Restorative Lake Sciences™

Big Star Lake 2017 Aquatic Vegetation, Water Quality, and 2018 Management Recommendations Report

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Table of Contents

Section 1

Big Star Lake 2017 Aquatic Vegetation, Water Quality, and 2018 Management Recommendations Report

The following Big Star Lake report is a summary of key lake findings collected in 2017.

The overall condition of Big Star Lake is ranked in the top 15% of developed lakes of similar size in the state of Michigan. The water clarity in the summer of 2017 was between 11-19 feet which is excellent. 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 (such as sands). 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 are able to grow in moderate nutrient waters and thus are a challenge to the Big Star Lake ecosystem. However, management of the plant has been a large success over the past several years with a total of < 7.3 acres requiring herbicide treatment in 2017. Protection of the 21 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 not experience a high depletion of dissolved oxygen with depth during mid-summer which is rare for a large inland lake that stratifies. In June, 2017 dissolved oxygen was high and averaged 8.5 mg/L and the water temperature varied by 3°C. Conductivity continues to be low which is favorable at under 165 mS/cm. Total phosphorus remained similar to previous years as well and was moderately low even at the lake bottom. The total nitrogen in considered moderate as well.

Section

2

Big Star Lake Water Quality Data (2017)

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 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 and total nitrate nitrogen (both in µg/L), chlorophyll-*a* (in µg/L), and algal species composition. Graphs that show trends for each parameter of each year are displayed below. Water quality was measured in the deep basin of Big Star Lake in late spring and summer of 2017. Trend data was calculated using mean values for each parameter for each season over the sampling location. Table 1 below demonstrates how lakes are classified based on key parameters. Big Star 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. General water quality classification criteria are defined in Table 1. 2017 water quality data for Big Star Lake is shown below in Tables 2-3.

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. Big Star Lake water quality parameter data collected over the deep basin on June 15, 2017.

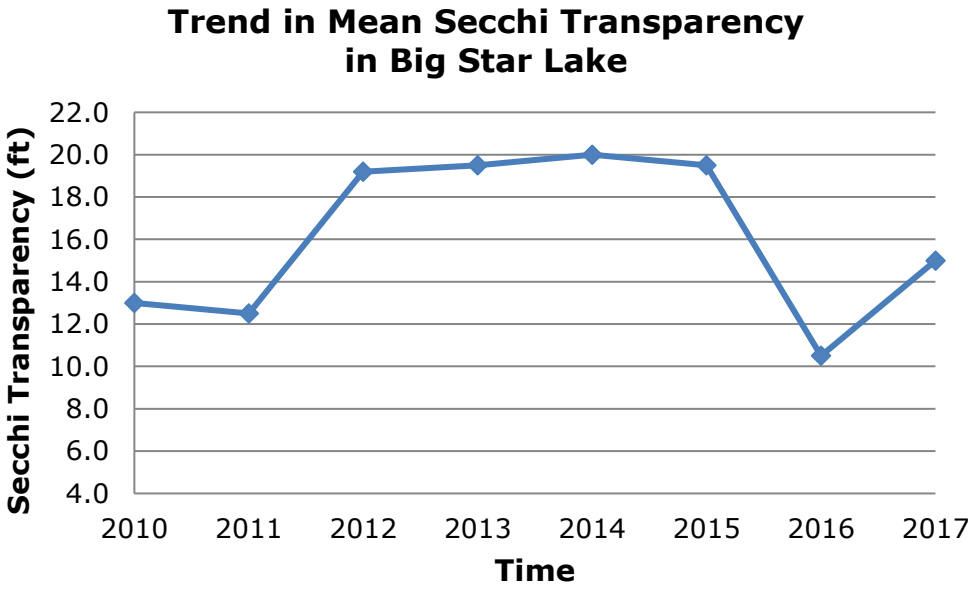
Depth ft.	*Water Temp °C*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Dissolved Solids mg L^{-1}*	*Total Alk. mg L^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	18.9	9.0	8.5	162	1.0	154.1	65	59	< 0.010
11	16.5	8.2	8.5	158	1.2	125.1	72	60	0.010
22	15.1	8.0	8.6	164	1.6	124.6	76	60	0.020

