in 2020.

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 is overall good with nutrients varying each year due to rainfall. The dissolved oxygen is abundant, and 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 2018-2020 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 2020 whole-lake survey. Protection of this emergent plant is critical to the lake and migratory wildlife as well as the lake fishery. A 50-acre area of Muddy Bay was planted with rice on September 22, 2020 and will be heavily evaluated in 2021.

Section

2

Houghton Lake Water Quality Data (2020)

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 2020 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 early October of 2020 (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. 2020 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.

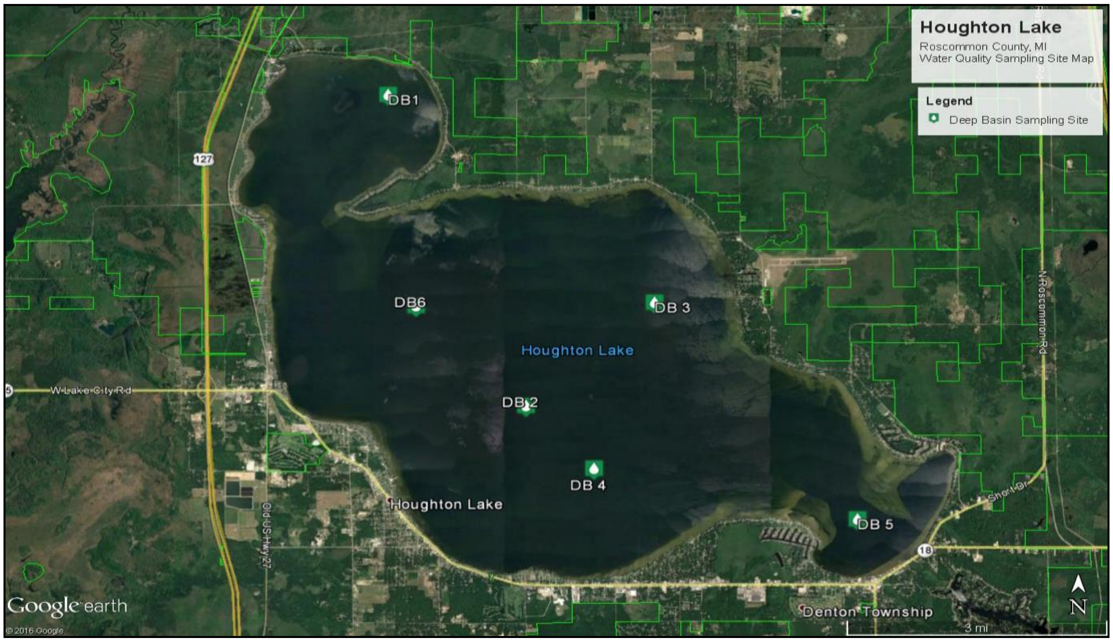

Figure 1. Deep basin water quality sampling locations in Houghton Lake (2016-2020).

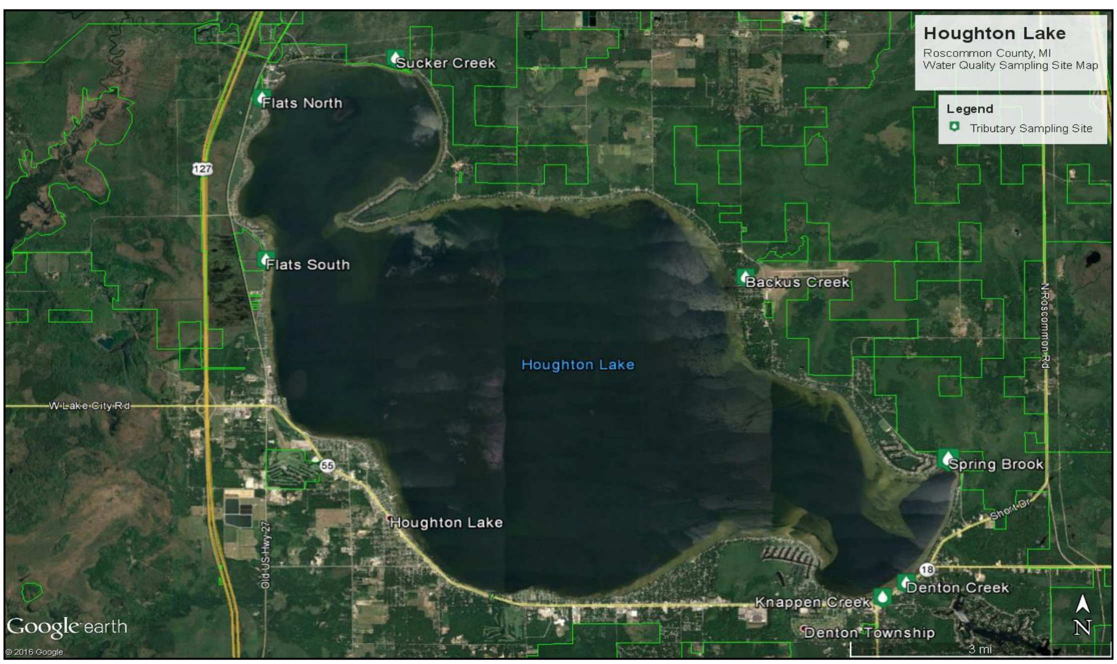

Figure 2. Tributary water quality sampling locations around Houghton Lake (2016-2020).

