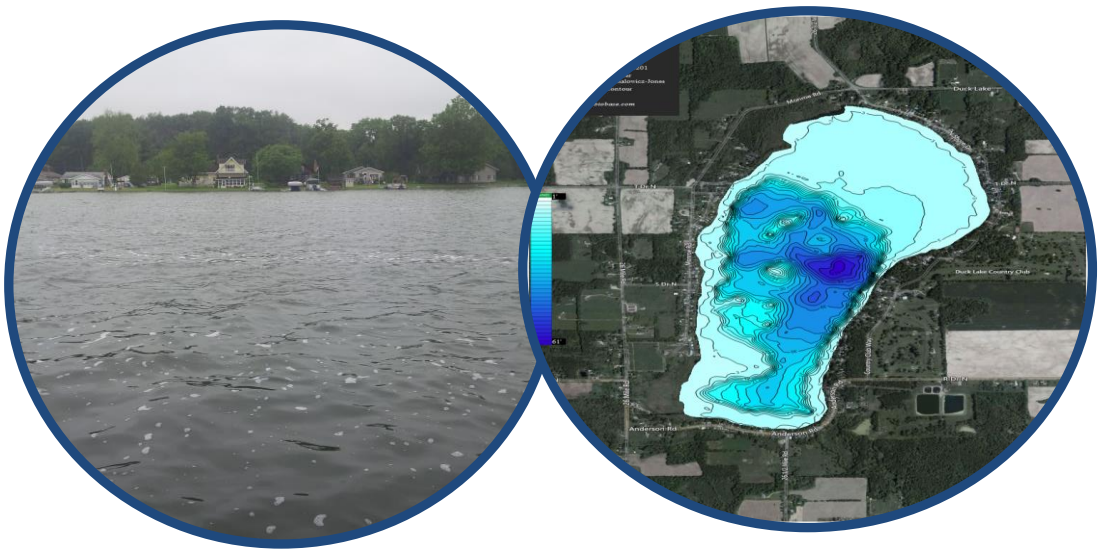
Restorative Lake Sciences™

Duck Lake 2016 Aquatic Vegetation & Water Quality Report & 2017 Management Recommendations



October, 2016

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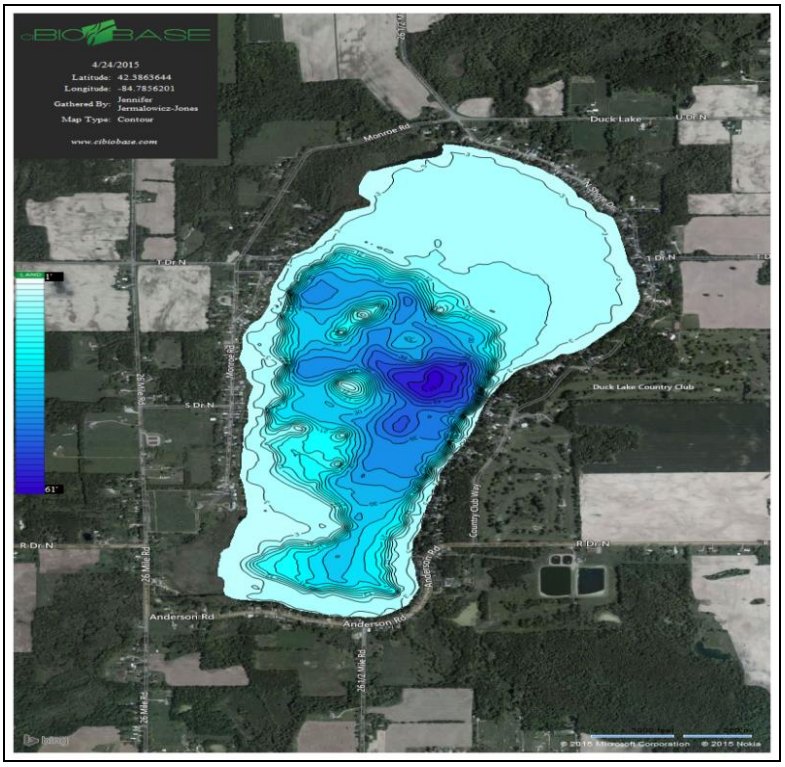

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Duck Lake 2016 Aquatic Vegetation & Water Quality Report & 2017 Management Recommendations

The following information is a summary of key lake findings collected during 2016.

