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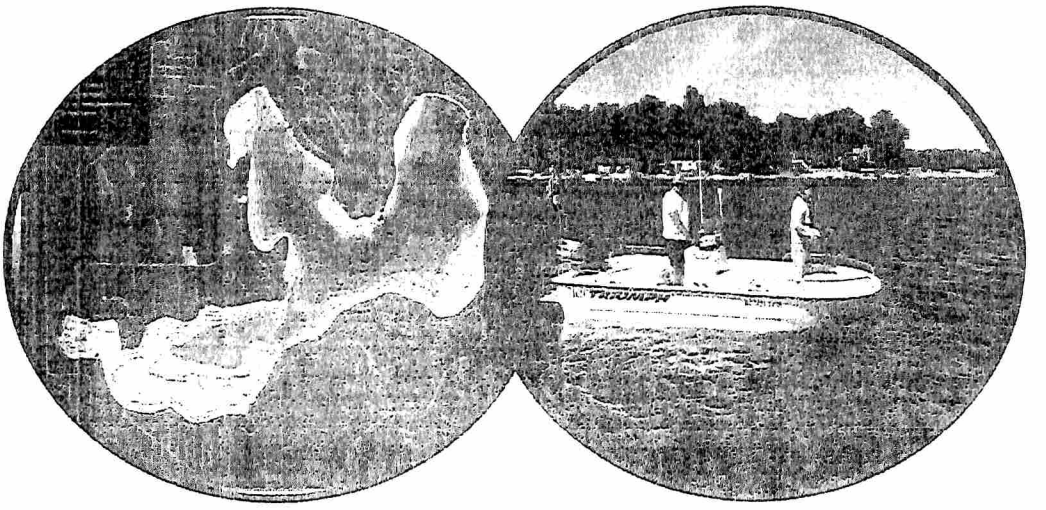
Big Star Lake 2016 Aquatic Vegetation & Water Quality Report & 2017 Management Recommendations



October, 2016

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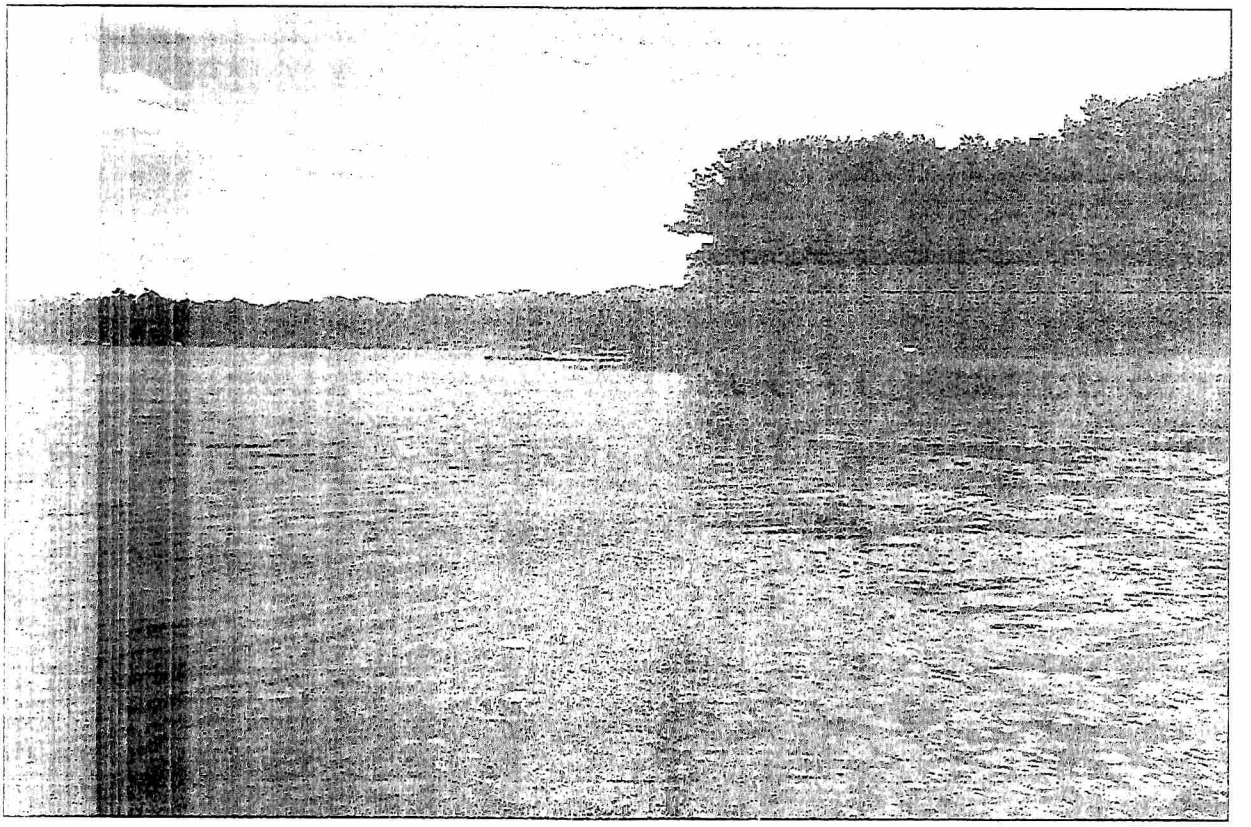

