Houghton Lake 2023 Annual Report with 2024 Management Recommendations

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Houghton Lake 2023 Annual Report with 2024 Management Recommendations

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Section

1

Houghton Lake 2023 Annual Report with 2024 Management Recommendations

The following Houghton Lake report is a summary of key lake findings collected in 2023 with recommendations for continued improvement

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 now 31 native aquatic plant species that are so important to the ecological balance of Houghton Lake. There was significant natural germination and colonization of Wild Rice in the Middle Grounds area which was possible due to effective sustainable control of the milfoil in that region. Continued growth of the Wild Rice in this region will allow for reduced colonization of milfoil or other invasives over time. If the natural population declines, seeding may be necessary and recommended.

The water quality of Houghton Lake in 2023 was excellent. The mean total phosphorus concentration in October of 2023 was 0.012 mg L^{-1} which is quite low and favorable. The mean total Kjeldahl nitrogen concentration was 0.7 mg L^{-1} which is also low and favorable. Nutrient concentrations in the lake were much lower in 2023 due to less runoff from reduced rainfall events. This indicates that the Houghton Lake ecosystem may be sensitive to runoff as a primary source of nutrients. The canals and tributaries have significantly higher nutrients than the lake basin and are thus a source. There was abundant sunlight in 2023 and this has resulted in a favorable increase in submersed native aquatic vegetation which was one of the original feasibility improvement goals. Other parameters such as dissolved oxygen, pH, and conductivity were ideal for an inland lake. The algal communities were diverse and a good source of primary productivity for the fishery.

However, the recent presence of blue-green algae (*Microcystis* sp.) in some of the canals (McKinley and Long Point) is concerning and all canals will be monitored for these blooms and treated if necessary. RLS also determined the presence of the green filamentous algae, *Cladophora* which was found in a few locations nearshore on rocks and concrete seawalls. The populations of both algal types are prevalent in lake systems with abundant populations of Zebra Mussels. The sediment macroinvertebrate community was also healthy relative to taxa and relative abundance, and this may change annually due to environmental conditions.

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 canals and Middle Grounds areas have proven to require earlier survey dates than the remainder of the lake due to germination patterns. Rotation of herbicides is important to reduce the probability of tolerance to one used in a given year for a specific area. Wild Rice is re-establishing in North Bay, Middle Grounds, and Muddy Bay. Wild Rice was planted in Muddy Bay in 2020 and showed a 98.8% germination success in 2021. However, by the end of 2023 due to a lack of available seed source, the population declined to 8.8%. The Muddy Bay location may not be the ideal location due to the influences of strong fetch and ice scouring that limit germination. RLS determined that the Wild Rice locations had significantly higher nutrient concentrations than other areas in the main Basin and this explains why those populations prefer those locations for sustained growth.

Key restoration and management recommendations were provided in the 2022 feasibility report and remain consistent for 2024. Pending data collection on the lake in 2024 will determine of those recommendations need any modifications.

Section

2

Houghton Lake Water Quality Data (2023)

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 2023 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 on August 30-31, 2023 (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 the most critical parameters over the sampling locations and mean values are represented as red lines on each graph (Figures 4-7). Table 1 below demonstrates how lakes are classified based on key parameters. Houghton Lake would be historically 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. 2023 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.

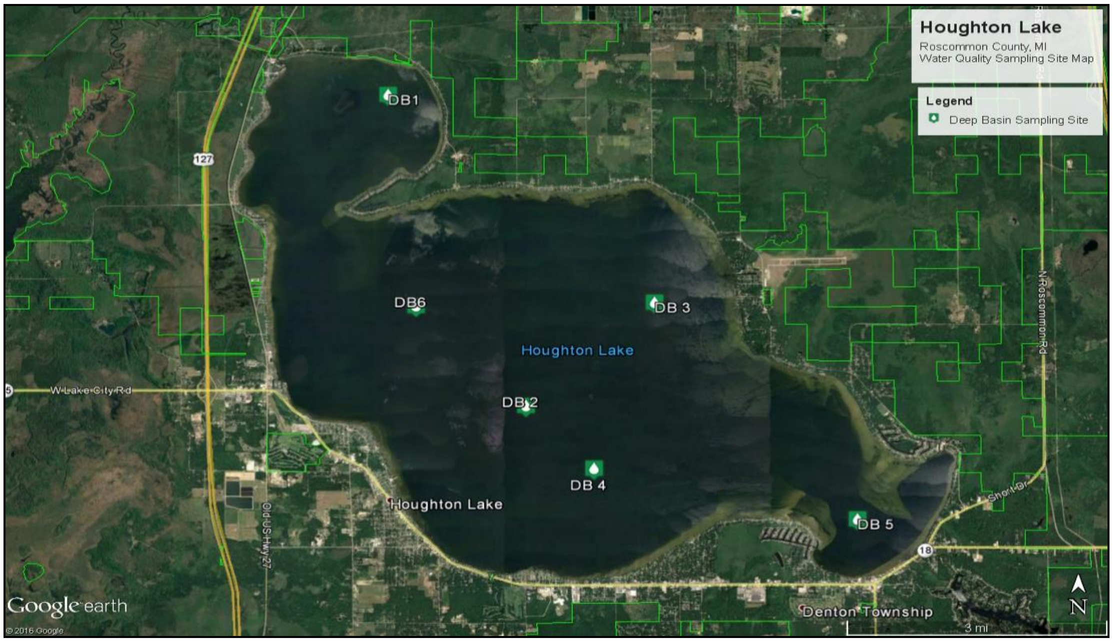

Figure 1. Deep basin water quality sampling locations in Houghton Lake (2016-2023).

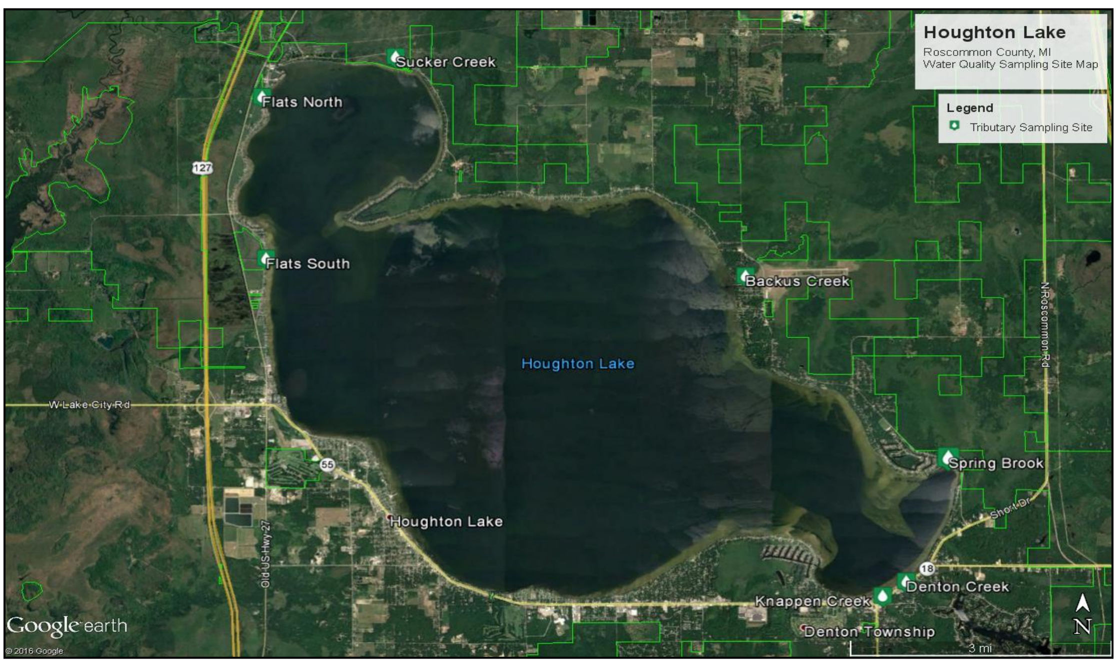

Figure 2. Tributary water quality sampling locations around Houghton Lake (2016-2023).

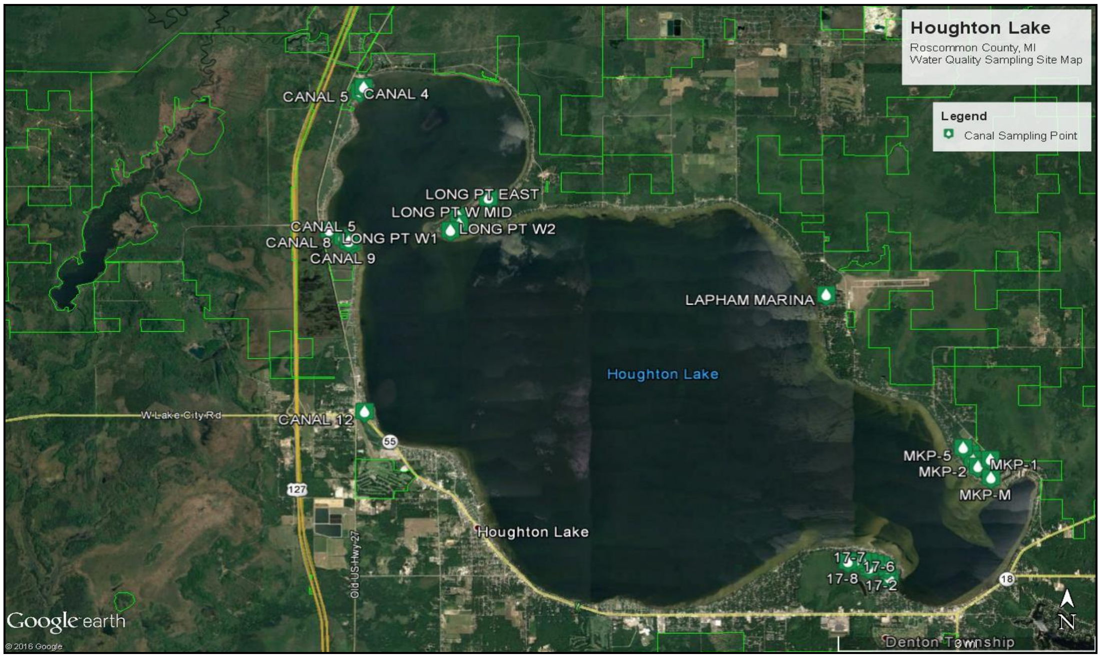

Figure 3. Houghton Lake canals water quality sampling locations (2016-2023).

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 August 30, 2023.

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}*	*Chl-a µg L^{-1}*	*Secchi (ft)*
0	19.0	9.3	8.9	226	0.5	144	<0.010	<0.010	0.6	--	--
2.5	19.0	9.6	8.9	226	0.8	144	<0.010	<0.010	0.6	2.0	5.4+
5.0	19.0	9.5	8.9	226	0.8	144	<0.010	<0.010	0.7	--	--

Table 3. Houghton Lake water quality parameter data collected in deep basin #2 on August 30, 2023.

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}*	*Chl-a µg L^{-1}*	*Secchi (ft)*
0	19.1	8.2	8.4	230	0.5	147	<0.010	<0.010	0.6	--	--
8.0	19.1	8.2	8.4	230	0.7	147	0.015	<0.010	0.5	4.0	6.3
16.0	19.1	5.7	8.3	231	0.7	149	0.013	0.011	0.9	--	--

Table 4. Houghton Lake water quality parameter data collected in deep basin #3 on August 30, 2023.

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}*	*Chl-a µg L^{-1}*	*Secchi (ft)*
0	19.2	8.4	8.4	229	0.4	147	0.017	0.017	0.6	--	--
8.0	19.1	8.4	8.4	229	0.6	147	0.013	<0.010	0.7	5.0	4.1
16.0	19.1	7.7	8.4	246	0.6	160	<0.010	<0.010	0.7	--	--

Table 5. Houghton Lake water quality parameter data collected in deep basin #4 on August 30, 2023.

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*	*Chl-a µg L-1*	*Secchi (ft)*
0	18.8	8.2	8.4	230	0.4	147	<0.010	<0.010	0.6	--	--
10.0	18.8	8.1	8.5	231	0.6	148	0.016	<0.010	0.7	3.0	5.6
20.0	18.7	7.9	8.3	231	0.8	148	<0.010	<0.010	0.8	--	--

Table 6. Houghton Lake water quality parameter data collected in deep basin #5 on August 30, 2023.