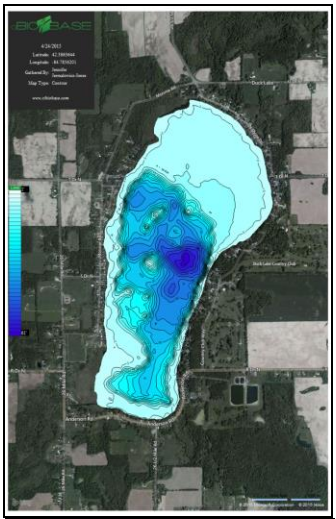
The overall condition of Duck Lake is ranked in the top 35% of developed lakes of similar size in the state of Michigan. **The water clarity ranged between 14-19 feet in 2016 which is very good.** Some of this clarity is due to filtration of the water by Zebra Mussels; however, the majority of the clarity is due to coarse bottom sediment that does not create silty, turbid conditions when high wave or boat activity agitates the lake water. Additionally, the lake has enough nutrients (phosphorus and nitrogen) to support some algae and submersed aquatic plant growth, but the nutrient levels are considered moderate. Invasive species such as Eurasian Watermilfoil (EWM) are able to grow in moderate nutrient waters and thus are a challenge to the Duck Lake ecosystem**. Fortunately the 15 acres of EWM present in 2016 was successfully treated with systemic herbicides such as Triclopyr and 2, 4-D. By the end of the 2016 season, nearly all of the EWM was dying from the summer 2016 treatment. Another survey in the spring of 2017 will be needed to determine if any EWM survives and would require treatment. Protection of the 25 native aquatic plant species is paramount for the health of the lake fishery and these plants should not be managed unless they are a nuisance to lakefront property owners and possess navigational and recreational hazards (i.e. lily pads).**

The lake did experience depletion of dissolved oxygen with depth during mid-summer which is common for a deep inland lake. In August, dissolved oxygen was high at the surface and low at the bottom between 8.5-1.0 mg L^{-1} and the water temperature varied by 15°C from top to bottom. Conductivity was moderate and the pH was ideal. Total phosphorus increased with depth as did the total nitrogen.

Section

2

Duck Lake Water Quality Data (2016)



Did You Know? Duck Lake has a maximum depth of 61 feet

Water Quality Parameters Measured

There are hundreds of water quality parameters one can measure on an inland lake but several are the most critical indicators of lake health. These parameters include water temperature (measured in °F), dissolved oxygen (measured in mg/L), pH (measured in standard units-SU), conductivity (measured in micro-siemens per centimeter-µS/cm), total dissolved solids (mg/L), Secchi transparency (feet), total phosphorus and total nitrogen (both in mg/L), chlorophyll-*a* (in µg/L), and algal species composition. Water quality was measured in the deep basin of Duck Lake on August 9, 2016.

Table 1 below demonstrates how lakes are classified based on key parameters. Duck Lake would be considered mesotrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth but has good water clarity and moderate algal growth. 2016 water quality data for Duck Lake is shown below in Table 2.

Table 1. Lake trophic classification (MDNR).

Lake Trophic Status	*Total Phosphorus (µg L^{-1})*	*Chlorophyll-a (µg 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**

Table 2. Duck Lake water quality parameter data collected in the deep basin (August 9, 2016).