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Big Star Lake 2016 Aquatic Vegetation & Water Quality Report & 2017 Management Recommendations

The following Big Star Lake report is a summary of key lake findings collected in 2016.

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 2016 was between 10.5-20 feet.** 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 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 12 acres requiring herbicide treatment in 2016. 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, 2016 dissolved oxygen was high and averaged 8.9 mg/L and the water temperature varied by 2°C. Conductivity continues to be low which is favorable but was higher in 2016 due to increased water temperatures. Total phosphorus remained similar to previous years as well and was moderate. The total nitrogen in considered moderate as well. In late August of 2015, Bernie Woltjer collected 28 E. coli bacteria samples and one came back positive. These results indicate that E. coli bacteria is not a problem on Big Star Lake at present.

Big Star Lake Water Quality Data (2016)

Water Quality Parameters Measured

Did You Know? Big Star Lake has a maximum depth of 25 feet

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 basins of Big Star Lake in late spring early summer of 2016. 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. 2016 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 ($\mu g\ L^{-1}$)*	*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

Table 2. Big Star Lake water quality parameter data collected over the deep basin on June 11, 2016.

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	22.5	9.0	8.0	300	1.6	106.3	89	57	0.010
12.5	22.3	8.9	7.8	302	1.9	111.5	85	58	0.020
25	20.1	8.9	7.7	298	1.7	104.9	84	57	0.040

Table 3. Big Star Lake water quality parameter data collected over the deep basin on June 11, 2016.

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	22.7	8.9	8.0	289	1.6	129.5	79	57	0.010
12.5	21.0	8.1	8.0	300	1.9	115.7	82	56	0.020
25	20.9	6.7	7.9	299	1.7	79.4	80	57	0.050

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 2016 (10.5-20 feet; Figure 1) 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 ≤1.9 NTU's (Figure 2) and ≤89 mg/L, respectively during recent and historic periods. All of these values were higher than in 2015, presumably because of the increased runoff from storm events.**