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*	*Chl-a µg L-1*	*Secchi (ft)*
0	18.8	8.6	8.5	231	0.4	148	<0.010	<0.010	0.7	--	--
10.0	18.3	8.5	8.5	231	0.6	148	<0.010	<0.010	0.7	4.0	6.3
20.0	18.2	8.4	8.4	231	0.9	148	0.024	<0.010	0.7	--	--

Table 7. Houghton Lake water quality parameter data collected in deep basin #6 on August 30, 2023.

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*	*Chl-a µg L-1*	*Secchi (ft)*
0	19.2	8.7	8.4	230	0.4	147	<0.010	<0.010	0.6	--	--
6.0	19.2	8.6	8.5	230	0.5	147	<0.010	<0.010	0.6	4.0	5.1
12.0	19.0	8.7	8.5	228	0.8	147	0.013	<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 August 31, 2023. 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}*	*Chl-a µg L^{-1}*	*Secchi (ft)*
C1	19.2	4.9	7.8	431	4.5	431	0.034	32.0	2.4
C2	19.1	5.7	7.9	447	6.0	447	0.038	46.0	2.5
C3	19.0	5.7	7.9	453	4.6	290	0.038	32.0	2.8
C4	18.9	7.0	8.0	453	3.0	290	0.063	19.0	3.0
C5	18.8	7.2	8.0	457	5.1	292	0.046	39.0	2.8
C6	18.5	6.3	7.9	461	3.0	295	0.043	19.0	2.8
C7	18.4	6.0	7.8	469	4.7	300	0.050	31.0	2.3
C8	18.4	7.2	8.1	471	2.7	301	0.100	15.0	3.1
CM	18.9	8.0	8.1	458	2.8	293	0.041	16.0	2.7

Table 9. Houghton Lake water quality parameter data collected in the McKinley Park (MPK) canals on August 31, 2023. 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*	*Chl-a µg L-1*	*Secchi (ft)*
MPK 1	**18.1**	**8.8**	**8.3**	**331**	**3.5**	**212**	**0.051**	**25.0**	**2.3**
MPK 2	**18.9**	**8.8**	**8.1**	**349**	**4.7**	**223**	**0.033**	**32.0**	**2.4**
MPK 3	**19.2**	**9.3**	**8.0**	**358**	**5.0**	**227**	**0.039**	**37.0**	**2.6**
MPK 4	**18.6**	**8.1**	**7.9**	**373**	**4.6**	**239**	**0.020**	**33.0**	**2.3**
MPK 5	**18.1**	**3.0**	**7.1**	**579**	**5.2**	**366**	**0.044**	**39.0**	**2.0**
MPK M	**19.5**	**10.6**	**8.5**	**343**	**2.4**	**219**	**0.033**	**54.0**	**2.1**

Table 10. Houghton Lake water quality parameter data collected in the Lapham and Long Point canals on August 31, 2023. 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*	*Secchi (ft)*
LAPHAM	**19.4**	**9.7**	**8.4**	**258**	**1.2**	**165**	**0.014**	**5.1**
L POINT MID	**16.8**	**8.5**	**8.5**	**275**	**4.0**	**176**	**0.017**	**2.6**
L POINT W1	**17.7**	**7.0**	**8.1**	**314**	**1.6**	**201**	**0.034**	**3.2**
L POINT W2	**17.9**	**6.0**	**8.0**	**324**	**1.9**	**209**	**0.033**	**3.9**
L POINT E	**17.7**	**7.8**	**8.2**	**304**	**1.6**	**194**	**0.038**	**2.9**

Table 11. Houghton Lake water quality parameter data collected in the canals north and west of Long Point canals #4-12 on August 31, 2023. Note: All samples were collected at mid-depth of 3.0 feet. Canal #5 was too shallow to enter.

Canal Site	*Canal Name*	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TP mg L^{-1}*	*Secchi (ft)*
CANAL 4	Porath	17.7	8.0	8.1	260	1.8	192	0.017	3.0+
CANAL 5	Ford	17.8	6.7	8.0	257	--	165	0.038	3.4
CANAL 6	Holt	17.0	6.7	7.9	296	1.4	187	0.025	3.0
CANAL 8	Siebert	17.9	8.0	8.3	245	1.6	157	<0.010	3.9
CANAL 9	Church	17.6	8.2	8.5	234	2.2	150	0.025	3.9
CANAL 10	Swick	16.9	7.5	8.1	254	1.9	163	0.024	2.5+
CANAL 12	Beebe	17.9	8.1	8.2	249	2.4	159	0.013	3.1+

Houghton Lake Tributary Water Quality Data Table:

Table 12. Houghton Lake water quality parameter data collected in the tributaries and flats on August 30, 2023.

Tributary Site	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*TDS mg L^{-1}*	*TSS mg L^{-1}*	*TP mg L^{-1}*	*TKN mg L^{-1}*
DENTON CREEK	22.4	5.0	8.1	232	0.5	148	<10	0.019	0.7
SPRING BROOK	19.5	9.3	7.8	256	0.8	164	<10	0.020	1.0
BACKUS/CUT	19.2	8.7	8.3	254	0.6	163	<10	<0.010	<0.5
KNAPPEN CREEK	20.5	8.8	8.2	243	0.5	150	<10	<0.010	0.6

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 26, 2023 sampling event averaged 8.4 mg L^{-1}. Figure 4 below shows the changes in mean DO with time in Houghton Lake with a historic mean of 9.1 mg L^{-1} which is excellent.

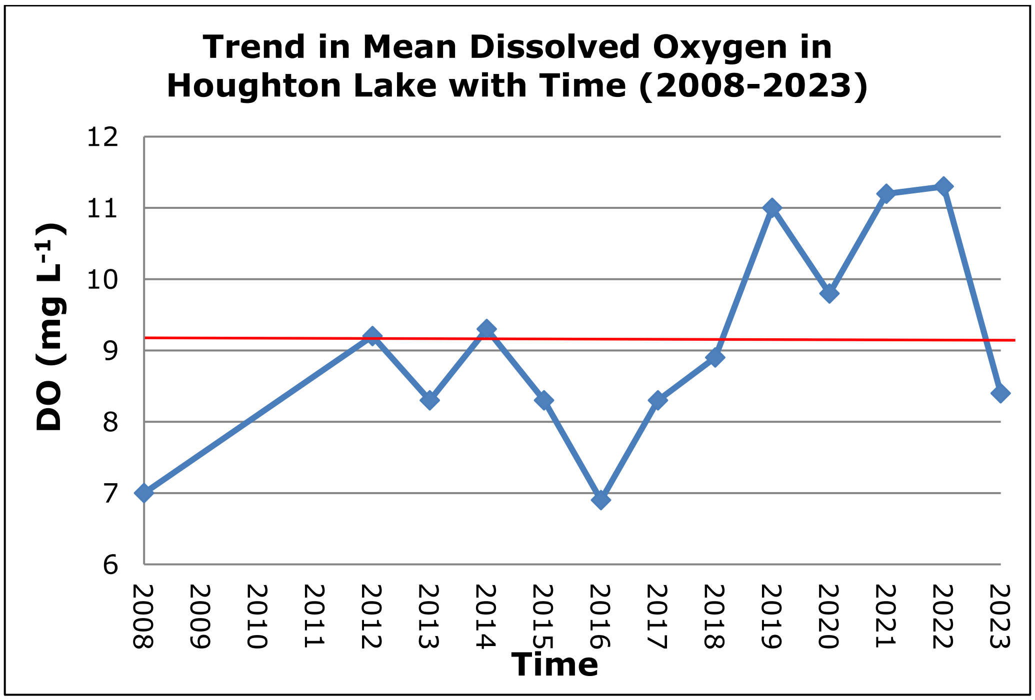

Figure 4. Changes in mean DO with time in Houghton Lake (2008-2023).

Water Clarity (Transparency)

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Houghton Lake was adequate on August 30, 2023 (mean of 5.5 feet) 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 below displays the trend in mean Secchi transparency with time. The historic mean is 6.0 feet which is moderate but common with large, shallow, high-energy systems.

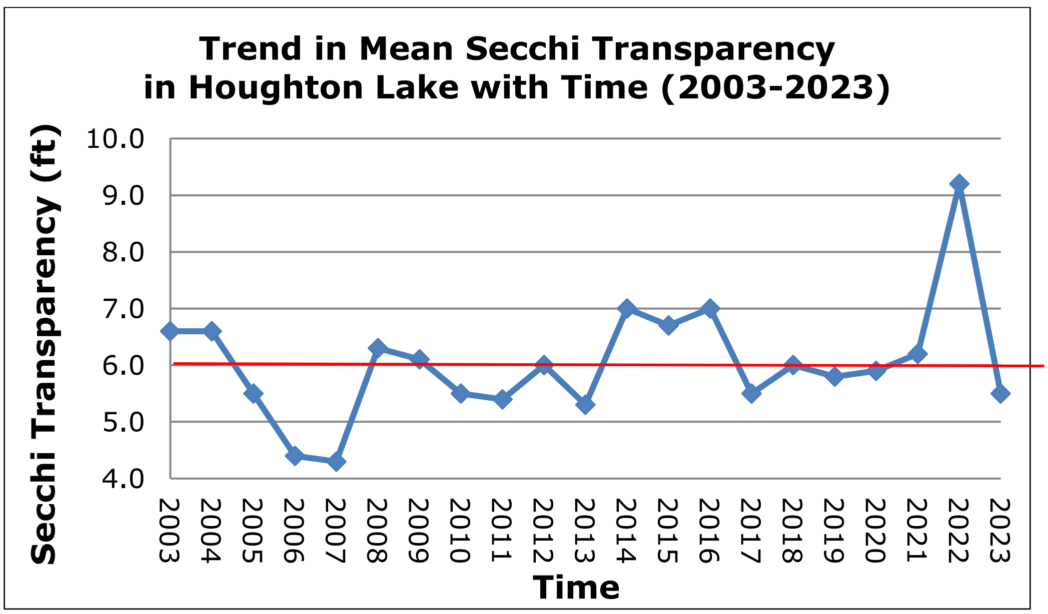

Figure 5. Changes in mean Secchi Transparency with time in Houghton Lake (2003-2023).

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 on August 30, 2023 was 0.012 mg L^{-1} (Figure 6), which is lower than in recent years and was 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 ≤ 0.017 mg L^{-1}, which were quite low and also favorable. The mean TP in the canals was higher at 0.036 mg L^{-1}. The mean TP in the tributaries was lower at 0.027 mg L^{-1}. The historic mean in the lake basin is 0.018 mg L^{-1} or 18.0 µg L^{-1} which is low and favorable.

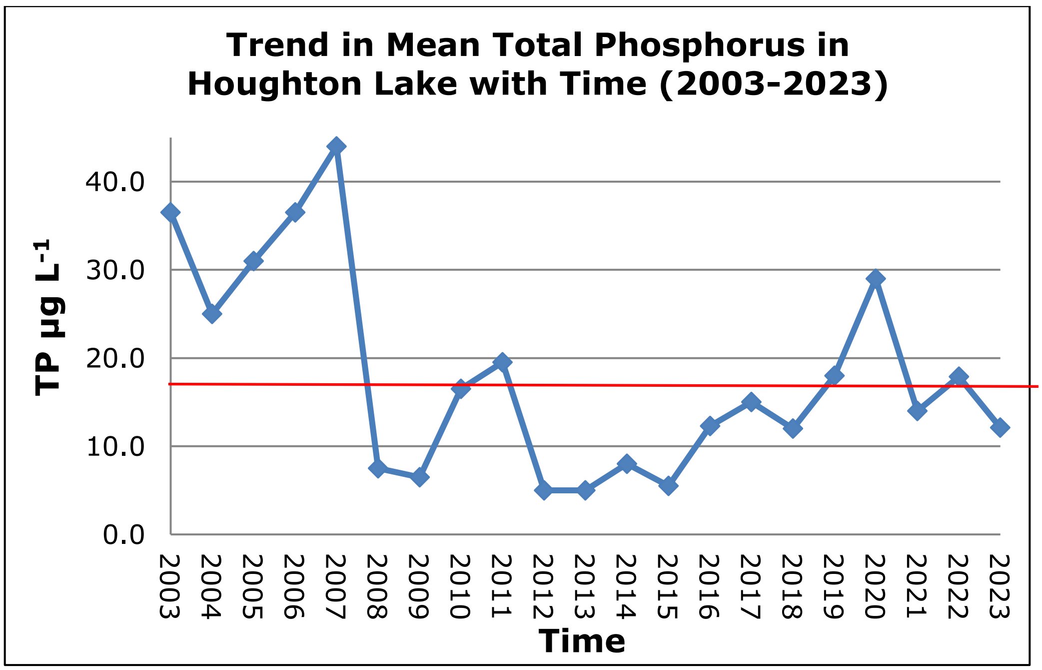

Figure 6. Changes in mean TP with time in Houghton Lake (2003-2023).