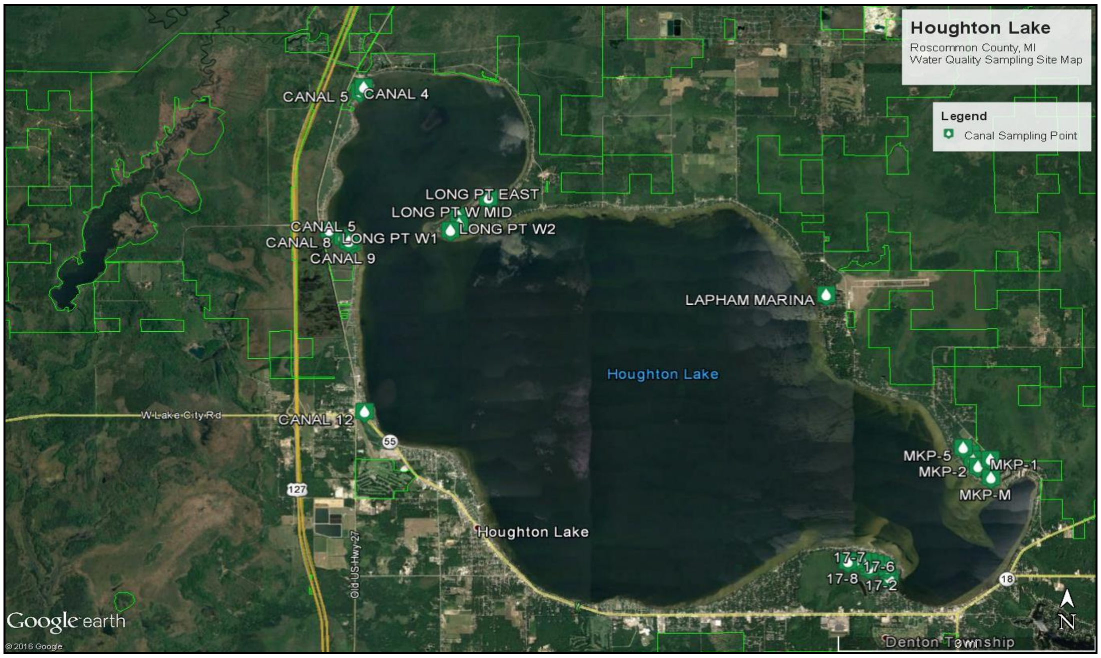

Figure 3. Houghton Lake canals water quality sampling locations (2016-2020).

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 8, 2020.

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	12.6	9.7	8.1	231	1.3	148	0.033	<0.010	0.8
2.5	12.6	10.1	8.1	231	1.4	148	0.030	<0.010	0.8
5.0	12.6	10.3	8.1	231	1.4	148	0.030	<0.010	0.8

Table 3. Houghton Lake water quality parameter data collected in deep basin #2 on October 8, 2020.

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	12.2	9.9	8.5	300	1.5	168	0.026	<0.010	<0.5
8.0	12.2	9.9	8.5	293	1.4	161	0.035	<0.010	1.3
16.0	12.2	10.0	8.5	229	1.5	146	0.035	<0.010	1.1

Table 4. Houghton Lake water quality parameter data collected in deep basin #3 on October 8, 2020.

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	12.3	10.1	8.5	274	1.1	146	0.023	<0.010	0.7
8.0	12.3	10.0	8.6	278	1.4	146	0.027	<0.010	<0.5
16.0	12.3	10.0	8.6	278	1.7	146	0.026	<0.010	<0.5

Table 5. Houghton Lake water quality parameter data collected in deep basin #4 on October 8, 2020.

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	12.2	9.9	8.5	255	0.9	167	0.025	<0.010	<0.5
10.0	12.2	10.0	8.5	227	1.0	161	0.037	<0.010	0.9
20.0	12.0	9.9	8.5	228	1.7	146	0.027	<0.010	0.9

Table 6. Houghton Lake water quality parameter data collected in deep basin #5 on October 8, 2020.

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	12.5	9.9	8.5	244	0.7	161	0.018	<0.010	<0.5
10.0	12.4	9.8	8.5	238	1.4	155	0.051	<0.010	1.0
20.0	12.2	9.8	8.5	229	2.4	146	0.026	<0.010	0.8

Table 7. Houghton Lake water quality parameter data collected in deep basin #6 on October 8, 2020.

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	12.4	10.2	8.2	227	0.6	145	0.025	<0.010	0.5
6.0	12.4	10.1	8.2	227	0.8	145	0.025	<0.010	0.5
12.0	12.4	9.9	8.1	228	1.4	145	0.025	<0.010	0.5

Houghton Lake Canal Water Quality Data Tables:

Table 8. Houghton Lake water quality parameter data collected in the Chippewa canals on October 8, 2020. 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	12.5	7.0	8.2	438	1.8	281	0.038
C2	12.7	6.4	8.2	475	1.1	303	0.037
C3	12.8	7.0	8.2	483	1.2	309	0.040
C4	13.5	6.6	8.2	492	1.4	314	0.033
C5	12.5	7.1	8.2	505	1.8	323	0.032
C6	12.1	6.8	8.3	522	1.5	334	0.040
C7	11.9	7.6	8.2	522	1.5	334	0.046
C8	11.9	7.0	8.2	522	1.5	334	0.047
CM	12.0	7.5	8.0	528	1.9	360	0.035

Table 9. Houghton Lake water quality parameter data collected in the McKinley Park (MPK) canals on October 8, 2020. 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	**12.2**	**9.8**	**8.0**	**336**	**2.2**	**215**	**0.047**
MPK 2	**12.8**	**9.2**	**7.6**	**360**	**2.4**	**231**	**0.036**
MPK 3	**12.6**	**8.9**	**7.7**	**382**	**2.1**	**244**	**0.025**
MPK 4	**12.0**	**7.5**	**7.6**	**402**	**2.4**	**257**	**0.048**
MPK 5	**11.5**	**8.7**	**7.6**	**394**	**2.3**	**252**	**0.063**
MPK M	**13.7**	**9.0**	**8.2**	**343**	**2.2**	**220**	**0.037**

Table 10. Houghton Lake water quality parameter data collected in the Lapham and Long Point canals on October 8, 2020. 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	**12.8**	**9.9**	**7.7**	**275**	**1.4**	**176**	**0.027**
L POINT MID	**11.5**	**7.6**	**7.5**	**366**	**1.9**	**234**	**0.052**
L POINT W1	**11.4**	**8.0**	**7.4**	**330**	**1.6**	**212**	**0.035**
L POINT W2	**11.8**	**8.9**	**7.4**	**360**	**1.9**	**234**	**0.047**
L POINT E	**10.8**	**6.3**	**7.2**	**326**	**1.6**	**209**	**0.045**

Table 11. Houghton Lake water quality parameter data collected in the canals north and west of Long Point canals #4-12 on October 8, 2020. Note: All samples were collected at mid-depth of 3.0 feet. Canal #5 was too shallow to enter.