Figure 1. Trend in Mean Secchi Transparency in Big Star Lake

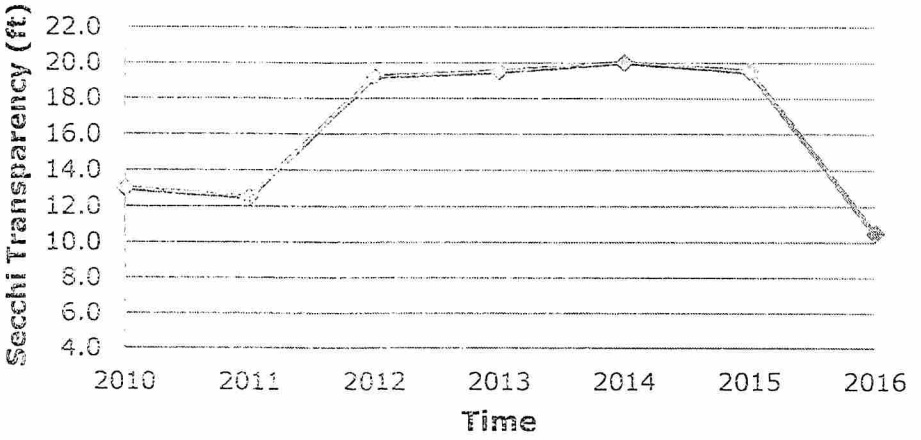
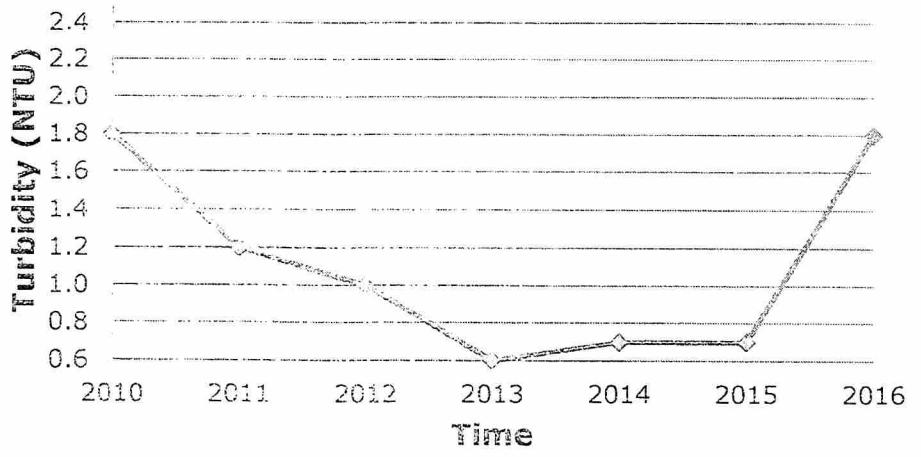


Figure 2. Trend in Mean Turbidity in Big Star Lake

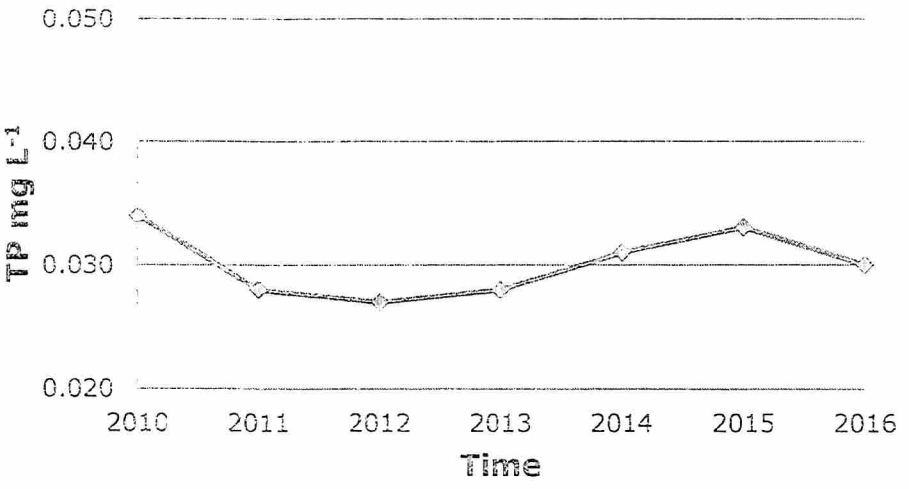


Total Phosphorus

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} (Figure 3), which is slightly lower than in 2015 but still high enough to create algal blooms.**