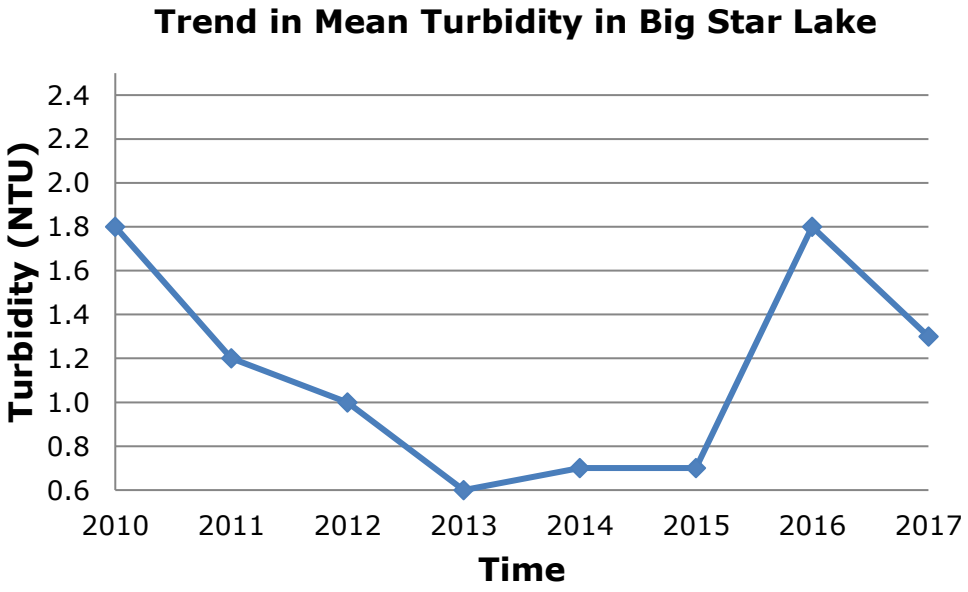
Table 3. Big Star Lake water quality parameter data collected over the deep basin on August 23, 2017.

Depth ft.	*Water Temp °C*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Dissolved Solids mg L^{-1}*	*Total Alk. mg L^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	23.1	8.7	8.7	143	1.2	136.5	69	59	< 0.010
11	23.1	8.7	8.6	143	1.2	120.6	72	59	0.010
22	22.9	8.6	8.5	143	1.5	115.7	72	60	0.013

Water Clarity (Transparency) Data

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Big Star Lake was adequate in 2017 (11-19 feet; below graph) 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 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) and Total Dissolved Solids (measured in mg/L) are correlated with water clarity and show an increase as clarity decreases. The turbidity and total dissolved solids in Big Star Lake have been quite low at ≤1.6 NTU's (below graph) and ≤76 mg/L, respectively during the recent period which is highly favorable.