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	14.0	12.0	8.1	231	1.4	148	0.034
CANAL 5	--	--	--	--	--	--	--
CANAL 6	13.8	10.2	8.1	238	1.6	152	0.030
CANAL 8	13.4	9.1	8.1	252	2.0	168	0.030
CANAL 9	12.8	9.9	7.8	255	2.0	167	0.020
CANAL 10	13.0	9.7	8.3	245	1.7	154	0.020
CANAL 12	13.6	9.7	8.4	256	2.0	169	0.030

Houghton Lake Tributary Water Quality Data Table:

Table 12. Houghton Lake water quality parameter data collected in the tributaries and flats on October 8, 2020.

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	9.9	8.2	7.4	260	1.7	166	<10	0.062	1.0
SPRING BROOK	11.3	9.2	7.3	360	2.3	235	<10	0.028	<0.50
BACKUS CRK	10.5	10.4	7.5	103	1.0	65	<10	0.020	<0.50
FLATS N	10.6	8.9	7.5	351	2.2	232	<10	0.030	1.0
FLATS S	10.9	9.1	7.4	227	1.8	141	<10	0.030	1.0
SUCKER CRK	11.0	8.5	7.4	120	1.4	71	<10	0.025	1.0
KNAPPEN CRK	10.4	8.8	7.4	345	1.9	228	130	0.024	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 8, 2020 sampling event averaged 9.8 mg L^{-1}. Figure 4 below shows the changes in mean DO with time in Houghton Lake.

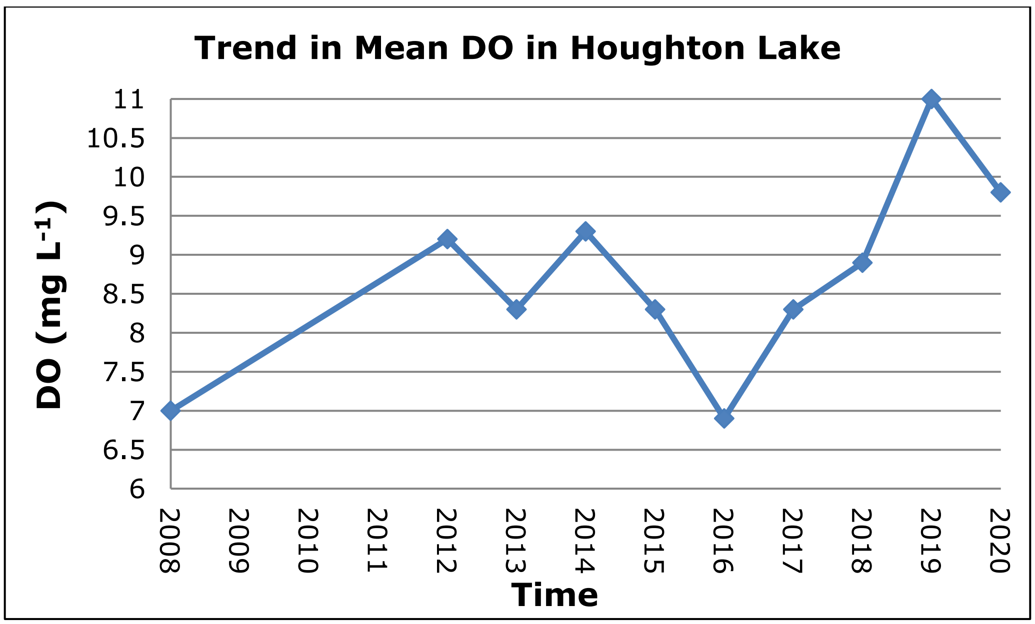

Figure 4. Changes in mean DO with time in Houghton Lake.

Water Clarity (Transparency)

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Houghton Lake was adequate in early-October of 2020 (mean of 5.9 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.

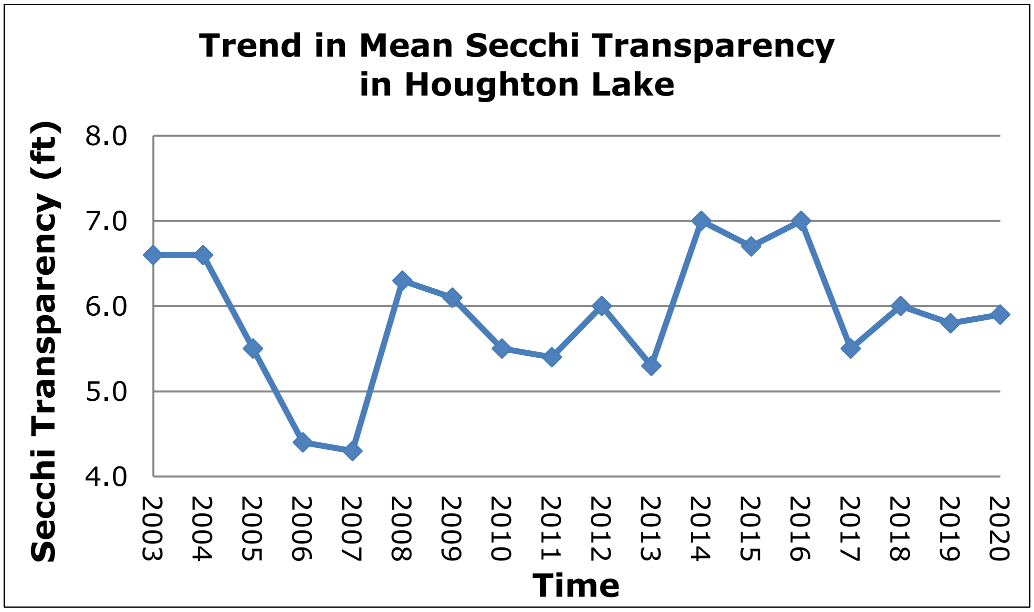

Figure 5. Changes in mean Secchi Transparency with time in Houghton Lake.

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 early-October 2020 was 0.029 mg L^{-1} (Figure 6), which is higher than in recent years and exceeds 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 0.038 mg L^{-1}. The mean TP in the tributaries was slightly lower at 0.031 mg L^{-1}.