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of 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 on August 30, 2023 averaged 0.7 mg L^{-1}, which is moderately low for an inland lake and similar to last year. The historic mean for the lake basin is 0.8 mg L^{-1}, which is favorable (Figure 7). The TKN in the tributaries ranged from <0.5-1.0 mg L^{-1}.

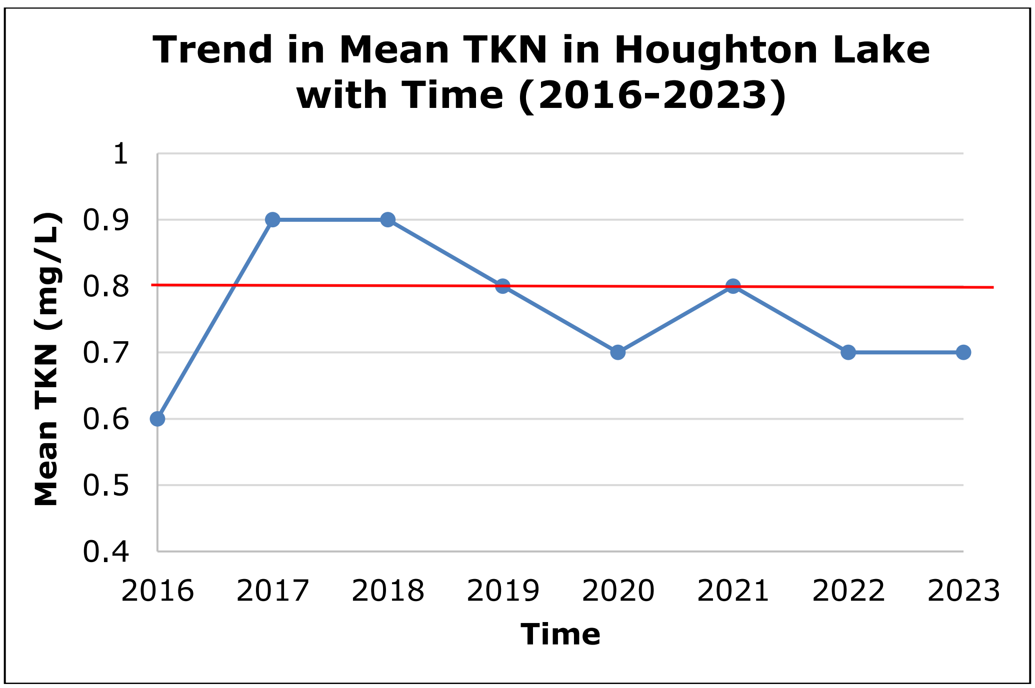

Figure 7. Changes in mean TKN with time in Houghton Lake (2016-2023).

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 on August 30, 2023 (mean of 88 mg L^{-1} of $CaCO_3$) and indicates a slightly soft-water lake. Total alkalinity is periodically evaluated to determine how the buffering capacity of the lake changes over time.

Turbidity & Total Dissolved 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 was measured in Nephelometric Turbidity Units (NTU's) with the use of a calibrated 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 ≤0.9 NTU's during the 2023 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 ≤6.0 NTU's and was higher in 2023 due to increases in algal blooms. The turbidity of the tributaries was ≤0.8 NTU's which is favorable and lower than in recent years due to less runoff.

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 ≤160 mg L^{-1} for the deep basins on August 30, 2023, 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 ≤447 mg L^{-1} which is higher than the lake and likely due to the presence of stormwater inputs and stagnant waters. The TDS of the tributaries was ≤164 mg L^{-1}.

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 were all ≤10 mg L^{-1}, which is overall low. The ideal concentration for TSS in inland lakes and streams is ≤20 mg L^{-1}. TSS may increase during periods of heavy rainfall/runoff.

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 8.5 S.U. (Figure 8) on August 30, 2023, which is ideal for an inland lake. The pH of the canals ranged from 7.1-8.5 S.U. and the pH of the tributaries ranged from 7.8-8.3 S.U. All of these values are normal and favorable for aquatic environments. The historic mean pH in the lake basin is 8.4 S.U.

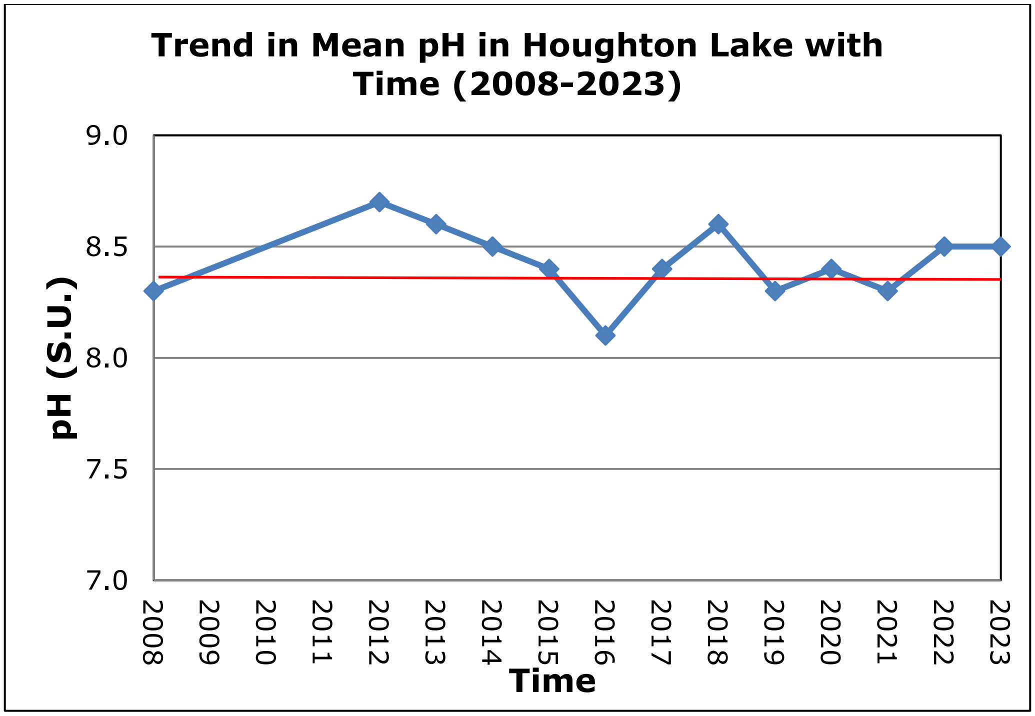

Figure 8. Changes in mean pH with time in Houghton Lake (2008-2023).

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 226-246 µS/cm on August 30, 2023. The conductivity of the canals ranged from 232-579 µS/cm and the conductivity in the tributaries ranged from 232-256 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. The historic mean for the lake basin is 235 µS/cm which is favorable, especially for a developed lake (Figure 9).

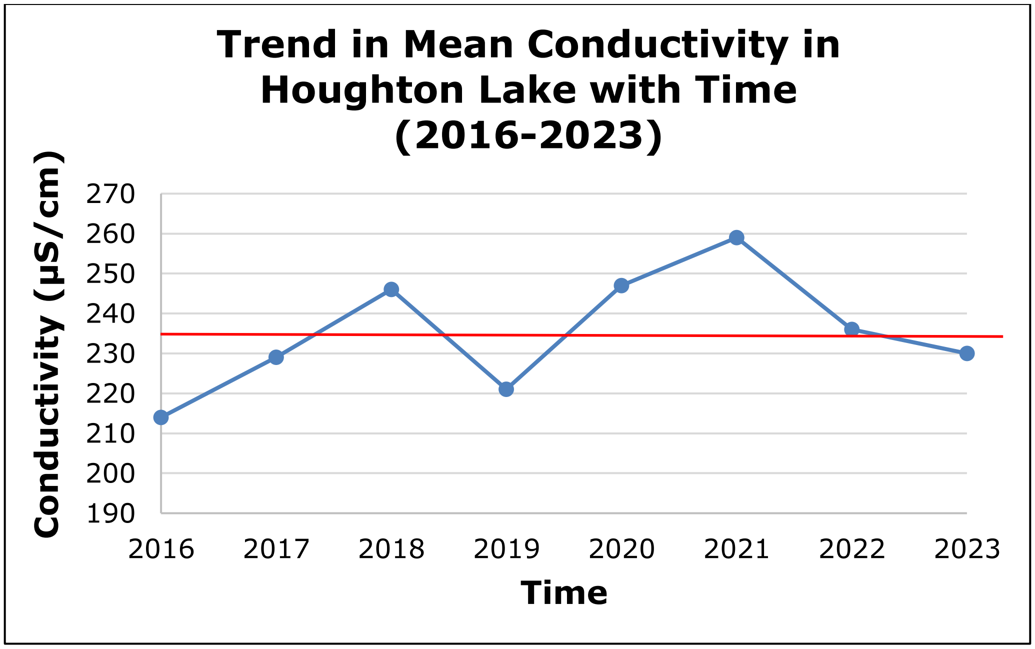

Figure 9. Changes in mean conductivity with time in Houghton Lake (2016-2023).

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 on August 30, 2023 (Figure 10) was 3.7 µg L^{-1} which was higher than in recent years and may be attributed to a much warmer summer with dry climate. The historic mean chlorophyll-a concentration is 1.8 µg L^{-1} which is favorable and low.

The algal genera were determined from composite water samples collected over the deep basins of Houghton Lake in 2023 were analyzed with a compound Zeiss® bright field microscope. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Chlorella* sp., *Spirogyra* sp., *Cladophora* sp., *Scenedesmus* sp., *Ulothrix* sp., *Pandorina* sp., and *Gleocystis* sp; The Cyanophyta (blue-green algae): *Oscillatoria* sp., and the Bascillariophyta (diatoms): *Navicula* sp., *Cymbella* sp., *Synedra* sp., *Rhoicosphenia* sp., *Eunotia* sp., *Amphora* sp. *Fragillaria* sp., and *Tabellaria* sp. The Chrysophyte *Synura* sp. was also present.

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.

Blue-green algae have been problematic in the McKinley Canal system in recent years and Phoslock® treatments were conducted in 2021. In 2023, one of the Long Point canals (Figure 11) had a substantial blue-green algal bloom that was quickly treated with the algaecide SeClear® with good success. RLS will continue to evaluate the algal communities in the canals and make site-specific treatment recommendations when extreme blooms occur.