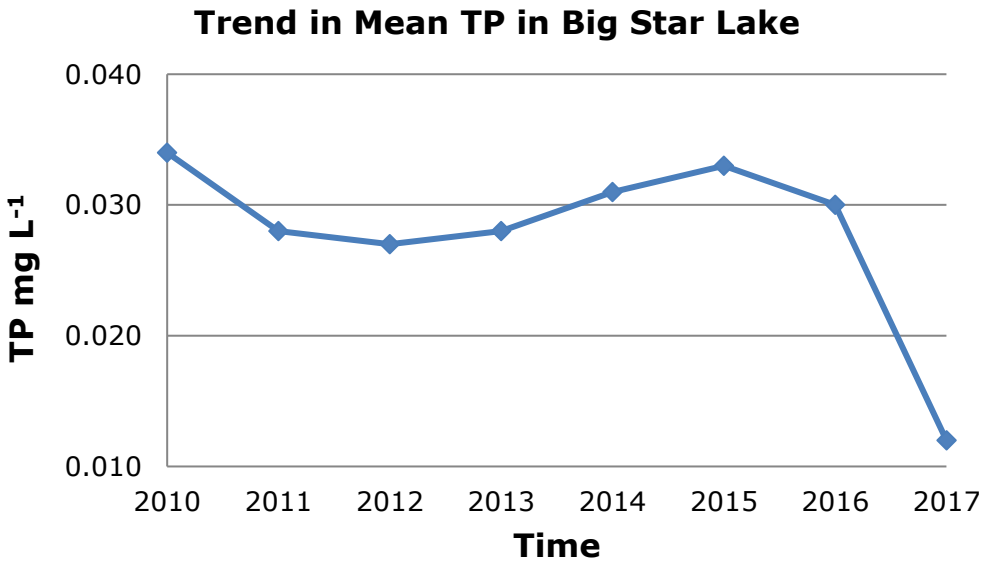




Total Phosphorus

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. Phosphorus may also be

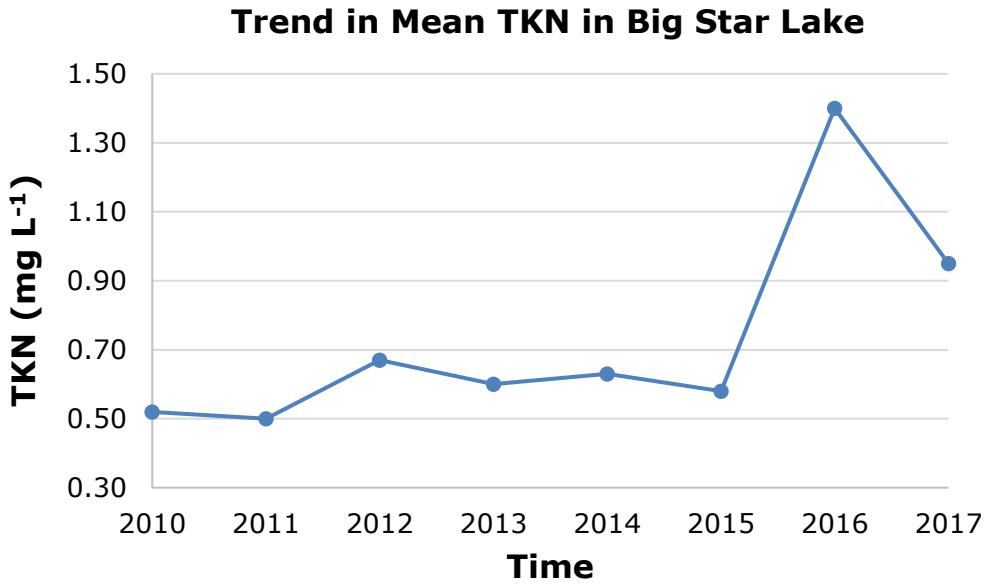
released from sediments as pH increases. Fortunately, even though the TP levels in Big Star Lake are moderate, the dissolved oxygen levels are good enough at the bottom to not cause release of phosphorus from the bottom. The mean TP concentration in summer of 2016 was 0.030 mg L^{-1} (below graph), which is slightly lower than in 2015 but still high enough to create algal blooms.



Total Nitrogen

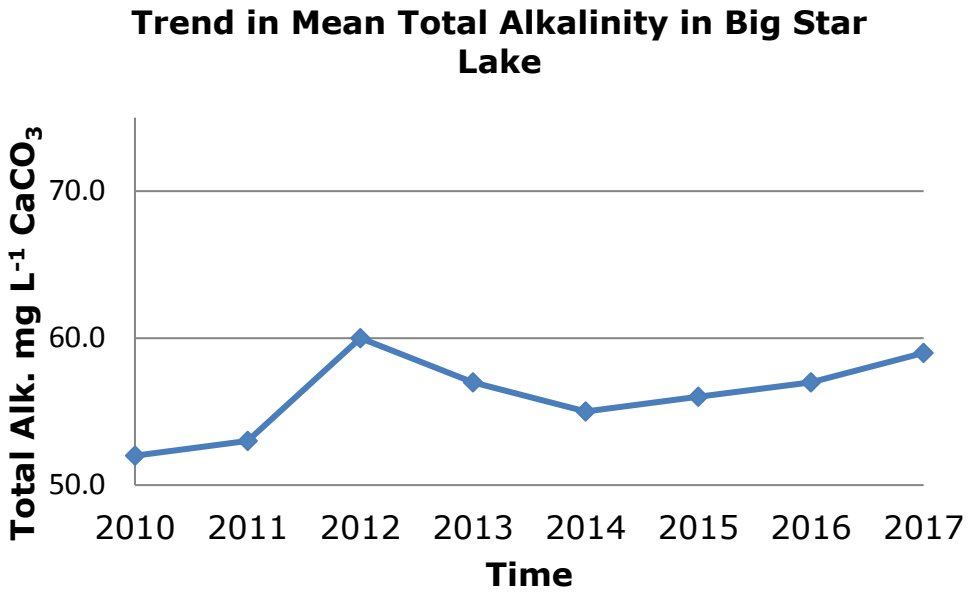
Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (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 Big Star

Lake in summer of 2017 averaged 0.95 mg L^{-1}, which is moderately low for an inland lake. The graph below demonstrates the changes in total nitrogen with time in Big Star Lake.