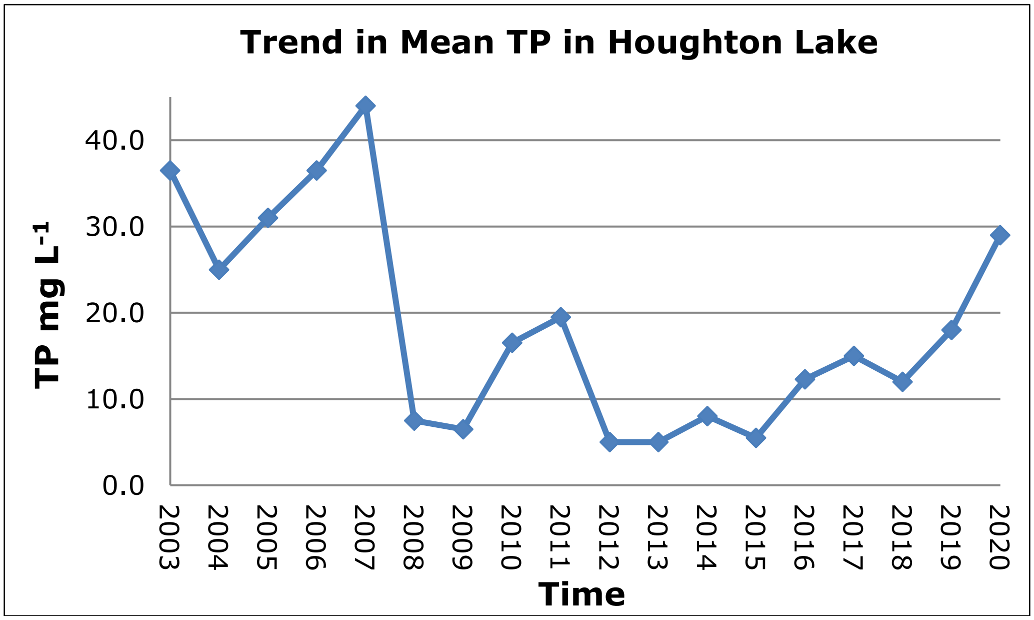

Figure 6. Changes in mean TP with time in Houghton Lake.

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 early-October of 2020 averaged 0.8 mg L^{-1}, which is moderately low for an inland lake and similar to last year. The TKN in the tributaries ranged from <0.5-1.0 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 early-October of 2020 (mean of 85 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 ≤2.4 NTU's and is favorable due to less wind and sediment re-suspension. The turbidity of the tributaries was ≤2.3 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 ≤168 mg L^{-1} for the deep basins in early-October of 2020, which is moderate for an inland lake but higher than last year.

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 ≤360 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 2020. The TDS of the tributaries was ≤235 mg L^{-1} which is similar to the canals for the same reason but was lower in 2020.

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 ≤10-130 mg L^{-1}, which is overall low for all but Knappen Creek. Knappen Creek also had the highest concentration in 2019. The ideal concentration for TSS in inland lakes and streams is ≤ 20 mg L^{-1}. It was raining the date of the tributary sampling and thus the solid increases may have been attributed to increased rainfall.

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 8.4 S.U. (Figure 7) in early-October of 2020 which is ideal for an inland lake. The pH of the canals ranged from 7.2-8.4 S.U. and the pH of the tributaries ranged from 7.3-7.5 S.U. All of these values are normal and favorable for aquatic environments.

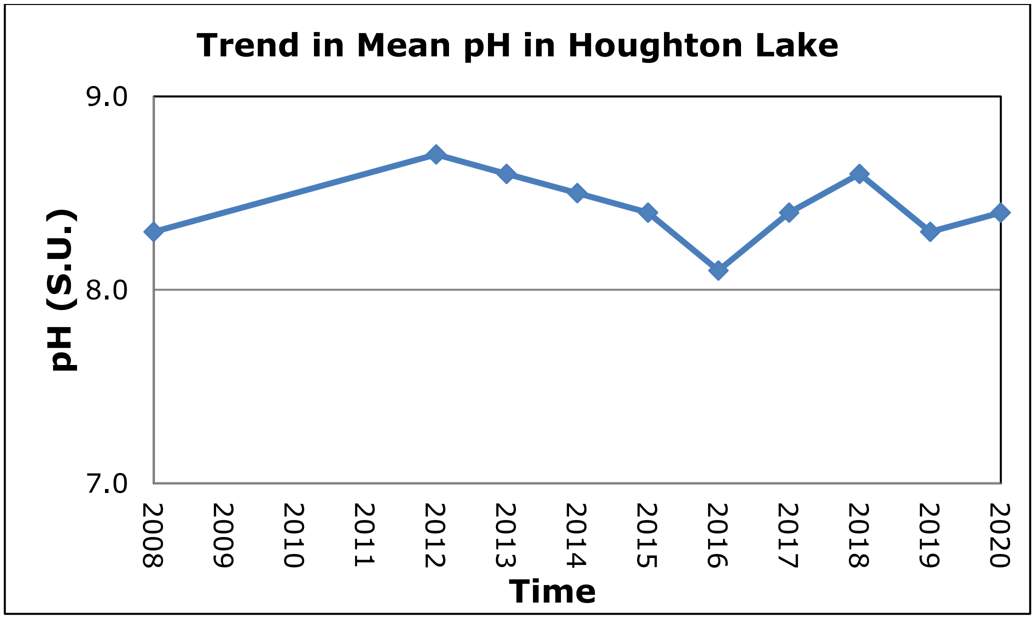

Figure 7. Changes in mean pH with time in Houghton Lake.

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 227-300 µS/cm in early-October of 2020. The conductivity of the canals ranged from 231-528 µS/cm and the conductivity in the tributaries ranged from 120-351 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 early-October of 2020 (Figure 8) was 3.1 µg L^{-1} which was higher than in recent years and may be attributed to a much warmer summer with dry climate.

The algal genera were determined from composite water samples collected over the deep basins of Houghton Lake in 2020 were analyzed with a compound Zeiss® bright field microscope. The genera present included the Chlorophyta (green algae): *Spirogyra* sp., *Haematococcus* sp., *Cladophora* sp., *Scenedesmus* sp., *Radiococcus* sp., *Chlorella* sp., *Mougeotia* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): *Oscillatoria* sp., and the Bascillariophyta (diatoms): *Navicula* sp., *Synedra* sp., *Fragillaria* sp., *Cymbella* 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.