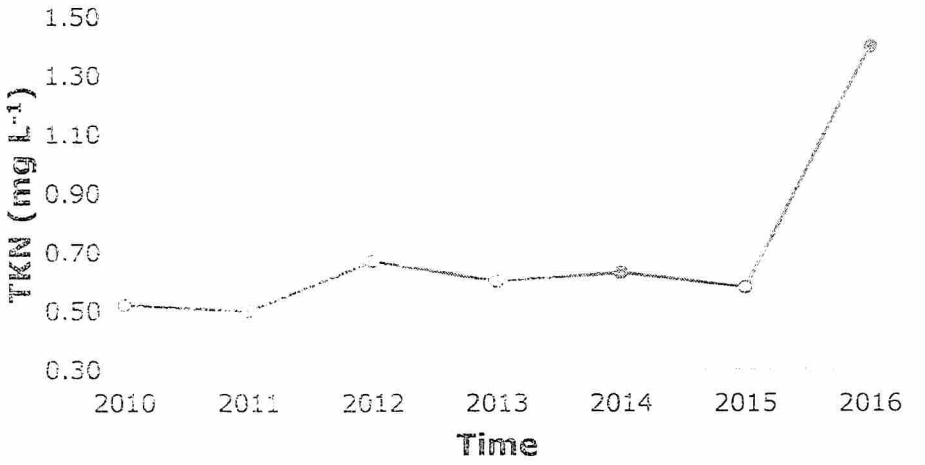
Figure 3. Trend in Mean TP in Big Star Lake



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 2016 averaged 1.4 mg L^{-1}, which is moderately low for an inland lake. Figure 4 below demonstrates the changes in total nitrogen with time in Big Star Lake.**

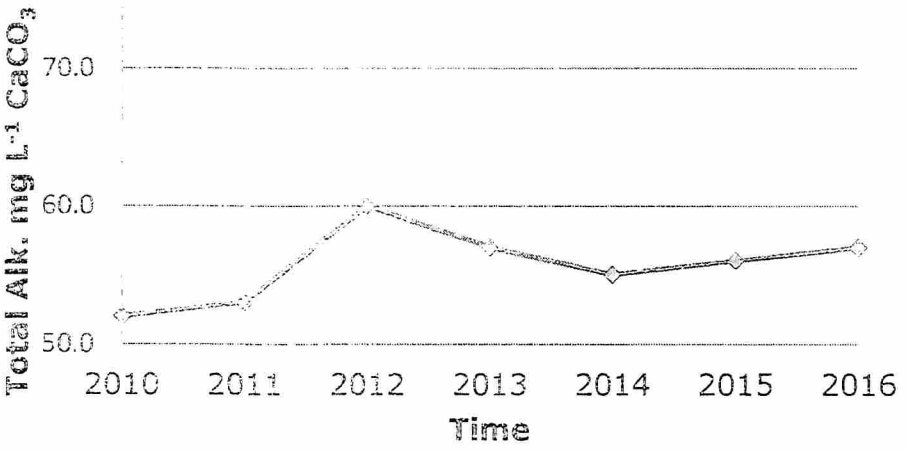
Figure 4. Trend in Mean TKN in Big Star Lake



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. Figure 5 demonstrates the changes in total alkalinity over time.**

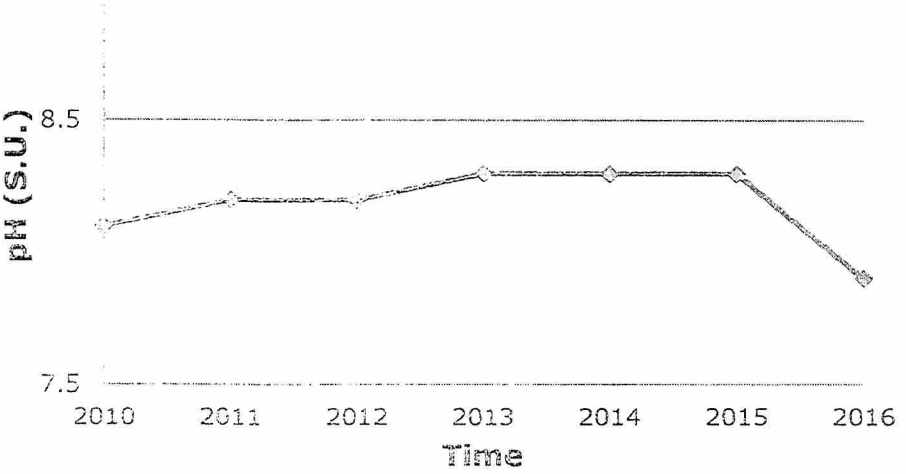
Figure 5. Trend in Mean Total Alkalinity in Big Star Lake