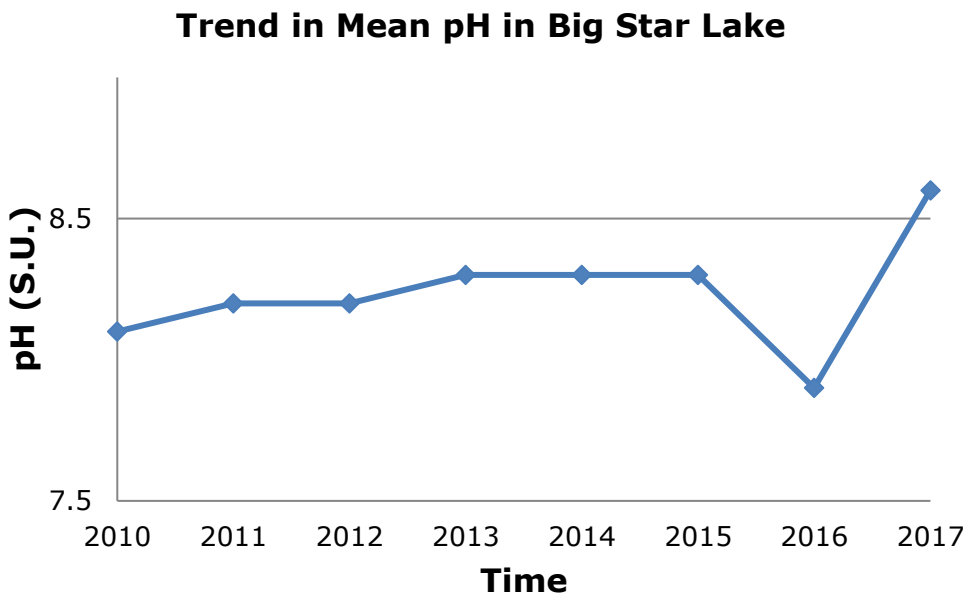
Total Alkalinity

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 Big Star Lake is moderately low and indicates a more soft water lake. The graph below demonstrates the changes in total alkalinity over time.



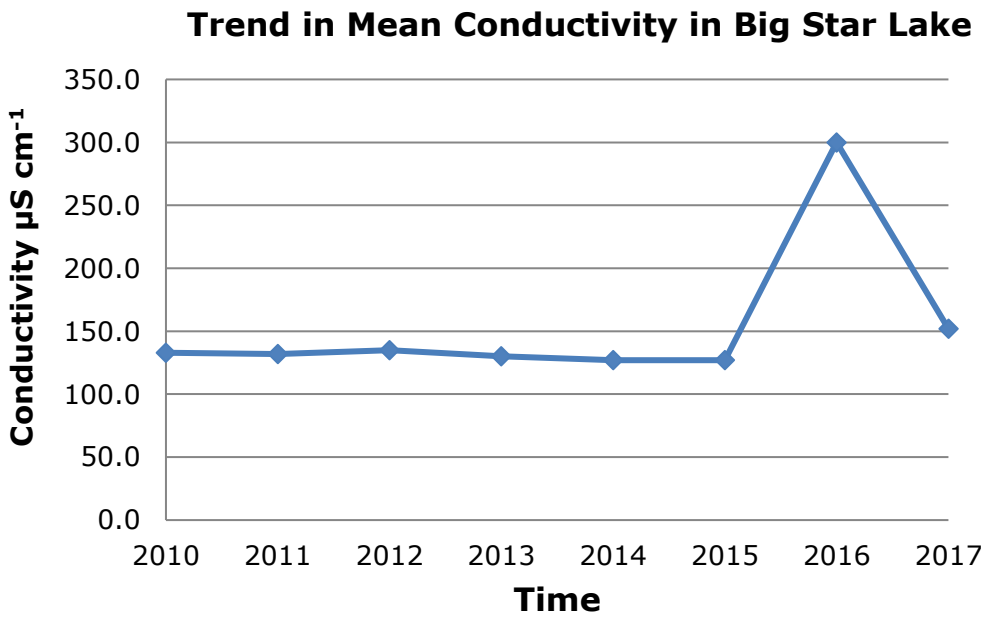
pH

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). Big Star Lake is considered "slightly basic" on the pH scale. The pH of Big Star Lake averaged 8.6 S.U. (below graph) in the summer of 2017 which is ideal for an inland lake that has a healthy aquatic vegetation community which is actively photosynthesizing.



Conductivity

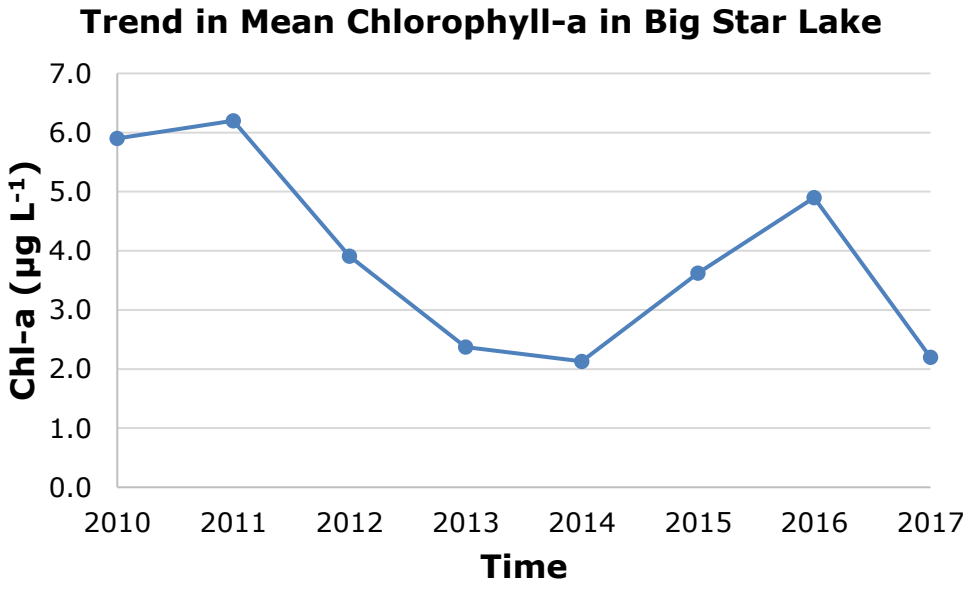
Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The conductivity values for Big Star Lake decreased in 2017 to an average of 152 µS/cm (below graph). If there is less salting of roads needed due to a mild winter, often these values will be lower for that season due to less salts and ions reaching the lake water. 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. Chlorophyll-*a* concentrations vary among years but were slightly lower in 2017 (below graph).