Depth ft.	*Water Temp °C*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Chl-a µg L^{-1}*	*Total Phos. mg L^{-1}*	*Secchi Depth (ft.)*	*TDS mg L^{-1}*
0	28.3	8.5	8.1	347	0.8	< 0.50	3.0	<0.010	--	137
30	21.5	8.4	8.1	310	0.9	1.1	--	0.029	15.0	135
61	13.5	1.0	8.0	285	1.7	7.1	--	0.071	--	120

Water Clarity (Transparency) Data

Secchi transparency is a measure of water clarity using a weighted disk with black and white markings. The depth is recorded as a mean of the depth at which the disk disappears and reappears. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. **The transparency throughout Duck Lake is adequate (8.5-25.0 feet; CLMP data range) to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake.** Secchi transparency depends on the amount 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) are correlated with water clarity and show an increase as clarity decreases. **The turbidity and total dissolved solids in Duck Lake were quite low at ≤ 1.7 NTU's and ≤ 137 mg L^{-1}, respectively during the 2016 sampling event.**

Total 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 and due to mineralization. Phosphorus may also be released from sediments as pH increases. In summer, the dissolved oxygen levels are lower at the bottom and likely cause release of phosphorus from the bottom. **TP concentrations ranged from <0.010 mg L^{-1} at the surface to 0.071 mg L^{-1} at the bottom during the August sampling event. The bottom TP concentration is high and contributes to aquatic vegetation and algae growth in Duck Lake.**

pH

Most Michigan lakes have pH values that range from 6.5 to 9.5 with typical being slightly basic (pH>7.0). 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). Duck Lake is considered "slightly basic" on the pH scale. **The pH of Duck Lake ranged from 8.0-8.1 S.U. which is ideal for an inland lake.** pH is usually lower at the lake bottom and can increase when aquatic vegetation is actively growing due to photosynthesis.

Conductivity

Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. **The conductivity values for Duck Lake were moderate and variable among depths and ranged from 285-347 µS/cm.** Severe water quality impairments in freshwater lakes 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 the primary photosynthetic pigment found in all plants and algae. 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* concentrations in August of 2016 in Duck Lake were around 3.0 µg/L which is moderate for an inland Michigan lake and favorable given the unprecedented high air and water temperatures in 2016.**

The algal genera were determined from composite water samples collected over the deep basin of Duck Lake in 2016 were analyzed with a compound bright field microscope. **The genera present included the Chlorophyta (green algae; Figure 1): *Scenedesmus* sp., *Chlorella* sp., *Cladophora* sp., Euglena sp., *Haematococcus* sp., *Pediastrum* sp., *Gleocystis* sp., *Radiococcus* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae; Figure 2): G*leocapsa* sp., the Bascillariophyta (diatoms; Figure 3)*: Synedra* sp., *Fragilaria* sp., *Navicula* sp., *Cymbella* sp., and *Tabellaria* sp.** The aforementioned species indicate a diverse algal flora and represent a good diversity of alga with an abundance of diatoms that are indicative of great water quality. Photos of the general algae types are shown below.

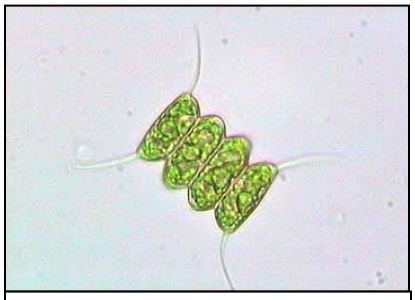


Figure 1. A Green Alga

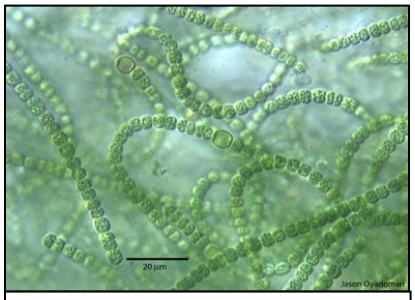


Figure 2. A Blue-Green Alga

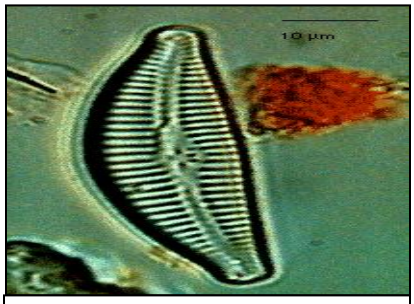


Figure 3. A Diatom Alga

Section

3

Aquatic Vegetation Data (2016)