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 7.9 S.U. (Figure 6) in the summer of 2016 which is ideal for an inland lake.**

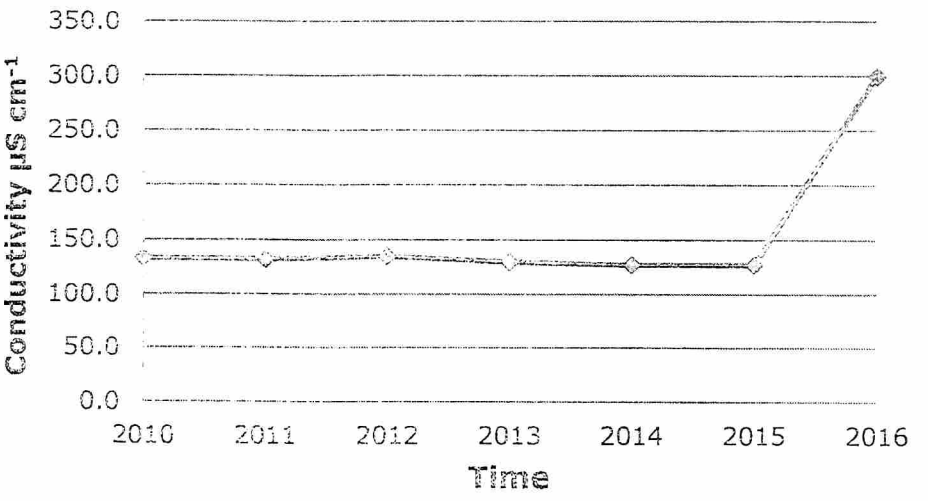
Figure 6. Trend in Mean pH in Big Star Lake



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 increased to an average of 300 µS/cm (Figure 7) in the summer of 2016, presumabie due to warmer water temperatures.** Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.

Figure 7. Trend in Mean Conductivity in Big Star Lake



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 higher in 2016 (Figure 8) due to the much warmer water temperatures and number of bright sunny days.**

The algal genera were determined from composite water samples collected over the deep basin of Big Star Lake in 2016 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae; Figure 9): *Scenedesmus* sp., *Chlorella* sp., *Cladophora* sp., *Haematococcus* sp., *Radiococcus* sp., *Gleocystis* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green

algae; Figure 10): *Oscillatoria* sp., the Bascillariophyta (diatoms; Figure 11): *Synedra* 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.

Figure 8. Trend in Mean Chlorophyll-*a* in Big Star Lake

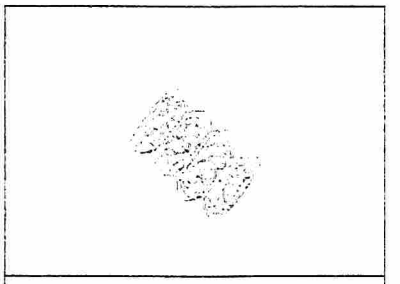


Figure 9. A Green Alga

Figure 10. A Blue-Green Alga

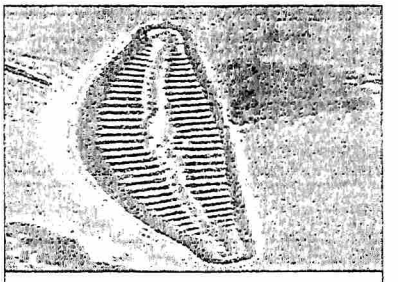


Figure 11. A Diatom

Aquatic Vegetation Data (2016)