The algal genera were determined from composite water samples collected over the deep basin of Big Star Lake in 2017 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae; Figure 1): *Scenedesmus* sp., *Chlorella* sp., *Cladophora* sp., *Radiococcus* sp., *Mougeotia* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae; Figure 2): *Oscillatoria* sp., the Bascillariophyta (diatoms; Figure 3)*: Synedra* sp., *Navicula* sp., *Fragillaria* 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.



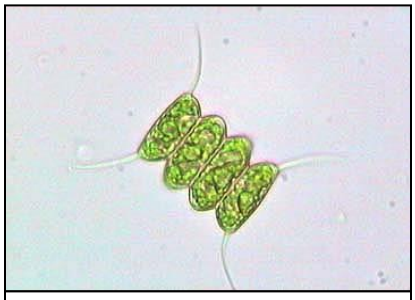


Figure 1. A Green Alga

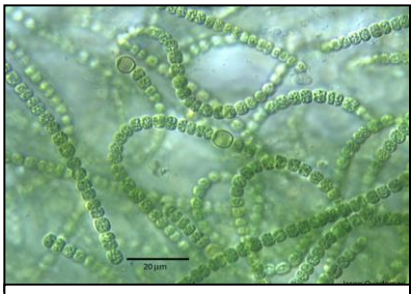


Figure 2. A Blue-Green Alga

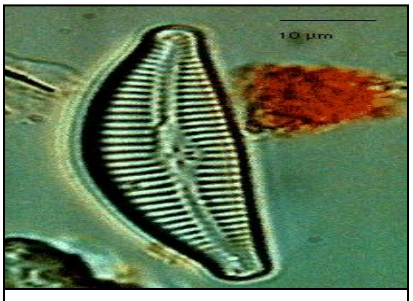


Figure 3. A Diatom

Section

3

Aquatic Vegetation Data (2017)

Status of Native Aquatic Vegetation in Big Star Lake

The native aquatic vegetation present in Big Star Lake is essential for the overall health of the lake and the support of the lake fishery. The June 15, 2017 whole-lake survey determined that there were a total of 21 native aquatic plant species in Big Star Lake. These include 12 submersed species, 3 floating-leaved species, and 6 emergent species. This indicates a very high biodiversity of aquatic vegetation in Big Star Lake. 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 unless growing near swim areas at nuisance levels. A list of all current native aquatic plant species is shown below in Table 4.

The most dominant aquatic plant species in June of 2017 included: 1) Leafless watermilfoil which appears as a small spike-like plant with fragile roots and has the appearance of sod on the lake bottom (Figure 4); 2) Common Bladderwort (Figure 5), which is bright green in color and has small clear bladders that trap zooplankton as a food source, and 3) the macro-alga Chara (Figure 6) which has a skunky odor and lies on the lake bottom. This macroalga is beneficial since it prevents EWM from rooting in the lake bottom and thus its growth is encouraged.

Table 4. Big Star Lake Native Aquatic Plant Species (June, 2017).