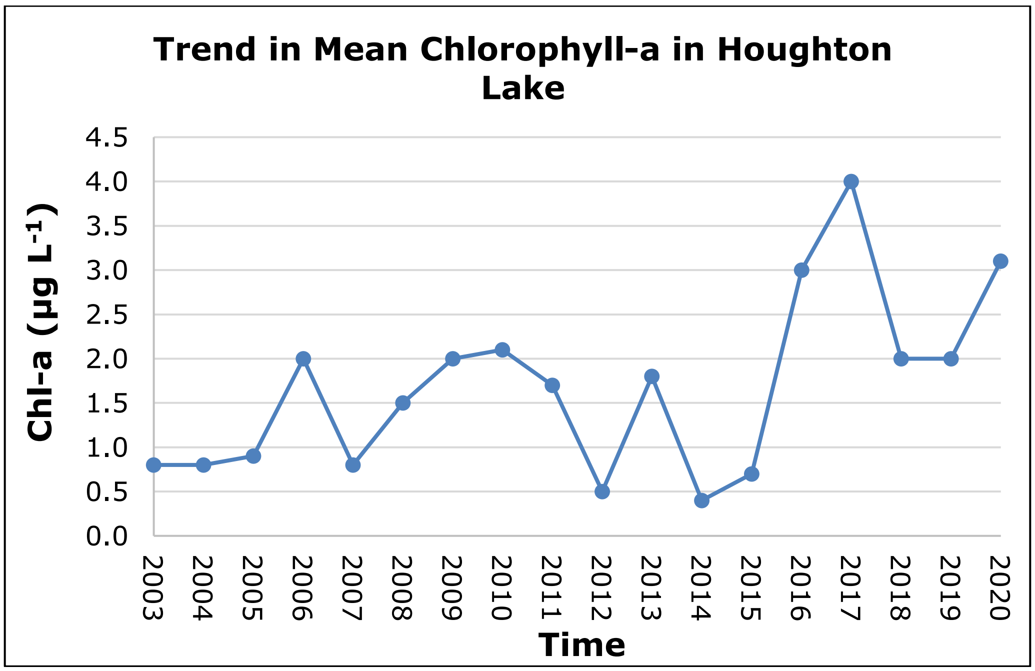

Figure 8. Changes in mean Chl-*a* with time in Houghton Lake.

Section

3

Aquatic Vegetation Data (2020)

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 2020 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 2021 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, 2020. 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 2021 to determine if native aquatic plant species are occupying the area once colonized by EWM.

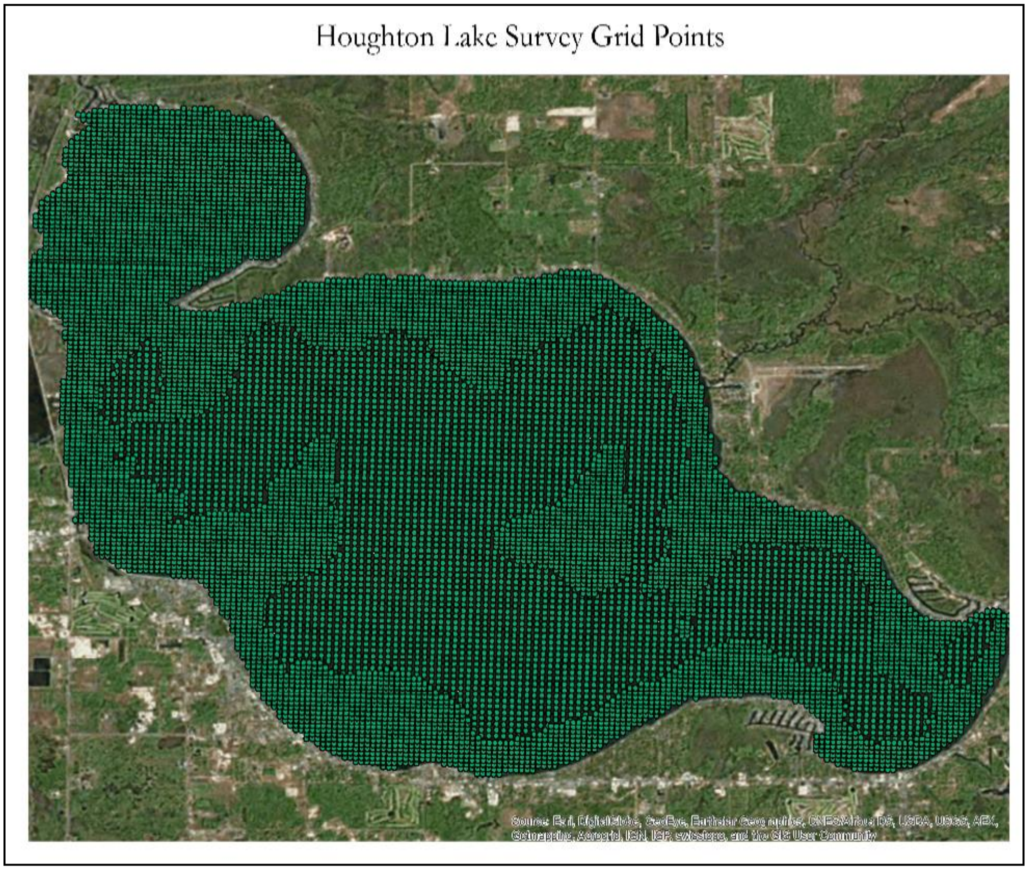

Figure 9. GPS Sampling Points in Houghton Lake (RLS).

Table 13. Changes in relative abundance (frequency) of native and invasive aquatic plants in the Middle Grounds before and after ProcellaCOR® herbicide treatment in 2019-2020.