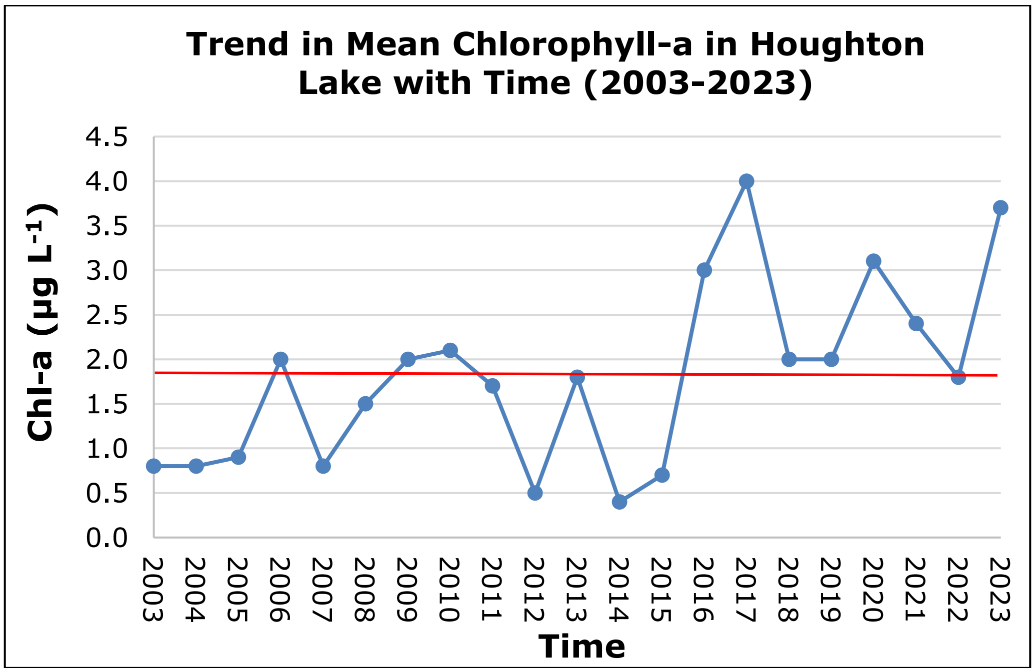

Figure 10. Changes in mean Chl-*a* with time in Houghton Lake (2003-2023).

The blue-green algae, *Microcystis* sp. has been the most prevalent algae in the canals, which is an indicator of poor water quality. The colonies are a few micrometers in diameter and are evenly distributed throughout a gelatinous matrix. Younger colonies are spherical and older ones are more irregularly shaped. There are numerous gas vesicles, and the algae can thrive at the surface with minimal photo-degradation (breaking down) by the sun. When the sunlight is excessive, the algae can break down and release toxins and lower the dissolved oxygen in the water column. The algae are the only type known to fix nitrogen gas into ammonia for growth. *Microcystis* has also been shown to overwinter in lake sediments (Fallon et *al.*, 1981). In addition, it may thrive in a mucilage layer with sediment bacteria that can release phosphorus under anaerobic conditions (Brunberg, 1995). They assume a high volume in the water column (Reynolds, 1984) compared to diatoms and other single-celled green algae. The blue-green algae have been on the planet nearly 2.15 billion years and have assumed strong adaptation mechanisms for survival. In general, calm surface conditions will facilitate enhanced growth of this type of algae since downward transport is reduced. *Microcystis* may also be toxic to zooplankton such as *Daphnia* which was a zooplankton present in Houghton Lake and in most lakes (Nizan et *al.*, 1986). Without adequate grazers to reduce algae, especially blue-greens, the blue-green population will continue to increase and create negative impacts to water bodies. Filamentous algae will also continue to increase in stagnant areas due to high nutrient levels in the lake.

Figure 11. A blue-green algal bloom in one of the Long Point canals (summer, 2023).

In 2023, a sample of algae on a rock was provided to RLS from a Houghton Lake Improvement Board member. The algae on the rock was identified with microscopy to be the green filamentous alga, *Cladophora* (Figure 12). *Cladophora* algae have become problematic in the Great Lakes and in many inland lakes and are considered a symptom of high nutrient loads processed by Zebra mussels (Higgins et *al*., 2008). *Cladophora* nearshore may become a nuisance because it produces strong sewage-like odors in nearshore areas, especially upon decay and may accumulate harmful bacteria such as *E. coli.*

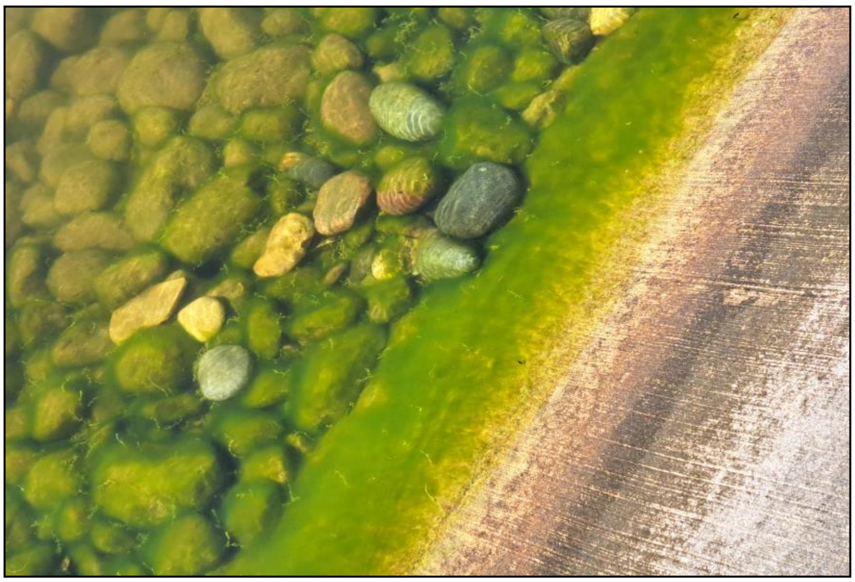

Figure 12. Green filamentous *Cladophora* algae growing on rocks and concrete in Houghton Lake (summer, 2023).

Section

3

Aquatic Vegetation Data (2023)

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 2-30 2023 whole-lake survey using the GPS Point-Intercept method as in Figure 13 below determined that there were a total of 31 native aquatic plant species in Houghton Lake. These included 23 native submersed species, 3 floating-leaved species, and 5 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 has been historically low relative to the lake size due to the great mean depth and thus these plants should be protected. The overall aquatic vegetation biovolume has increased in 2023 which is a positive sign that more low-growing native aquatic plants are thriving. The aquatic plant species found in the main open waters of the lake are shown below in Table 13. Aquatic vegetation biovolume for 2023 is displayed in Figure 14 below.

The EWM was significantly reduced in the Middle Grounds after the ProcellaCOR® treatment in 2019-20; however, the systemic herbicide triclopyr (Renovate 3® at doses of 4-5 gallons per acre) was used in 2021 since the EWM significantly rebounded in the Middle Grounds and use of the same product was not recommended in order to allow for product rotation. The Wild Rice population in the Middle Grounds is showing signs of re-establishment and thus treatments in this area will continue to include protective buffer zones to allow for this establishment.

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. The milfoil in the North Bay has responded very well to treatments and native aquatic plants are increasing in that region as well.

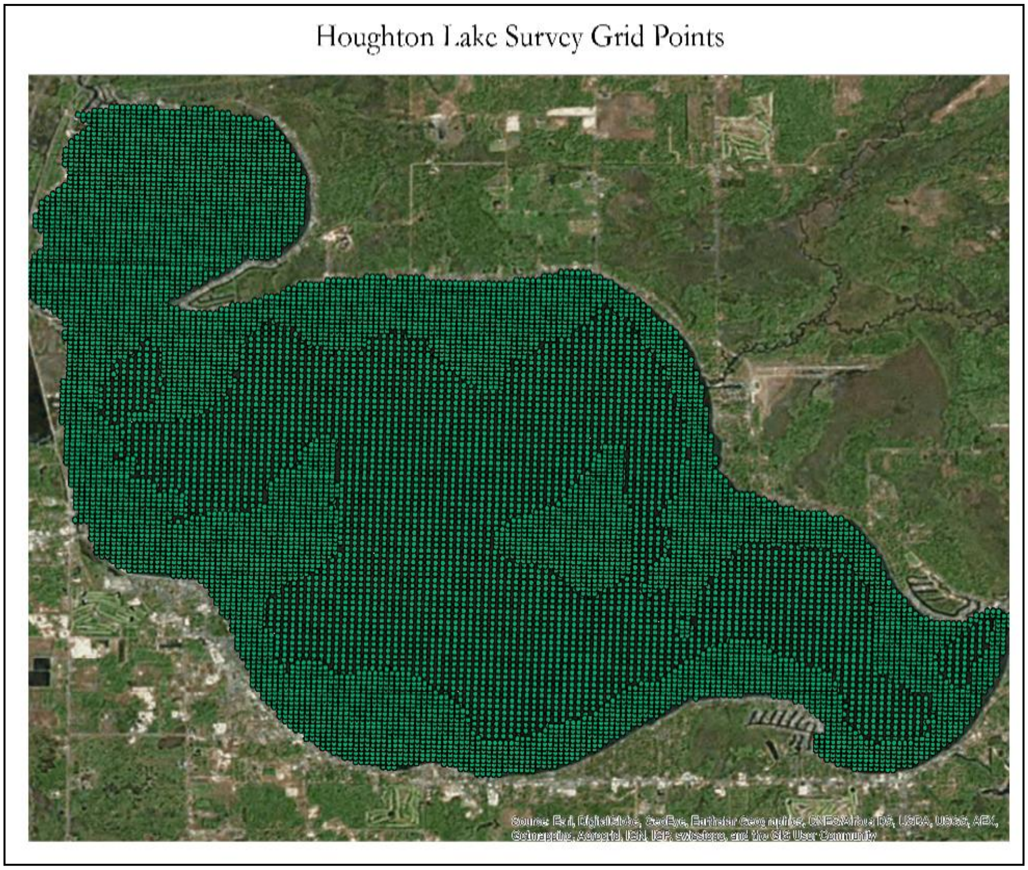

Figure 13. GPS Sampling Points in Houghton Lake (RLS).

Table 13. Native aquatic plant species relative abundance (frequency) in the main portion of the lake with vegetation present excluding canals (June 2-30, 2023).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of total)
Muskgrass	*Chara vulgaris*	273	101	17	0	2.6
Sago Pondweed	*Stuckenia pectinata*	31	17	9	1	<0.1
Flat-stem Pondweed	*Potamogeton zosteriformis*	313	589	247	37	7.9
Fern-leaf Pondweed	*Potamogeton robbinsii*	349	178	42	0	0.04
Thin-leaf Pondweed	*Potamogeton* spp.	501	69	16	0	0.04
Long-leaf Pondweed	*Potamogeton nodosus*	28	27	26	8	0.6
Variable-leaf Pondweed	*Potamogeton gramineus*	27	164	93	10	0.02
White-stem Pondweed	*Potamogeton praelongus*	9	91	44	0	1.0
Clasping-leaf Pondweed	*Potamogeton richardsonii*	469	42	13	7	3.5
Illinois Pondweed	*Potamogeton illinoensis*	710	0	0	1	4.7
Large-leaf Pondweed	*Potamogeton amplifolius*	1425	116	5	1	10.3
Floating-leaf Pondweed	*Potamogeton natans*	8	10	10	0	0.2
Small Pondweed	*Potamogeton pusillus*	38	5	0	0	0.3
Wild Celery	*Vallisneria americana*	0	7	12	1	0.1
Northern Watermilfoil	*Myriophyllum sibiricum*	114	18	0	0	0.9
Whorled Watermilfoil	*Myriophyllum verticillatum*	3	0	8	2	0.1
Coontail	*Ceratophyllum demersum*	47	239	139	6	2.9
Common Waterweed	*Elodea canadensis*	540	750	390	139	12.1
Water Marigold	*Megalodonta beckii*	0	2	0	0	0.01
Bladderwort	*Utricularia vulgaris*	71	105	48	11	1.6
Southern Naiad	*Najas guadalupensis*	76	31	38	0	1.0
Brittle Naiad	*Najas minor*	0	0	1	0	<0.1
Nitella	*Nitella* sp.	146	63	1	0	1.4
White Waterlily	*Nymphaea odorata*	9	0	3	0	0.1
Yellow Waterlily	*Nuphar variegata*	11	0	0	0	0.1
Watershield	*Brasenia schreberi*	4	15	4	0	0.2
Cattails	*Typha latifolia*	9	0	0	0	0.1
Swamp Loosestrife	*Decodon verticillatus*	0	0	0	6	0.04
Bulrushes	*Schoenoplectus acutus*	14	9	0	0	0.2
Pickerelweed	*Pontedaria cordata*	0	2	0	0	0.01
Wild Rice	*Zizania aquatica*	1	3	7	10	0.1

Note: There were a total of 15,000 points surveyed in the littoral zone of the main lake and canals and of those 11,391 contained aquatic plants (76% contained vegetation). The remainder of the points (3,000) fall in deep water zones that lack vegetation.