Status of Native Aquatic Vegetation in Duck Lake

Native aquatic vegetation is essential for the overall health of the lake and the support of the lake fishery. **The whole-lake aquatic vegetation survey on May 10, 2016 determined that there were a total of 25 native aquatic plant species. These include 15 submersed species, 4 floating-leaved species, and 6 emergent species. The most common native aquatic plant species in 2016 included the submersed macro alga *Chara vulgaris* (Figure 4) and Water Star grass (Figure 5).**

This indicates a very high biodiversity of aquatic vegetation in Duck Lake. This means that there are a lot of different aquatic plants that serve varying functions in the ecology of Duck Lake. The overall percent 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 unless growing near swim areas at nuisance levels. A list of all current native aquatic plant species is shown below in Table 3.

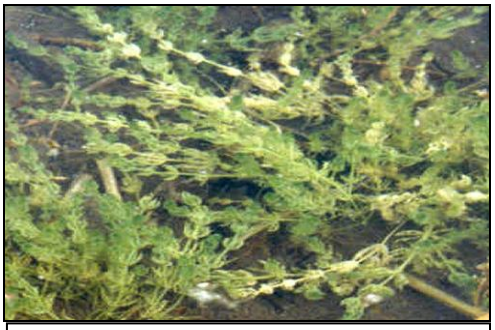


Figure 4. Chara vulgaris

Figure 5. Water Stargrass

Table 3. Duck Lake Native Aquatic Plant Species and Relative Abundance (May 10, 2016).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Abundance in/around Duck Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	23.5	Submersed, Rooted
Potamogeton pectinatus	Thinleaf Pondweed	16.1	Submersed, Rooted
Potamogeton zosteriformis	Flatstem Pondweed	14.6	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	0.9	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	2.0	Submersed, Rooted
Potamogeton praelongus	White-stem Pondweed	0.4	Submersed, Rooted
Potamogeton pusillus	Small-leaf Pondweed	5.6	Submersed, Rooted
Potamogeton zosteriformis	Flat-stem Pondweed	4.2	Submersed, Rooted
Zosterella dubia	Water Stargrass	19.7	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	6.3	Submersed, Rooted
Vallisneria americana	Wild Celery	10.1	Submersed, Rooted
Myriophyllum verticillatum	Whorled Watermilfoil	11.8	Submersed, Rooted
Ceratophyllum demersum	Coontail	12.5	Submersed, Non-Rooted
Utricularia vulgaris	Bladderwort	2.5	Submersed, Non-Rooted
Najas guadalupensis	Southern Naiad	0.9	Submersed, Rooted
Nymphaea odorata	White Waterlily	4.7	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	14.9	Floating-Leaved, Rooted
Lemna minor	Duckweed	1.5	Floating-Leaved, non-rooted
Azolla sp.	Watermeal	1.9	Floating-Leaved, non-rooted
Typha latifolia	Cattails	15.5	Emergent
Scirpus acutus	Bulrushes	7.9	Emergent
Sagittaria sp.	Arrowhead	0.7	Emergent
Pontedaria cordata	Pickerelweed	2.9	Emergent
Decodon verticillatus	Swamp Loosestrife	13.8	Emergent
Iris sp.	Iris	0.9	Emergent

Status of Invasive (Exotic) Aquatic Vegetation in Duck Lake

Eurasian Watermilfoil (EWM) is an invasive, submersed aquatic plant (Figure 6) that spreads through fragmentation, seed dispersal, and underground stolons. A lake management plan study conducted by RLS in 2015 found that approximately 30 acres infested the lake.