Aquatic Plant Species	June 2019 (Pre-ProcellaCOR®)	October 2019 (Post-ProcellaCOR®)	October 2020 (Post-ProcellaCOR®)
Hybrid EWM	45.3	17.2	5.2
Curly-leaf Pondweed	6.9	2.0	1.8
Chara	35.2	70.7	55.4
Thin-leaf Pondweed	0	0.5	1.7
Flat-stem Pondweed	0.5	0	0
White-stem Pondweed	3.9	11.8	9.7
Clasping-leaf Pondweed	0.2	0	0.5
Large-leaf Pondweed	0.2	0	0
Wild Celery	27.6	27.6	30.2
Coontail	1.7	2.7	2.1
Elodea	17.2	49.5	59.8
Slender Naiad	30.3	25.1	32.5
Starry Stonewort	6.4	7.4	5.7
Wild Rice	2.2	2.2	2.1

Table 14. Aquatic plant species relative abundance (frequency) in the main portion of the lake with vegetation present excluding canals (June 8-17, 2020). NOTE: These values represent pre-treatment conditions.

Aquatic Plant Species	Main Lake Frequency	Aquatic Plant Species	Main Lake Frequency
Hybrid EWM	16.3	**Bladderwort**	0.4
Curly-leaf Pondweed	5.5	**Slender Naiad**	1.1
Chara	31.1	**Sago Pondweed**	0.06
Thin-leaf Pondweed	1.9	**Starry Stonewort**	16.3
Water Stargrass	0.8	**Variable-leaf Pondweed**	1.5
Flat-stem Pondweed	0.2	**White Waterlily**	2.0
White-stem Pondweed	10.5	**Yellow Waterlily**	1.2
Clasping-leaf Pondweed	6.4	**Duckweed**	0.0
Fern-leaf Pondweed	0.6	**Bulrushes**	0.2
Illinois Pondweed	10.0	**Cattails**	0.7
Large-leaf Pondweed	5.5	**Pickerelweed**	0.1
American Pondweed	0.06	**Arrowhead**	0.1
Floating-leaf Pondweed	0.3	**Wild Rice**	0.2
Wild Celery	4.3	**Iris**	0.01
Coontail	0.7		
Elodea	18.2		