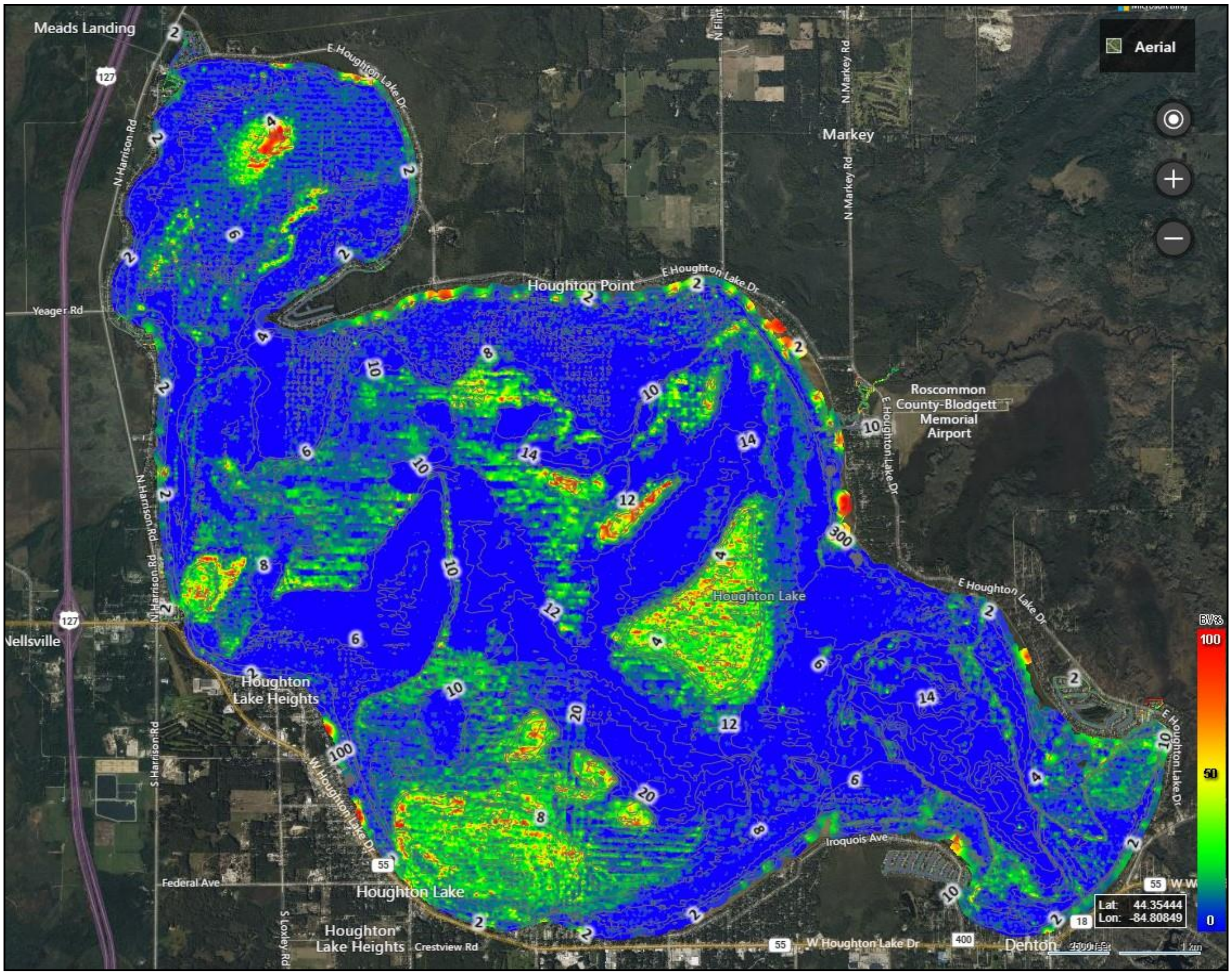

Figure 14. Aquatic vegetation biovolume scan and map of Houghton Lake in June, 2023 (RLS). NOTE: The blue color represents no vegetation present (previously this was displayed as blue and will be in the future); Red color represents tall, high-growing aquatic plants; Green color represents low-growing vegetation on the lake bottom such as *Chara.*

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 15) present in Houghton Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. The climate in 2023 consisted of low rainfall and abundant sunshine. Nutrient concentrations in the lake were lower than in recent years due to less runoff, so presumably less nutrients were available for submersed aquatic vegetation growth. However, an abundance of sunlight encouraged the growth of native aquatic plants throughout the lake basin. The majority of the treatment areas in 2023 were in the canals as growth was limited in the main basin. The 2023 surveys revealed that a total of approximately 74.9 acres of milfoil were found throughout the main lake basin and necessitated treatment. These areas were treated beginning on June 15, 2023 and ending August 9, 2023. Treatments were conducted by PLM with oversight by RLS. Figures 16-26 display critical treatment areas in 2023.

Table 14 below shows the history to date on the amounts of contact and systemic herbicides used in Houghton Lake for milfoil/nuisance growth treatments and in some canals the use of contacts for extremely dense vegetation.

Figure 15. Eurasian Watermilfoil with seed head and lateral branches.

Figure 16. EWM Treatment Area (Long Point)

Figure 17. EWM Treatment Area (Heights Marina)

Figure 18. EWM Treatment Area (West Launch)

Figure 19. EWM Treatment Area (Beebe Canal)

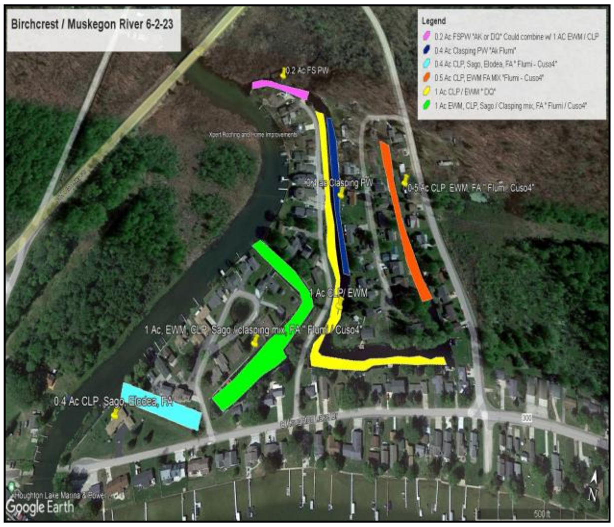

Figure 20. EWM Treatment Areas (Birchcrest Muskegon River)

Figure 21. EWM Treatment Area (Chippewa Canals)

Figure 22. Cut River Treatment

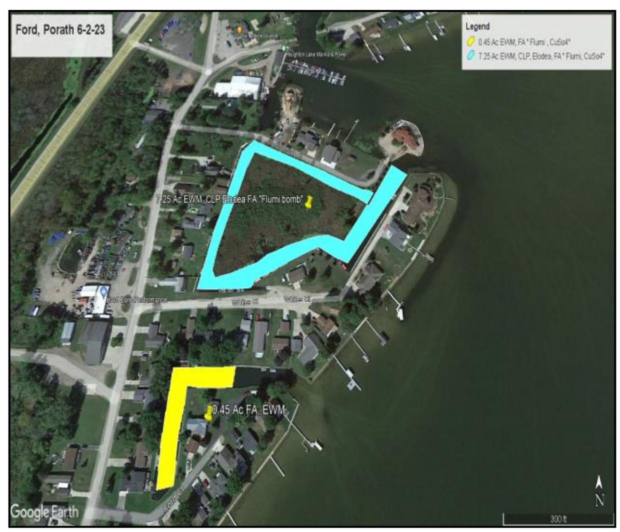

Figure 23. EWM Treatment Area (Porath Canals)

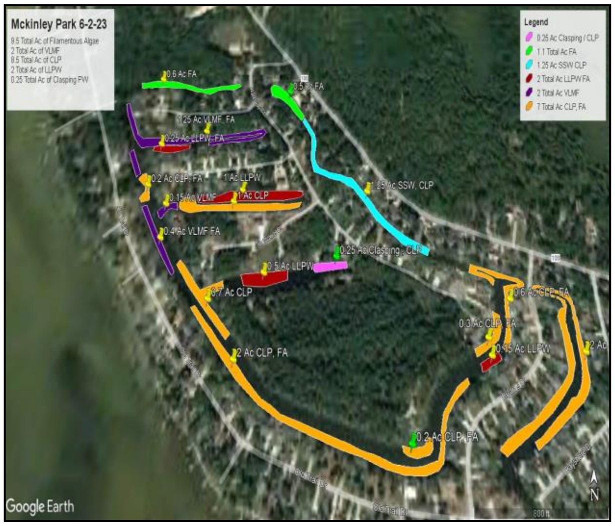

Figure 24. EWM Treatment Areas
(McKinley Park Canals)

Figure 25. EWM Treatment areas
(Long Point Canals)

Figure 26. EWM Treatment
(Swick, Church, Siebert, Fox Canals)

Table 14. A table showing the accumulative treatment history of Houghton Lake (2015-2023). This table will be appended in the 2024 report with 2024 data in the report main body.

Houghton Lake Treatment History

Year	Date	Product	target species	Rate/ Acre	unit	Acre s	Total Product	unit	% active ingredi-ent	Total active used	unit
2023	15-Jun	Aquathal K	CLP/EWM	1.5	gals	74.67	11.5	gals	40.30%	4.6	gals
		Flumioxazin	EWM/SSW	1.33	lbs	62	82.5	lbs	51%	42	lbs
		Diquat	EWM/CLP	1.42	gal	68.52	89	gals	37.30%	33.9	gals
	29-Jun	Diquat	EWM	1	gal	0.25	0.25	gals	37.30%	0.09	gals
	18-Jul	ProcellaCOR	EWM	54.42	oz	27.5	1496.39	oz	2.70%	40.4	oz
		Renovate 3	EWM	4.5	gals	309	1410	gals	44.40%	626.04	gals
		Flumioxazin	SSW/EWM	3	lbs	6.6	20	lbs	51%	10.2	lbs
	9-Aug	SeClear G	Pl. Algae	20	lbs	9	180	lbs	58.90%	106	lbs
2022	23-Jun	Flumioxazin	EWM	1.26	lbs	55	70	lbs	51%	35.7	lbs
		Diquat	EWM	1	gal		55	gal	37.30%	20.51	gal
	29-Jun	Flumioxazin	EWM	1.5	lbs	2.6	4	lbs	51%	2.04	lbs
		Diquat	EWM	1.5	gal		4	gal	37.30%	1.49	gal
	14-Jul	Renovate 3	EWM	1	gal	107	321	gal	44.40%	142.5	gal
		Renovate 3	EWM	1.334	gal	349	1396	gal	44.40%	619.82	gal
		Renovate 3	EWM	1.667	gal	95	475	gal	44.40%	210.9	gal
	16-Aug	Flumioxazin	EWM	3	lbs	1.167	3.5	lbs	51%	1.78	gal
		Diquat	EWM	1	gal	0.25	0.25	gal	37.30%	0.093	gal
		Renovate 3	EWM	6	gal	215	1290	gal	44.40%	572.76	gal
	23-Aug	Renovate 3	EWM	5	gal	27	135	gal	44.40%	59.94	gal
		Sculpin G	EWM	200	lbs	5	1000	lbs	20%	200	lbs
2021	15-Jun	Flumioxazin	EWM	3	lbs	14.5	64	lbs	51%	32.64	lbs
		Diquat	EWM	1	gal	14.5	14.5	gal	37.30%	5.4	gal
		SeClear G	SSW/Algae	20	lbs	2.5	50	lbs	58.90%	29.45	lbs
	16-Jun	Flumioxazin	EWM	3	lbs	3.34	10	lbs	51%	5.1	lbs
		Renovate 3	EWM	5	gal	100	500	gal	44.40%	222	gals
		Renovate 3	EWM	4	gal	400	1600	gal	44.40%	710.4	gals
		Diquat	EWM	0.5	gal	500	250	gal	37.30%	93.25	gals
		Diquat	EWM	1	gal	1.5	1.5	gal	37.30%	0.55	gals
	24-Jun	Flumioxazin	EWM	3	lbs	6	18	lbs	51%	9.18	gals
		Diquat	EWM	1.5	gal	5	7.5	gal	37.30%	2.79	gals
	8-Jul	Flumioxazin	EWM	3	lbs	2.67	8	lbs	51%	4	lbs
		Diquat	EWM	1	gals	2.5	2.5	gal	37.30%	0.93	gal
		Phoslock	Phosphorus	45.5	lbs	24.8	1127.5	lbs			
	14-Jul	Sculpin G	EWM	240	lbs	50	12000	lbs	20%	2400	lbs
		SeClear G	Algae	20	lbs	3.25	65	lbs	58.90%	38.28	lbs
	2-Aug	Phoslock	Phosphorus	45.5	lbs	24.8	1127.5	lbs			
	24-Aug	Flumioxazin	EWM	2.3	lbs	0.75	1.75	lbs	51%	0.89	lbs
		Sculpin G	EWM	240	lbs	65	15600	lbs	20%	3120	lbs
		Diquat	EWM	1	gal	0.75	0.75	gal	37.30%	0.27	gals
	31-Aug	Renovate 3	EWM	5	gal	490	2450	gal	44.40%	1087.8	gals
		Diquat	EWM	0.5	gal	490	241	gal	37.30%	89.89	gals
	16-Sep	Flumioxazin	EWM	3	lbs	1.5	1.5	lbs	51%	0.76	gals