Aquatic Plant Species and Code	*Aquatic Plant Common Name*	*% Cover in Littoral (Shallow) Zone of Big Star Lake (2017)*
Chara vulgaris **(macro alga)**	**Muskgrass**	**16.9**
Potamogeton pectinatus	**Thinleaf Pondweed**	**4.5**
Potamogeton gramineus	**Variable-leaved Pondweed**	**11.6**
Potamogeton praelongus	**White-Stemmed Pondweed**	**7.5**
Potamogeton illinoensis	**Illinois Pondweed**	**16.4**
Potamogeton amplifolius	**Large-leaf Pondweed**	**10.4**
Potamogeton natans	**Floating-leaf Pondweed**	**2.1**
Zosterella dubia	**Water Stargrass**	**0.1**
Vallisneria americana	**Wild Celery**	**9.4**
Utricularia vulgaris	**Common Bladderwort**	**22.6**
Najas guadalupensis	**Southern Naiad**	**8.8**
Myriophyllum tenellum	**Leafless Watermilfoil**	**32.5**
Nymphaea odorata	**White Waterlily**	**4.2**
Nuphar advena	**Yellow Waterlily**	**5.6**
Brasenia schreberi	**Watershield**	**3.7**
Typha latifolia	**Cattails**	**3.6**
Scirpus acutus	**Bulrushes**	**0.5**
Iris versicolor	**Blueflag Iris**	**1.1**
Decodon verticillatus	**Swamp Loosestrife**	**3.9**
Polygonum amphibium	**Water Smartweed**	**1.2**
Eriocaulon sp.	**Pipewort**	**2.1**

Figure 4. Leafless Watermilfoil

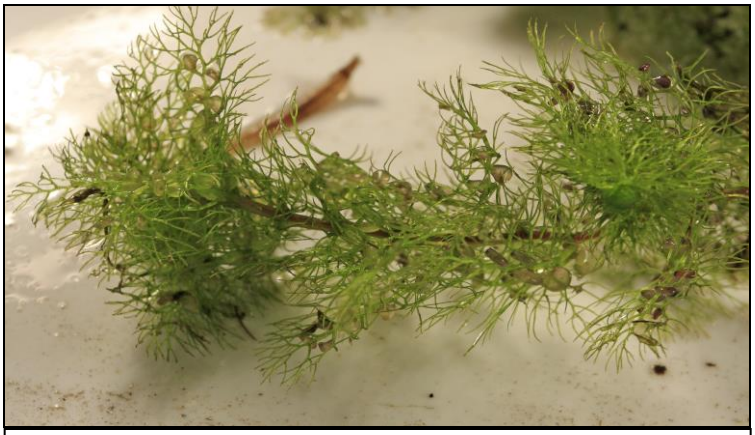


Figure 5. Common Bladderwort

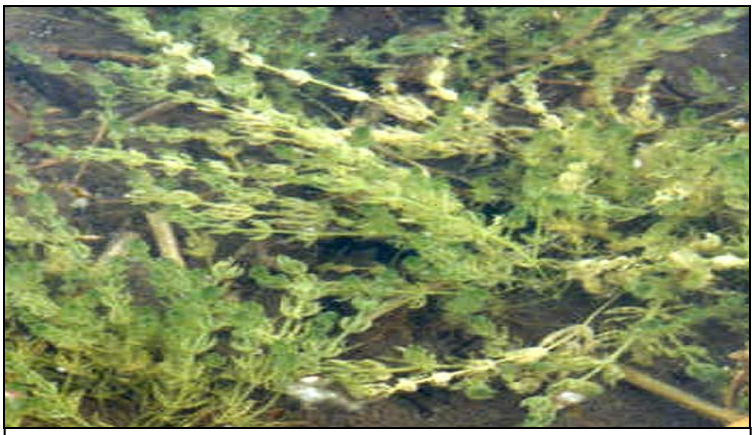


Figure 6. Chara

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 7) present in Big Star Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. In 2017, there were some intense rainfall events and this led to the transport of nutrients from the surrounding land to the lake water in many lakes and resulted in spikes of EWM and algae growth. In Big Star Lake the June 15, 2017 survey revealed that approximately 6.7 acres of milfoil was found throughout the entire lake. In July, the milfoil was treated with high dose granular triclopyr (Renovate OTF®) and Sculpin® where far enough offshore. The treatment was successful overall but late in the season another 0.6 acres of milfoil grew and also required a treatment with granular systemic herbicide.

Native aquatic plants did not necessitate treatment in 2017 but may require treatments in future years if the water level drops or if the plants are found in recreational or beach areas. Treatment maps for the EWM are shown in the maps below (Figures 8 and 9). Figure 10 shows the overall aquatic vegetation biovolume in Big Star Lake in June, 2017.