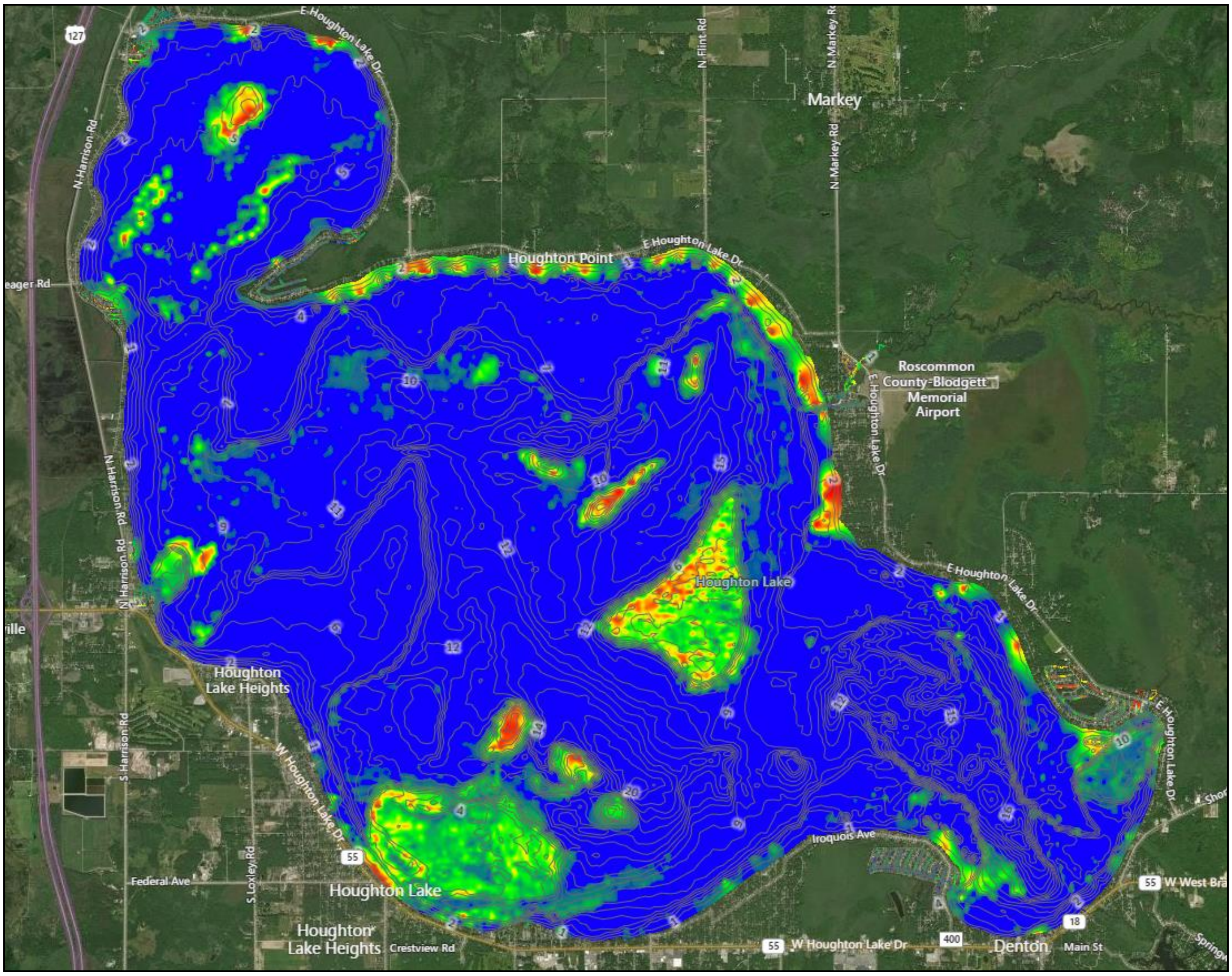

Figure 10. Aquatic vegetation biovolume scan and map of Houghton Lake in June/July, 2020 (RLS). NOTE: The blue color represents no vegetation present (previously this was displayed as blue and will be in the future); Red color represent tall, high-growing aquatic plants; Green color represents low-growing 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. The June 2020 survey revealed that approximately 219.5 acres of milfoil was found throughout the entire lake. These areas were treated June 24-29, 2020 by PLM with systemic herbicides such as Sculpin G at a dose of 240 lbs./acre, and ProcellaCOR® at a dose of 4 PDU/acre combined with diquat at 1 gal/acre, and flumioxazin at a dose of 200 ppb. An additional 132.5 acres were found during an additional lake August survey and were treated by PLM on September 1, 2020 with Sculpin G® at a dose of 240 lbs. /acre and 7 of those acres were treated with ProcellaCOR® at a dose of 4 PDU/acre and diquat at 1 gal/acre. Some canals were treated on June 24, 2020 with Clipper® at 200 ppb and diquat at 1 gal/acre for a total of 15.3 acres of nuisance milfoil and again on June 29, 2020 for 15 acres with flumioxazin at a dose of 200 ppb for nuisance milfoil. On July 27, 2020, PLM treated 5.8 acres of new milfoil in the canals with a combination of diquat, SeClear G® at 50 lbs./acre (for algae), and flumioxazin at 200 ppb. On July 30, 2020, Canal #6 and #7 were treated by PLM with flumioxazin at a dose of 200 ppb and diquat at a dose of 1 gal/acre for nuisance milfoil and dense weeds. On August 3, 2020, PLM treated a canal for dense Starry Stonewort using Se Clear G® at a dose of 50 lbs./acre. Figures 12-19 display areas of critical treatment areas in 2020.

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.

Figure 11. Eurasian Watermilfoil

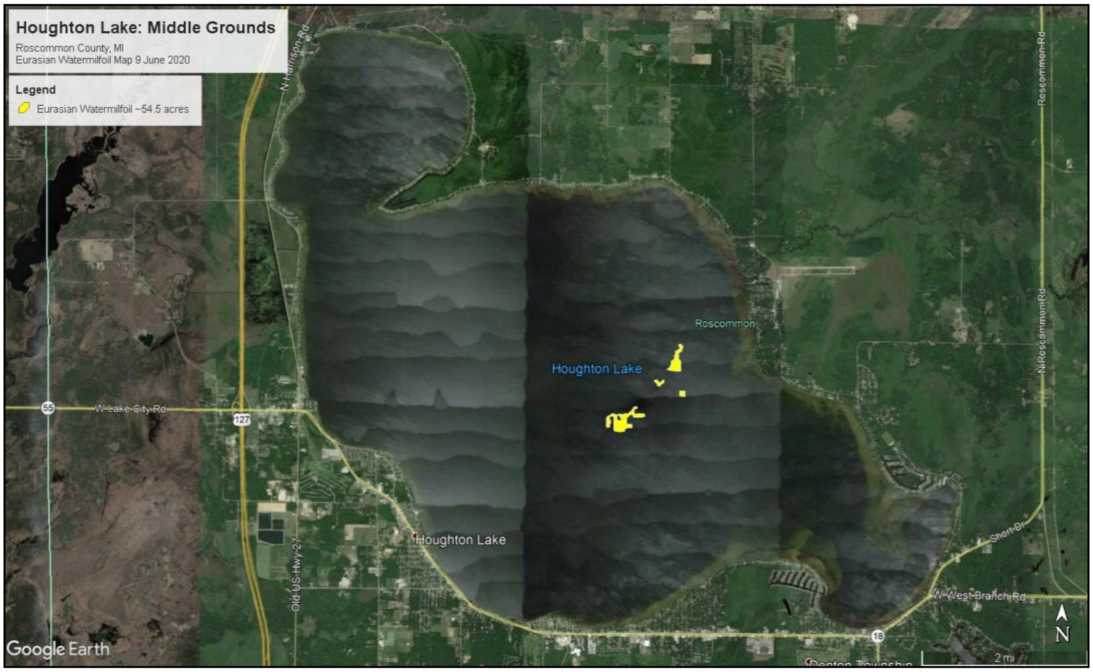

Figure 12. EWM dense polygons for treatment (June 9, 2020).

Figure 13. EWM in NE Section of Houghton Lake (June 9, 2020).

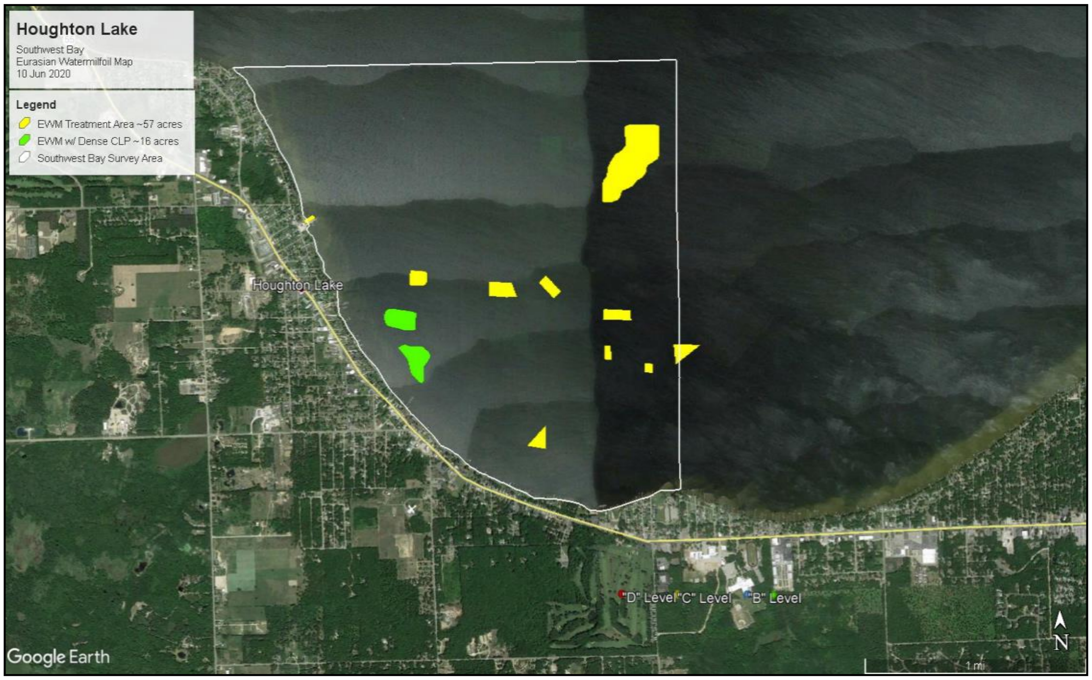

Figure 14. EWM in SW Bay of Houghton Lake (June 10, 2020).