Year	Date	Product	target species	Rate/ Acre	unit	Acres	Total Product	unit	% active ingredi- ent	Total active used	unit
2020	24-Jun	Flumioxazin	EWM	3.2	lbs	15	48	lbs	51%	24.48	gals
		Sculpin G	EWM	240	lbs	74	17760	lbs	20%	3552	gals
		Diquat	EWM	1	gal	15	15	gal	37.30%	5.59	gals
	29-Jun	ProcellaCOR	EWM	12.68	oz	55	697.4	oz	2.70%	18.8	oz
		Flumioxazin	EWM	3.15	lbs	37.5	118	lbs	51%	60.18	lbs
		Diquat	EWM	1	gal	32.5	32.5	gal	37.30%	12.12	gals
	27-Jul	Flumioxazin	EWM	3.2	lbs	5.8	18.5	lbs	51%	9.43	lbs
		SeClear G	SSW	50	lbs	5.7	285	lbs	58.9%	167.8	lbs
		Diquat	EWM	1	gal	4	4	gals	37.30%	1.49	gals
	30-Jul	Flumioxazin	EWM	3	lbs	2.4	7.2	lbs	51%	3.67	lbs
		Renovate OTF	EWM	80	lbs	20.5	1640	lbs	14%	229.6	lbs
		Sculpin G	EWM	240	lbs	66.67	16000	lbs	20%	3200	lbs
		Diquat	EWM	1.5	gals	2.4	3.6	gals	37.30%	1.34	gals
	3-Aug	SeClear G	SSW	50	lbs	2	100	lbs	58.90%	58.9	lbs
	1-Sep	ProcellaCOR	EWM	12.68	oz	7	88.76	oz	2.70%	23.96	oz
		Sculpin G	EWM	240	lbs	12.5	30120	lbs	20%	6024	lbs
		Diquat	EWM	1	gal	7	7	gals	37.30%	2.611	gals
2019	20-Jun	Flumioxazin	EWM	3.15	lbs	7.7	24.15	lbs	51%	12.31	lbs
	26-Jun	ProcellaCOR	EWM	15.85	oz	16	1521.6	oz	2.70%	42.14	oz
		ProcellaCOR	EWM	10.018	oz	147	7367.08	oz	2.70%	198.91	oz
		Sculpin G	EWM	240	lbs	145	34800	lbs	20%	6960	lbs
		Flumioxazin	EWM	3.12	lbs	2.5	7.8	lbs	51%	3.97	lbs
		Diquat	EWM	1.52	gals	2.5	3.8	gals	37.30%	1.41	gals
	31-Jul	Flumioxazin	EWM	3.15	lbs	3.85	12	lbs	51%	6.12	lbs
		Sculpin G	EWM	200	lbs	109	21800	lbs	20%	4360	lbs
2018	31-Jul	Flumioxazin	SSW	6.37	lbs	3.2	20	lbs	51%	10.2	lbs
		Sculpin G	EWM	220	lbs	8.7	1920	lbs	20%	384	lbs
		Diquat	EWM	1.5	gal	18	27	gal	37.30%	10.07	gals
	1-Aug	Sculpin G	EWM	200	lbs	439.8	87960	lbs	20%	17592	lbs
		Sculpin G	EWM	240	lbs	20	4800	lbs	20%	960	lbs
	8-Aug	Sculpin G	EWM	240	lbs	9	2160	lbs	20%	432	lbs
		ProcellaCOR	EWM	19.31	oz	289	5580.66	oz	2.70%	150.67	oz
		ProcellaCOR	EWM	28.53	oz	118	3366.54	oz	2.70%	90.89	oz
	14-Aug	Flumioxazin	EWM	5.99	lbs	1.67	10	lbs	51%	5.1	lbs
		Diquat	EWM	1.52	gals	3.3	5	gals	37.30%	1.865	gals
2017	9-Aug	Renovate 3	EWM	2	gals	36	71.75	gals	44.40%	31.85	gals
		Diquat	EWM	2	gals	5.38	10.75	gals	37.30%	4	gals
	9-Aug	Renovate OTF	EWM	81	lbs	50	4050	lbs	14%	567	lbs
		Renovate OTF	EWM	108	lbs	50.8	5450	lbs	14%	763	lbs
		Renovate OTF	EWM	135	lbs	100	13500	lbs	14%	1890	lbs
		Sculpin G	EWM	250	lbs	24	6000	lbs	20%	1200	lbs
	15-Aug	Flumioxazin	EWM	4	lbs	0.25	1	lb	51%	0.51	lbs
	12-Sep	Flumioxazin	EWM	3	lbs	0.033	0.1	lb	51%	0.05	lbs
	2-Oct	Sculpin G	EWM	200	lbs	210	42000	lbs	20%	8400	lbs

Year	Date	Product	target species	Rate/ Acre	unit	Acres	Total Prod-uct	unit	% active ingredi-ent	Total active used	unit
2016	7-Sep	Flumioxazin	SSW	3.15	lbs	46	145	lbs	51%	73.95	lbs
		Renovate OTF	EWM	82	lbs	63.5	5160	lbs	14%	722.4	lbs
		Sculpin G	EWM	200	lbs	41	8200	lbs	20%	1640	lbs
	14-Sep	Flumioxazin	SSW	3.15	lbs	403.9	1272.5	lbs	51%	648.97	lbs
		Renovate OTF	EWM	81	lbs	224	18144	lbs	14%	2540	lbs
		Renovate OTF	EWM	200	lbs	9.28	1856	lbs	14%	259	lbs
		Sculpin G	EWM	200	lbs	161	32200	lbs	20%	6440	lbs
	20-Sep	Renovate OTF	EWM	202	lbs	7.33	1480	lbs	14%	207	lbs
2015	10-Jun	Flumioxazin	EWM	4.77	lbs	64	101.75	lbs	51%	51.89	lbs
		Renovate OTF	EWM	180	lbs	0.88	160	lbs	14%	22.4	lbs
		Diquat	EWM	1	gal	64	64	gals	37.30%	23.87	lbs
	29-Jul	Flumioxazin	EWM	3.6	gals	0.5	0.6	lbs	51%	0.3	lbs
	6-Sep	Renovate OTF	EWM	200	lbs	100	20000	lbs	14%	2800	lbs
		Sculpin G	EWM	200	lbs	300	60000	lbs	20%	12000	lbs
	9-Sep	Sculpin G	EWM	200	lbs	200	40000	lbs	20%	8000	lbs

Section

4

Houghton Lake Sediment Aquatic Macroinvertebrates

RLS scientists collected sediment macroinvertebrate communities from the North Bay, Central Basin, and South Bay on October 10, 2023 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 15-17 list all of the aquatic macroinvertebrates found during the sampling. Figure 27 displays a Water Strider which is rare in Houghton Lake as they are usually on the surface but have been found in benthic samples.

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 10, 2023 samples demonstrated 12 different taxa in the lake sediments and this number is likely to fluctuate among seasons due to changes in environmental and climatic conditions. Thus, future preservation is important since these organisms support the lake food chain and fishery. In 2023, the Central Basin had the highest macroinvertebrate count followed by the North Basin. Taxa found in the samples included:

1. Pond snails
2. Mayfly larvae
3. Sow bugs
4. Wheel snails
5. Dragonfly larvae
6. Midge larvae
7. Caddisfly larvae
8. Flatworms
9. Crane fly larvae
10. Damselfly larvae
11. Predaceous water beetles
12. Water strider

Figure 27. A Water Strider.

Table 15. Houghton Lake sediment macroinvertebrate sampling data from the North Bay (October 10, 2023).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	4	Crane fly larvae
		Ephemeroptera	Ephemeridae	2	Mayfly larvae
		Planaria	Planariidae	2	Flatworms
		Diptera	Chironomidae	23	Midge larvae
		Gastropoda	Physidae	1	Pond snails
		Coleoptera	Dytiscidae	1	Predaceous water beetle
		Gastropoda	Planorbidae	10	Wheel snails
			Total	**43**	
Sample 2	**Grab**	**Order**	**Family/Genus**	**Number**	**Common Name**
		Gastropoda	Physidae	9	Pond snails
		Ephemeroptera	Ephemeridae	2	Mayfly larvae
		Isopoda	Asellidae	8	Sow bugs
		Diptera	Tipulidae	2	Crane fly larvae
		Gastropoda	Planorbidae	15	Wheel snails
		Odonata	Coenagrionidae	1	Damselfly larvae
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	16	Midge larvae
			Total	**55**	

Table 16. Houghton Lake sediment macroinvertebrate sampling data from the Central Basin (October 10, 2023).

Sample 1	Grab	Order	Family/Genus	Count	Common name
		Diptera	Tipulidae	9	Crane fly larvae
		Ephemeroptera	Ephemeridae	11	Mayfly larvae
		Diptera	Chironomidae	13	Midge larvae
		Odonata	Coenagrionidae	4	Damselfly larvae
		Gastropoda	Planorbidae	9	Wheel snails
		Hemiptera	Gerridae	1	Water Strider larvae
			Total	**47**	
Sample 2	**Grab**				
		Gastropoda	Physidae	8	Pond snails
		Ephemeroptera	Ephemeridae	8	Mayfly larvae
		Gastropoda	Coenagrionidae	5	Damselfly larvae
		Gastropoda	Planorbidae	16	Wheel snails
		Isopoda	Asellidae	5	Sow bugs
		Diptera	Chironomidae	11	Midge larvae
		Diptera	Tipulidae	6	Crane fly larvae
			Total	**59**	

Table 17. Houghton Lake sediment macroinvertebrate sampling data from the South Basin (October 10, 2023).

Sample 1	Grab	Order	Family/Genus	Number	Common name
		Diptera	Tipulidae	3	Crane fly larvae
		Gastropoda	Planorbidae	14	Wheel Snails
		Ephemeroptera	Ephemeridae	1	Mayfly larvae
		Diptera	Chironomidae	13	Midge larvae
		Gastropoda	Physidae	6	Pond snails
		Trichoptera	Phryganeidae	1	Caddis fly larvae
		Isopoda	Asellidae	11	Sow Bugs
			Total	**49**	
Sample 2	**Grab**				
		Gastropoda	Physidae	6	Pond snails
		Ephemeroptera	Ephemeridae	3	Mayfly larvae
		Gastropoda	Planorbidae	11	Wheel snails
		Odonata	Aeshniidae	2	Dragonfly larvae
		Diptera	Chironomidae	16	Midge larvae
		Trichoptera	Phryganeidae	4	Caddis fly larvae
			Total	**42**	

Section

5

2023 Wild Rice Restoration Update and 2024 Restoration Recommendations:

Previously, 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. Conditions in the Muddy Bay region were ideal for Wild Rice with shallow depths and highly organic bottom substrate. A total of 108 geo-referenced GPS points were recorded and randomly selected from within the 50-acre area for data recording. 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. A follow-up survey of this seeded area occurred on May 17, 2021 to carefully monitor the efficacy of the Wild Rice planting. Table 18 below displays the data collected which includes the presence of 7 native submersed aquatic plants in addition to the emergent Wild Rice. Wild Rice was the most dominant aquatic plant present, occupying around 98.8% of the sampling sites. This was a very successful germination. A second survey (Table 19) was conducted on May 13, 2022 and determined that the Wild Rice population had declined to 12.5% of the sampling sites and invasive hybrid Eurasian Watermilfoil occupied 37.5% of the sampling sites. The most recent survey on May 26, 2023 (Table 20) revealed 8.8% of the sampling sites contained Wild Rice and milfoil had declined to 13.8%.