The amount of EWM present in Duck Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. 2016 was among the hottest year on record and many lakes experienced nuisance milfoil and algal outbreaks even despite two consecutive harsh winters. **The May 10, 2016 survey revealed approximately 15.0 acres of milfoil and 1.0 acres of Curly-leaf Pondweed (Figure 7) in the lake. On June 2, 2016, the milfoil and nuisance pondweeds were treated with Renovate OTF and Sculpin and Aquathol-K®, respectively. The treatment was very successful with only a few stems of EWM and few pondweeds in the treated areas remaining at the end of 2016.**

Treatment maps of invasive EWM (Figure 8) and Curly-leaf Pondweed (Figure 9) from 2016 are shown below.

Figure 6. Eurasian Watermilfoil

Figure 7. Curly-leaf Pondweed

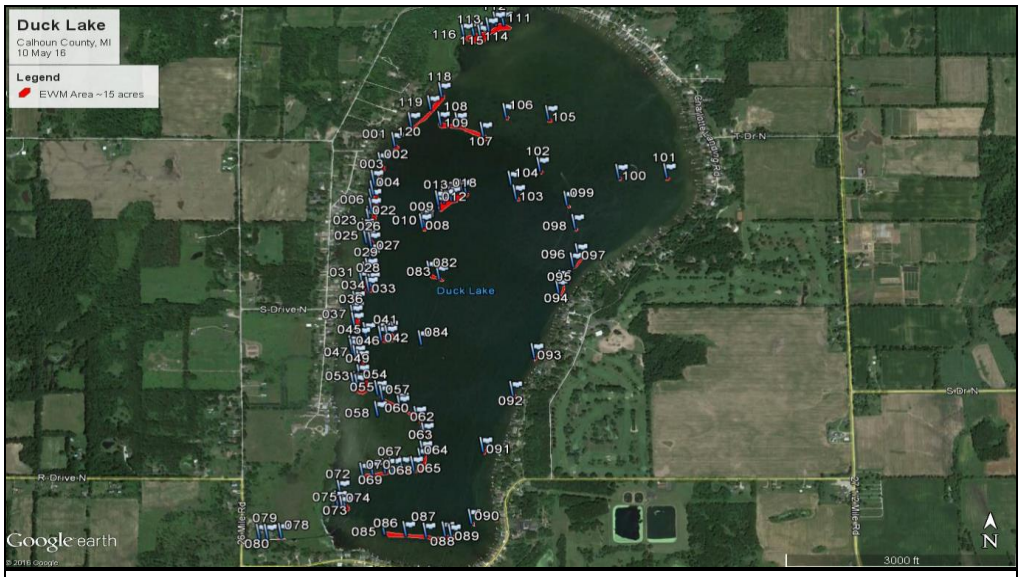


Figure 8. EWM in Duck Lake (2016).

Figure 9. Curly-leaf Pondweed in Duck Lake (2016).

Section

4

Management Recommendations for 2017

Continuous aquatic vegetation surveys are needed to determine the precise locations of EWM, Curly-leaf Pondweed or other problematic invasives or dense nuisance native aquatic vegetation in and around Duck Lake. These surveys should occur in late-May to early-June and again post-treatment in 2017.

Due to the great overall depths of Duck Lake and limited areas with native aquatic vegetation in Duck Lake, the treatment of these species with aquatic herbicides is not recommended (one exception is the overgrowth of nuisance pondweeds and algae in a few select areas of the lake). The plan for 2017 includes the use of high dose systemic aquatic herbicides for effective Eurasian Watermilfoil control. The nuisance Pondweeds will respond well to Aquathol-K® at 2-3 gallons per acre.

Water quality parameters in the lake will also be monitored in 2017 and given in the annual report.

In conclusion, Duck Lake is a healthy lake with excellent aquatic plant biodiversity, high water clarity, moderate/high nutrients (depending on depth), and a healthy lake fishery. Management of the EWM, Curly-leaf Pondweed and protection of the water quality are paramount for the long-term health of the lake.

Glossary of Scientific Terms used in this Report

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

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

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

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

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