Figure 15. EWM near Long Point East in Houghton Lake (June 10, 2020).

Figure 16. EWM near Long Point West in Houghton Lake (June 10, 2020).

Figure 17. EWM in North Bay of Houghton Lake (June 10, 2020).

Figure 18. EWM in SW Bay of Houghton Lake (August, 2020).

Figure 19. EWM in East Bay of Houghton Lake (August, 2020).

Table 15. Houghton Lake invasive aquatic plant treatment history to date (2002-2020). Note: This includes treatments in all canals and 2020 required rigorous treatment of some canals with algaecides and contact to address dense algae along with EWM.

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	--	--
2020	--	110	351	--	--

Section

4

Houghton Lake Sediment Aquatic Macroinvertebrates

RLS scientists collected sediment macroinvertebrate communities from the North Bay, Central Basin, and South Bay on October 8, 2020 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 2020 samples demonstrated 14 different taxa in the lake sediments and the numbers increased since 2018 but were similar to 2019. 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

Macros found Houghton Lake in 2020.

Table 16. Houghton Lake sediment macroinvertebrate sampling data from the North Bay (October 8, 2020).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	1	Crane fly larvae
		Ephemeroptera	Ephemerillidae	7	Mayfly larvae
		Planaria	Planariidae	1	Flatworms
		Diptera	Chironomidae	16	Midge larvae
		Gastropoda	Physidae	1	Pond snails
		Coleoptera	Dytiscidae	2	Predaceous water beetle
		Gastropoda	Planorbidae	7	Wheel Snails
			Total	**35**	
Sample 2	**Grab**	**Order**	**Family/Genus**	**Number**	**Common Name**
		Gastropoda	Physidae	3	Pond snails
		Ephemeroptera	Ephemerillidae	7	Mayfly larvae
		Isopoda	Asellidae	6	Sow bugs
		Gastropoda	Planorbidae	9	Wheel snail
		Odonata	Calopterygidae	3	Damselfly larvae
		Odonata	Aeshniidae	4	Dragonfly larvae
		Diptera	Chironomidae	11	Midge larvae
			Total	**43**	

Table 17. Houghton Lake sediment macroinvertebrate sampling data from the Central Basin (October 8, 2020).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	1	Crane fly larvae
		Ephemeroptera	Ephemerillidae	5	Mayfly larvae
		Bivalvia	Sphaeriidae	2	Fingernail Clams
		Planaria	Planariidae	2	Flatworms
		Diptera	Chironomidae	13	Midge larvae
		Gastropoda	Physidae	2	Pond snails
		Gastropoda		17	Wheel Snails
			Total	**42**	
Sample 2	**Grab**				
		Gastropoda	Physidae	1	Pond snails
		Ephemeroptera	Ephemerillidae	5	Mayfly larvae
		Isopoda	Asellidae	4	Sow bugs
		Gastropoda	Planorbidae	11	Wheel snail
		Odonata	Calopterygidae	2	Damselfly larvae
		Planaria	Planariidae	1	Flatworm
		Diptera	Chironomidae	12	Midge larvae
			Total	**36**	

Table 18. Houghton Lake sediment macroinvertebrate sampling data from the South Basin (October 8, 2020).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	2	Crane fly larvae
		Gastropoda		11	Wheel Snails
		Diptera	Chironomidae	16	Midge larvae
		Gastropoda	Physidae	1	Pond snails
		Trichoptera	Phryganeidae	3	Caddis fly larvae
		Isopoda	Asellidae	7	Sow Bugs
			Total	**40**	
Sample 2	**Grab**				
		Gastropoda	Physidae	1	Pond snails
		Ephemeroptera	Ephemerillidae	3	Mayfly larvae
		Gastropoda	Planorbidae	9	Wheel snail
		Odonata	Aeshniidae	3	Dragonfly larvae
		Diptera	Chironomidae	9	Midge larvae
			Total	**25**	

Section 5

Wild Rice Restoration

RLS accompanied Dr. Scott Herron from Ferris State University on September 22, 2020 to a 50-acre area of Muddy Bay to complete the initial planting of Wild Rice in that region. A total of 108 geo-referenced GPS points were recorded and randomly selected from within the 50-acre area for data recording (Figure 20). A total of 22 bags of Wild Rice were carefully hand-tossed into the water and the seeds made fast contact with the lake bottom. RLS will return with Dr. Herron in spring of 2021 to determine the sampling locations where germination has occurred. Additionally, there will be follow-up surveys and visits to the lake during 2021 to carefully monitor the efficacy of the Wild Rice planting. Conditions in the Muddy Bay region were ideal for Wild Rice with shallow depths and highly organic bottom substrate. Figures 21-24 demonstrate some of the project highlights to date.

Figure 20. Wild Rice Planting and sampling locations in Muddy Bay (September, 2020).

Figure 21. Wild Rice being collected for the Houghton Lake replanting project (September, 2020).

Figure 22. Wild Rice bags used to retain the rice prior to planting.

Figure 23. Blessing of the rice prior to planting (September, 2020).

Figure 24. Wild Rice (Manoomin) seed (September, 2020)

Section 6

Management Recommendations for 2021

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 and in the canals as in past years. These surveys should include a whole lake inventory in late June-early July 2021 and partial surveys post-treatment as needed in 2021. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2021 as in previous years. Treatment results will then be compared with previous years in the 2021 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 2021 includes the use of high doses of systemic aquatic herbicides (such as triclopyr nearshore and 2, 4-D or ProcellaCOR® 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*). Previous presentations from Dr. Scott Herron from Ferris State University recommended that Muddy Bay would also be a favorable area for planting. RLS worked with Dr. Herron on the restoration of Wild Rice in Muddy Bay in 2020 and will continue to evaluate those efforts in 2021 with special reporting to the HLIB. RLS plans to publish a peer-reviewed paper with Dr. Herron on this project as it contributes to lake restoration efforts.

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. RLS has recommended possible aeration for problematic canals due to excessive algae. Repeated algaecide treatments can cause more harm than good and thus RLS is recommending aeration and bioaugmentation for those canals. Cost may be an issue and will be discussed with the HLIB to plan any possible future improvements.

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 2019-2020, 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 with a community-wide workshop highly recommended for 2022.

Glossary of Some 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.