During the summer of 2023, Wild Rice began to naturally re-colonize the Middle Grounds with over 4 acres of active growth (Figure 28). May of the plants developed healthy seeds (Figure 29) where some dropped to the lake bottom and others were consumed by waterfowl. RLS will be monitoring this population in 2024 and it is likely to increase if the milfoil remains controlled from previous intensive systemic herbicide treatments. It is possible that the Middle Grounds may not require seeding in 2024 due to natural germination.

However, viable stems of Wild Rice were noted in North Bay and that area is a favorable candidate for seeding in 2024. Muddy Bay may be prone to excessive scouring from ice and also intense winds due to its position in the lake basin relative to the fetch.

In addition to the surveys conducted, RLS also collected a total of 12 sediment samples using an Ekman hand dredge in the lake basin and in areas with Wild Rice present. These sediment samples were analyzed for sediment percentage of organic matter (carbon) and nutrients such as phosphorus and inorganic nitrogen. The results indicated that there were no significant differences in mean sediment organic matter between the Wild Rice and main basin sites. However, the Wild Rice sites contained significantly higher mean concentrations of ammonia and phosphorus in the sediments. This indicates rationale for the presence of Wild Rice beds in specific areas of Houghton Lake and is useful for consideration of possible future planting sites for successful germination and survival. This research was presented at the October, 2023 NALMS conference in Erie, PA. It is currently in the process of being prepared and submitted for publication in a peer-reviewed scientific journal.

Figure 28. Rigorous natural Wild Rice growth emergent in the Middle Grounds of Houghton Lake (summer, 2023).

Figure 29. A mature and seeding Wild Rice plant in the Middle Grounds of Houghton Lake (summer, 2023).

Table 18. Aquatic vegetation survey data for the Wild Rice seeded area of Muddy Bay on May 17, 2021.

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of N=80 sites)
Muskgrass	***Chara vulgaris***	2	2	0	0	5.0
Curly-leaf Pondweed	***Potamogeton crispus***	21	19	9	0	61.3
Flat-stem Pondweed	***Potamogeton zosteriformis***	1	0	0	0	1.3
White-stem Pondweed	***Potamogeton praelongus***	1	0	0	0	1.3
Illinois Pondweed	***Potamogeton illinoensis***	12	17	0	0	36.3
Common Waterweed	***Elodea canadensis***	3	1	0	0	5.0
Southern Naiad	***Najas guadalupensis***	0	1	0	0	1.3
Wild Rice	***Zizania palustris***	4	48	27	0	98.8

Table 19. Aquatic vegetation survey data for the Wild Rice seeded area of Muddy Bay on May 13, 2022.

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of N=80 sites)
Muskgrass	***Chara vulgaris***	33	11	0	0	55.0
Hybrid Watermilfoil	***Myriophyllum spicatum* var. *sibiricum***	15	15	0	0	37.5
Fern-leaf Pondweed	***Potamogeton robbinsii***	1	0	0	0	1.3
Common Waterweed	***Elodea canadensis***	1	0	0	0	1.3
Southern Naiad	***Najas guadalupensis***	0	1	0	0	1.3
Wild Rice	***Zizania palustris***	10	0	0	0	12.5

Table 20. Aquatic vegetation survey data for the Wild Rice seeded area of Muddy Bay on May 26, 2023.

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	# Sites Found (% of N=80 sites)
Muskgrass	***Chara vulgaris***	12	6	1	0	23.8
Curly-leaf Pondweed	***Potamogeton crispus***	6	2	2	1	13.8
Illinois Pondweed	***Potamogeton illinoensis***	18	1	4	0	28.8
Hybrid Watermilfoil	***Myriophyllum spicatum* var. *sibiricum***	8	2	1	0	13.8
Fern-leaf Pondweed	***Potamogeton robbinsii***	1	1	0	0	2.5
Common Waterweed	***Elodea canadensis***	2	1	0	0	3.8
Southern Naiad	***Najas guadalupensis***	6	1	2	1	12.5
Wild Rice	***Zizania palustris***	3	3	1	0	8.8

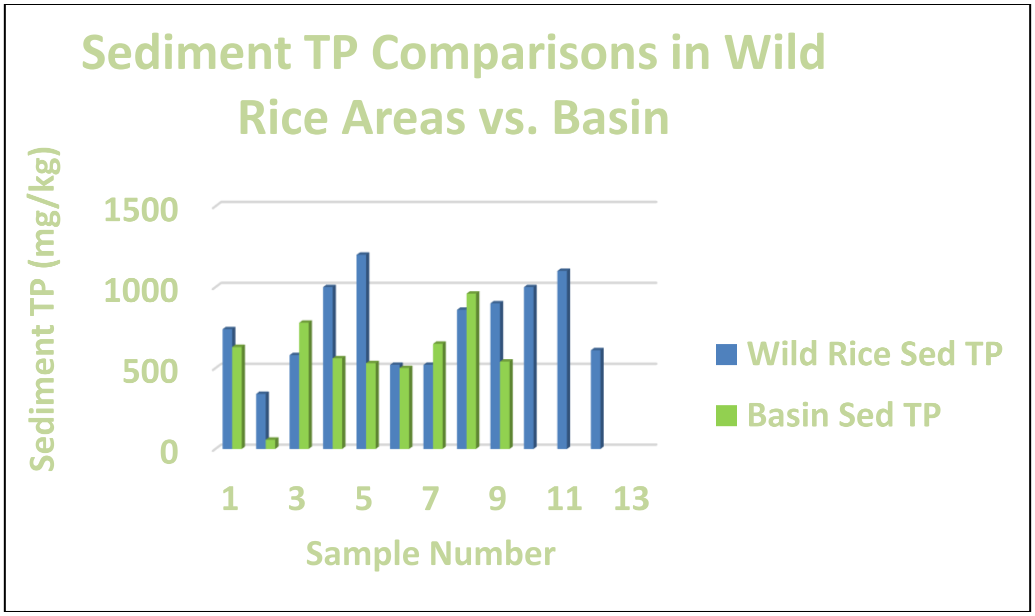

Figure 30. Differences in sediment TP in Wild Rice areas relative to lake basin sites (2023).

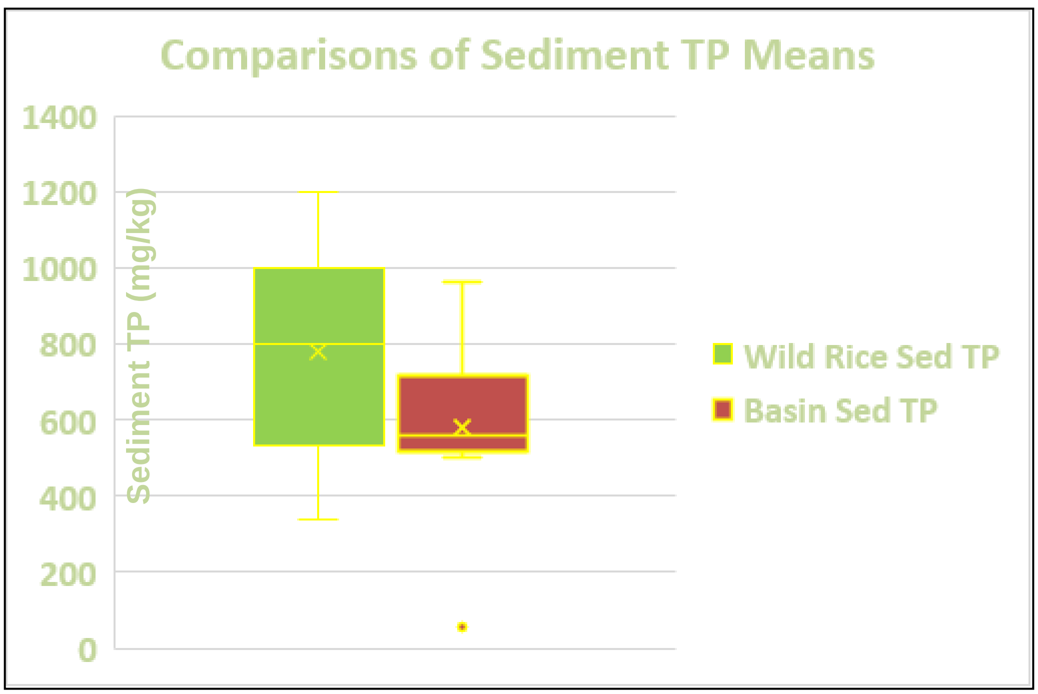

Figure 31. Differences in sediment TP means in Wild Rice areas relative to lake basin sites (2023).

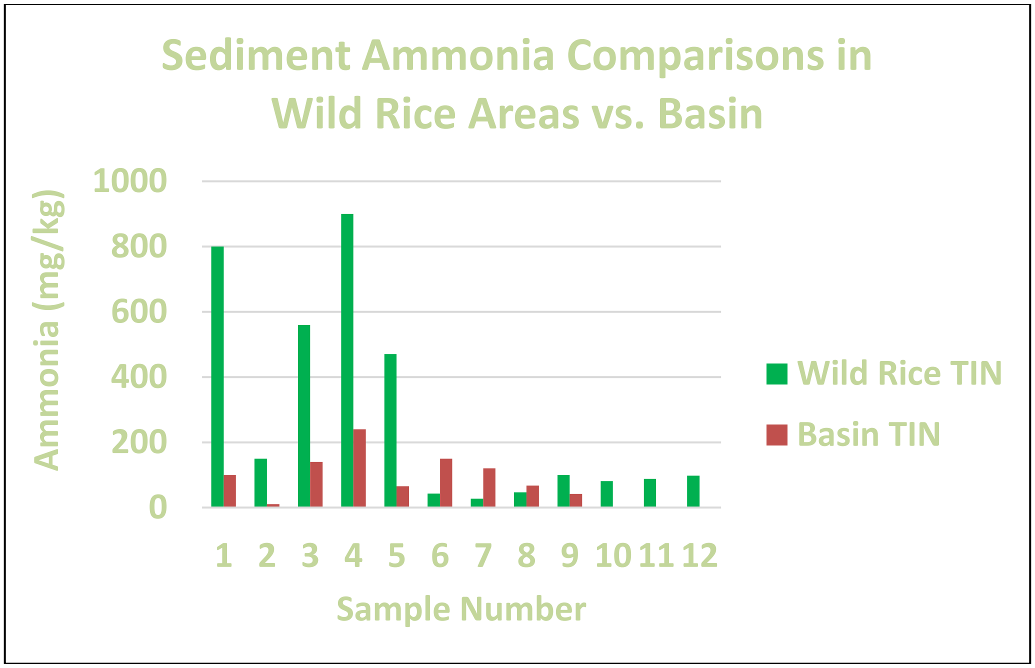

Figure 32. Differences in sediment ammonia in Wild Rice areas relative to lake basin sites (2023).