Figure 7. Eurasian Watermilfoil

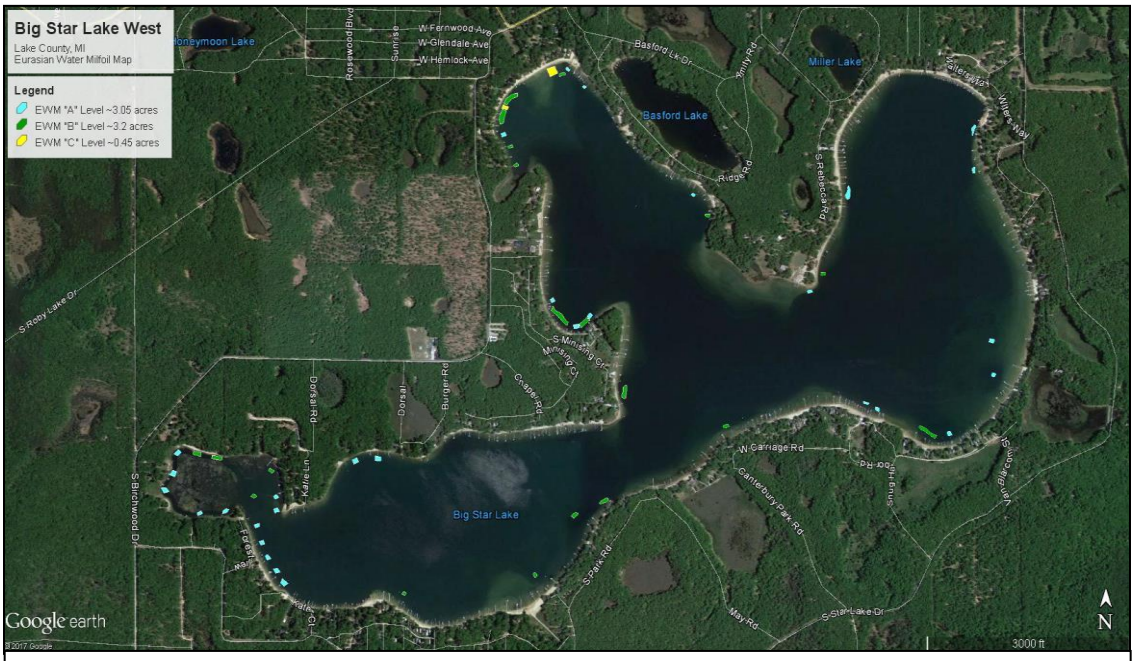


Figure 8. EWM Distribution in Big Star Lake (June 15, 2017).

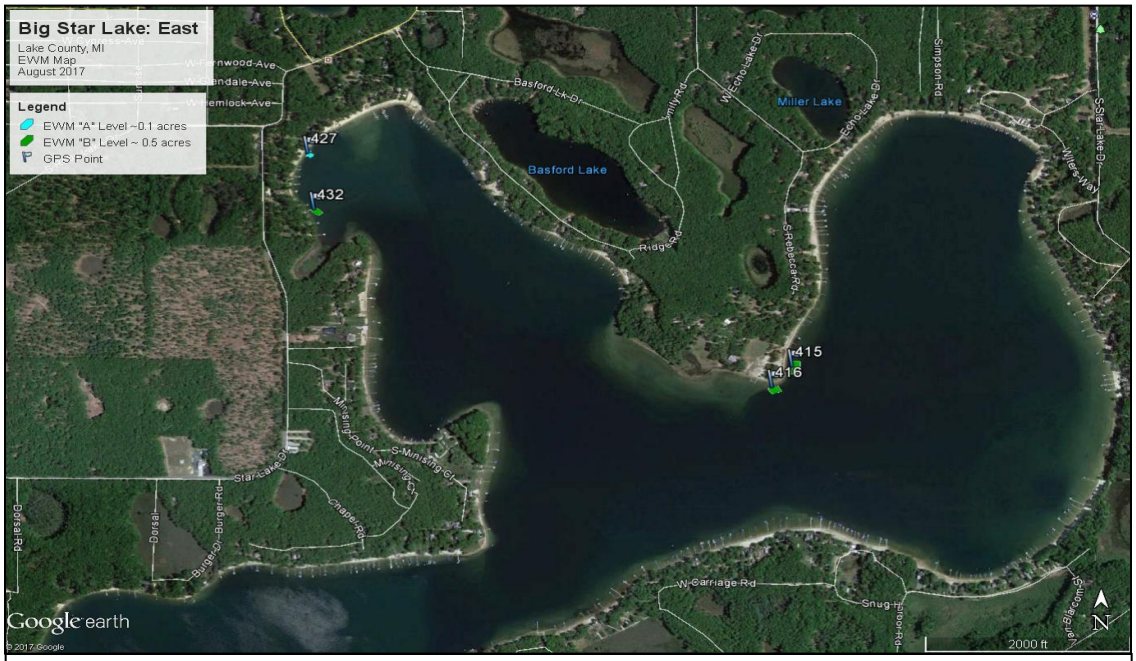


Figure 9. EWM Distribution in Big Star Lake (August 23, 2017).

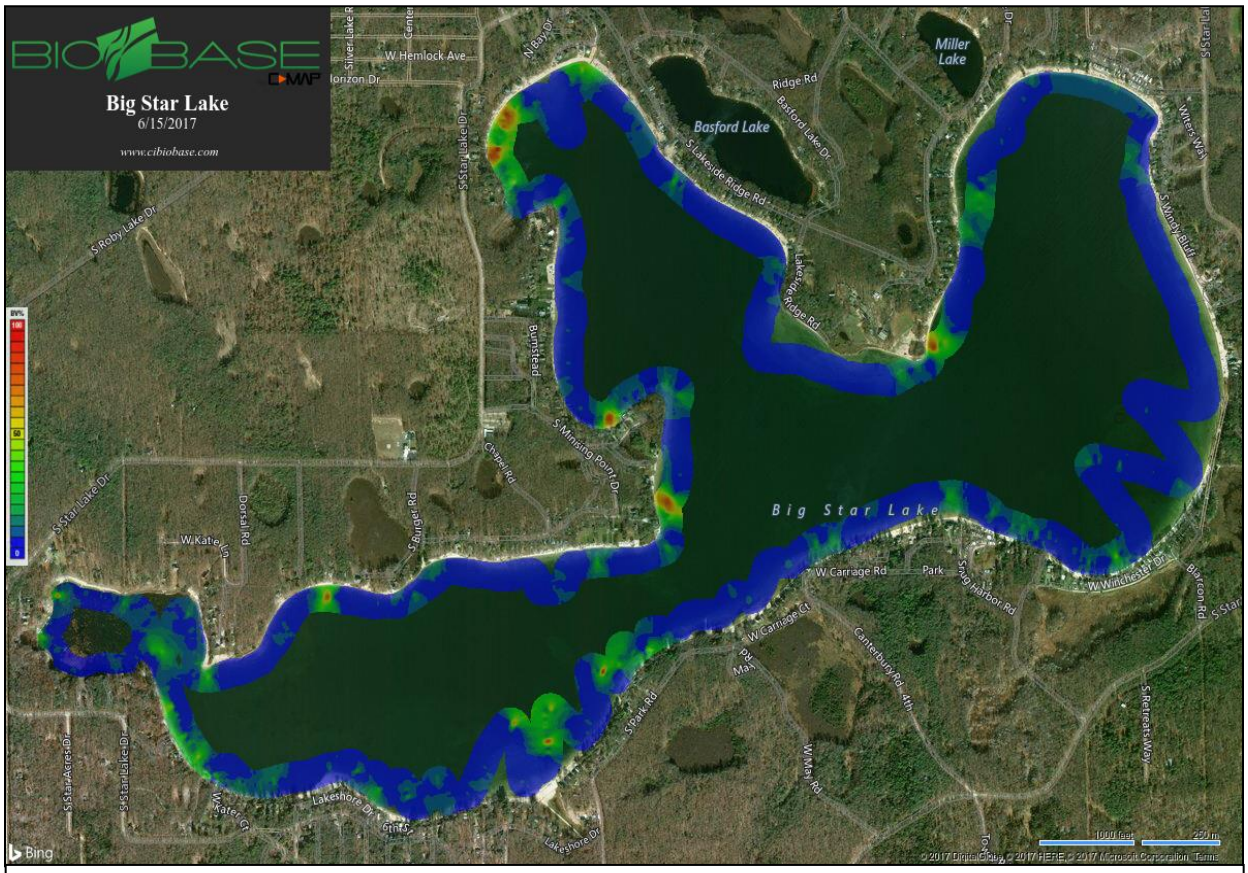


Figure 10. Aquatic Vegetation Biovolume in Big Star Lake (June, 2016).

Section

4

Management Recommendations for 2018

Aquatic vegetation surveys will be conducted in late May or early June with treatments to follow within a week or two. These surveys will prescribe treatments for EWM, CLP, and nuisance native aquatic vegetation. During this survey, bottom scans of the lake will take place to determine changes in bottom hardness, hydrographic bottom contours and bio-mass of the existing vegetation. An additional survey after the treatment will determine the efficacy of the treatment and any follow-up treatments that may be needed. EWM will be treated with Renovate OTF® at 200 pounds/acre in near shore areas and Sculpin G® at 200 pounds/acre for areas more off-shore. Areas of less than an acre in size will be treated at 240 pounds/acre to better maintain herbicide contact in these areas. CLP will be treated with Aquathol K®. Diquat and/or Clipper® will be used on the nuisance native aquatic weeds if necessary. Areas in the wetlands near the boat launch and the marina will continue to be emphasized for possible treatment.

Water quality will be monitored in the lake in 2018 and graphed with historic data to determine any trends over time. In conclusion, water quality in Big Star Lake remains high. Water clarity is moderately high allowing light penetration to deeper water that helps support an abundant aquatic plant growth throughout many areas of the lake. Levels of nutrients such as phosphorus and nitrogen are moderate, but sufficient to support aquatic plant growth. There is a robust fishery in the lake. Management of EWM and nuisance natives will continue to be emphasized in 2018.

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) CaCO3- 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.