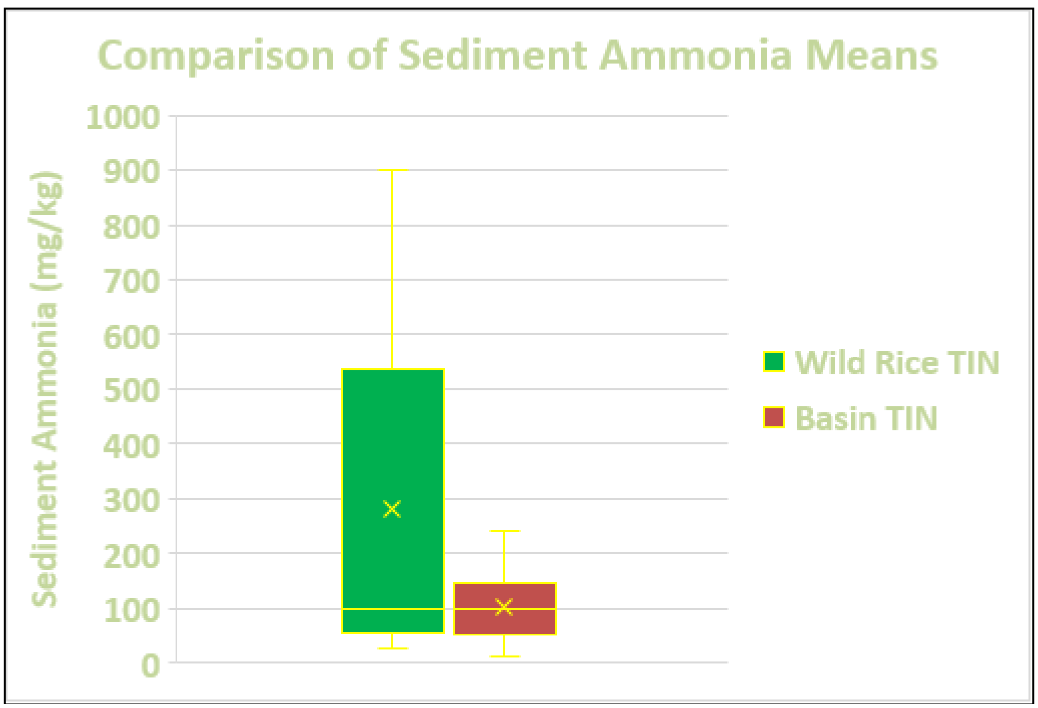

Figure 33. Differences in sediment ammonia means in Wild Rice areas relative to lake basin sites (2023).

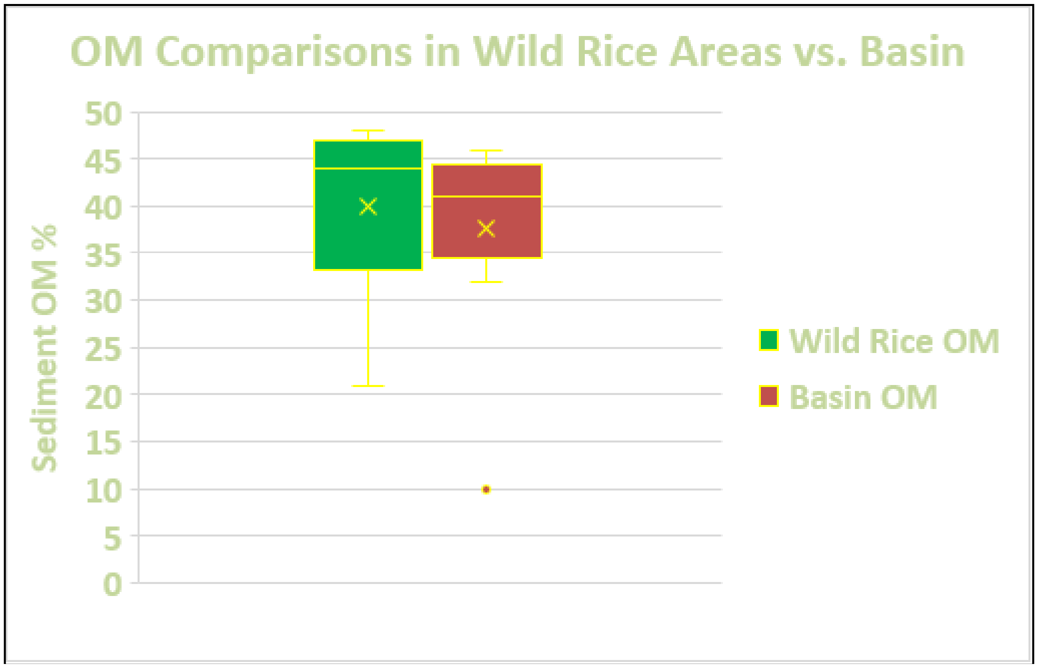

Figure 34. Differences in sediment organic matter (carbon) means in Wild Rice areas relative to lake basin sites (2023).

Section

6

Management Recommendations for 2024-2026

As previously recommended in the 2022 Houghton Lake Improvement Feasibility Study report, RLS has recommended the following management activities for 2022-2026 as critical components for a continuing lake improvement (management) program. The primary and secondary goals of these management activities are shown below in Table 21. Ongoing proposed costs for 2024-2026 are displayed below in Table 22.

1. Whole-lake Aquatic Vegetation Surveys & Scans:

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 will include a whole lake inventory in late June-early July 2022-2026 and partial surveys post-treatment as needed. The canals and Middle Grounds as well as the southwest regions of the lake may require earlier surveys beginning in mid to late May, depending on climatic conditions. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2024 as in previous years. Treatment results will then be compared with previous years in the 2024 annual lake report.

2. Aquatic Herbicide Treatments for Invasive Species in the Main Lake and Canals:

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 2022-2026 includes the use of high doses of systemic aquatic herbicides (such as triclopyr, 2,4-D, and/or ProcellaCOR® 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. Use of it may be alternated with other products to allow for reduced probability of tolerance. It has been particularly favorable as a product in rotation with triclopyr in the Middle Grounds where Wild Rice is showing strong natural germination and growth.

3. Phoslock® Treatment of Select Canals:

The presence of toxic blue-green algal blooms is a threat to the health of some canals and pets that may drink from them. RLS recommended and evaluated the innovative product Phoslock® on the McKinley Canal System in 2021. Overall, the product showed significant reductions in blue-green algal concentrations. In 2023, the Long Point canal had a significant blue-green algae bloom as was promptly treated with SeClear with positive visible and measurable results. RLS will continue to evaluate all canals that may need this treatment.

4. Benthic Barriers and Weed Rollers:

Both of these technologies are simple to install and may be used in nearshore areas to reduce and/or prevent germination of submersed aquatic vegetation in beach areas and around docks. They act to reduce germination of all aquatic plants and lead to a local area free of most aquatic vegetation. Benthic barriers may come in various sizes between 100-400 feet in length. They are anchored to the lake bottom to avoid becoming a navigation hazard. The implementation of a benthic barrier mat requires a minor permit from EGLE which can cost around $50-$100. The cost of the barriers varies among vendors but can range from $100-$1,000 per mat. Benthic barrier mats can be purchased online at: www.lakemat.com or www.lakebottomblanket.com. The efficacy of benthic barrier mats has been studied by Laitala et *al.* (2012) who report a minimum of 75% reduction in invasive milfoil in the treatment areas. Lastly, benthic barrier mats should not be placed in areas where fishery spawning habitat is present and/or spawning activity is occurring.

Weed Rollers are electrical devices which utilize a rolling arm that rolls along the lake bottom in small areas (usually not more than 50 feet) and pulverizes the lake bottom to reduce germination of any aquatic vegetation in that area. They can be purchased online at: www.crary.com/marine or at: www.lakegroomer.net.

5. Mechanical Harvesting in Select Areas:

The use of a mechanical harvesting machine may continue to be needed for problem areas with extremely dense aquatic vegetation such as the Beebe Canal or other canals. This method is often preferred when the quantity of biomass is so large that contact herbicides may cause an unacceptable decline in dissolved oxygen in the water column upon rapid decay. This may not be needed every year but will be evaluated on an as-needed basis. Permission is obtained from John Hanes with the Wastewater Treatment Authority to dump on their property. The exact location is the facility off of Knapp and Old HW27 on the SW end of Houghton Lake.

6. 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 evaluations in 2021 showed great success with germination. A follow-up survey in 2023 revealed that continued germination had declined, and this could be attributed to ice scouring and wind fetch due to the position in the lake basin and the very shallow depths. Surprisingly, Wild Rice colonization was naturally strong in the Middle Grounds in 2023 and detailed surveys will be conducted in 2024 to evaluate additional colonization and re-growth. If the population there declines, RLS may recommend additional seeding in the fall of 2024. The North Bay would also be a suitable candidate for future seedings. RLS is actively working on a scientific publication/peer-reviewed paper with Dr. Herron on this project as it contributes to lake restoration efforts and will share with the community and HLIB when completed. Additional research on the lake sediments in 2023 revealed that sites where Wild Rice is present contained higher concentrations of ammonia nitrogen and phosphorus than uncolonized areas in the lake basin.

7. Boat Washing Stations:

RLS has recommended installation of boat washing stations at all points of entry to reduce the presence of invasive species into and out of Houghton Lake. Although this equipment is not patrolled regularly, it is of benefit if it is available for use. The HLIB and HLA are working together to determine the average use of each station and plan to promote increased use over time. This technology in an important tool for reducing herbicide treatment costs in the future.

8. Water Quality & Macroinvertebrate Monitoring:

Water quality parameters from the lake will also be monitored and graphed with historical data annually 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. Sediment macroinvertebrates are good indicators of lake health and regular assessments allow for determination of lake health over time.

9. 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 2019-2021, 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 in upcoming years.

Table 21. Primary and Secondary Management Goals and Activities for each year of the 2022-2026 Houghton Lake Improvement Program.

Lake Management Activity	Primary Goal	Secondary Goal	Best Locations to Use
Aquatic herbicide treatment of hybrid milfoil	To reduce areas where the milfoil is prominent	To prevent dense areas from spreading in the lake	Main lake & canals
Aquatic Herbicide treatment of Starry Stonewort	To reduce areas where it is dense	To prevent plant from carpeting lake bottom	Main lake & canals
Mechanical Harvesting	Reduce dense areas in problem canals	Reduce DO depletion in canals	Canals
Benthic Barriers/Weed Rollers	To prevent germination of nuisance weeds in beach areas or canals	To reduce dependency on chemicals in nearshore areas	Beach areas, canals
Wild Rice Cultivation	To allow for new growth of Wild Rice in previously colonized areas	To increase biodiversity of native aquatic vegetation	Middle Grounds, North Bay, Muddy Bay
Phoslock® of canals	To reduce presence of blue-green blooms in problem canals	To reduce nutrients that exacerbate blue-green blooms	Canals (especially MKP-5 canal system and Long Point canal as needed)
Lake Vegetation Surveys/Scans	To determine % cover by invasives and use as data tool for management	To compare year to year reductions in invasive vegetation areas	Main lake, canals
Boat Washing Stations	To clean boats of invasives before entering the lake	To educate boaters on the proper cleaning of boats and on invasives	All points of access as funding becomes available
Water Quality Lake & Tributary Monitoring	To troubleshoot areas that have poor water quality	To compare trend in water quality parameters with time	Main Lake, canals, tributaries
Macroinvertebrate Sampling	To determine changes in community structure as food source annually	To determine if herbicides have an impact on populations	Areas consistently sampled annually in main lake
Educational Outreach	To educate riparians and lake users on current lake health	To promote citizen lake protection	Proposed workshops in program years

Table 22. Proposed Houghton Lake improvement costs for the five year program.

Proposed Houghton Lake Management Improvement Item	*Estimated 2024-2026 Cost*
Herbicides for Hybrid Watermilfoil and Starry Stonewort and/or DASH Boat removal of invasives, Permit Fees	$580,000
Professional Limnologist Services (limnologist surveys, sampling, contractor oversight, education)	$75,000
Attorney Fees	$2,500
Assessment Roll Mgmt.	$4,000
Board Audit	$3,400
Conferences	$1,000
Insurance	$2,600
Memberships	$200
Printing/Publishing	$4,000
Board Secretary	$4,200
Board Treasurer	$3,000
Office Supplies & Rent	$2,100
Publications/Postage	$3,250
Refunds	$500
Travel Expenses	$250
Boat Washing Support	$20,000

TV/Radio	$12,000
Wild Rice Restoration	$10,000
Contingency (15%)	$110,220
TOTAL ANNUAL ESTIMATED COST	$837,200
APPROX. ANNUAL COST PER UNIT OF BENEFIT	$183.27

Section

7

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