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, 2016 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 2016 included: 1) Bladderwort (Figure 12), which is a rootless, bright green plant that has clear bladders and lies on the lake bottom; 2) Leafless Watermilfoil (Figure 13), which creates a dense sod-like carpet on the lake bottom and is very small in size, and 3) the macro-alga Chara (Figure 14) which has a skunky odor and lies on the lake bottom.

Table 4. Big Star Lake Native Aquatic Plant Species (June, 2016).

Aquatic Plant Species and Code	*Aquatic Plant Common Name*	*% Cover in Littoral (Shallow) Zone of Big Star Lake (2016)*
Chara vulgaris (macro alga)	Muskgrass	12.9
Potamogeton pectinatus	Thinleaf Pondweed	0.6
Potamogeton gramineus	Variable-leaved Pondweed	6.8
Potamogeton praelongus	White-Stemmed Pondweed	9.7
Potamogeton illinoensis	Illinois Pondweed	10.5
Potamogeton amplifolius	Large-leaf Pondweed	7.8
Potamogeton natans	Floating-leaf Pondweed	2.9
Zosterella dubia	Water Stargrass	1.5
Vallisneria americana	Wild Celery	11.5
Utricularia vulgaris	Common Bladderwort	16.7
Najas guadalupensis	Southern Naiad	6.8
Myriophyllum tenellum	Leafless Watermilfoil	15.7
Nymphaea odorata	White Waterlily	4.6
Nuphar advena	Yellow Waterlily	5.4
Brasenia schreberi	Watershield	3.3
Typha latifolia	Cattails	3.4
Scirpus acutus	Bulrushes	0.6
Iris versicolor	Blueflag Iris	1.0
Decodon verticillatus	Swamp Loosestrife	3.4
Polygonum amphibium	Water Smartweed	1.9
Eriocaulon sp.	Pipewort	3.0

Figure 12. Bladderwort

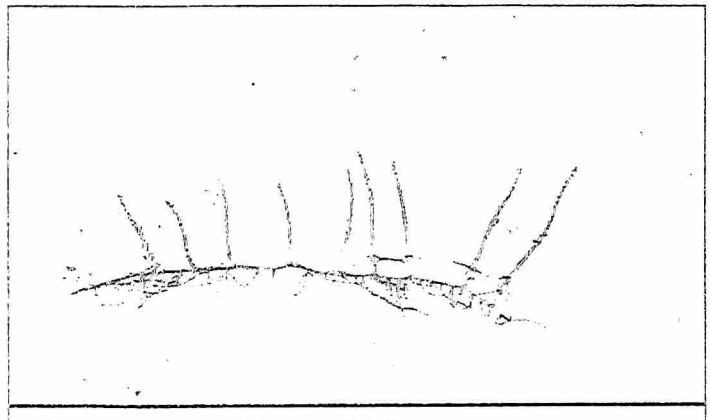


Figure 13. Leafless Watermilfoil

Figure 14. Chara

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 15) present in Big Star Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. 2016 was amongst the hottest years record and many lakes experienced nuisance milfoil and algal outbreaks. **The June 2016 survey revealed that approximately 10.3 acres of milfoil was found throughout the entire lake. In July, the milfoil was treated with high dose granular triclopyr (Renovate OTF®) and Sculpin®. The treatment was successful overall but late in the season another 1.6 acres of milfoil grew and also required a treatment with granular systemic herbicide.**

Native aquatic plants did not necessitate treatment in 2016 and this is likely due to the two consecutive harsh winters that reduced overall growth. Treatment maps for each of these invasive species are shown in the maps below (Figures 16 and 17). Figure 18 shows the overall aquatic vegetation biovolume in Big Star Lake in June, 2016.

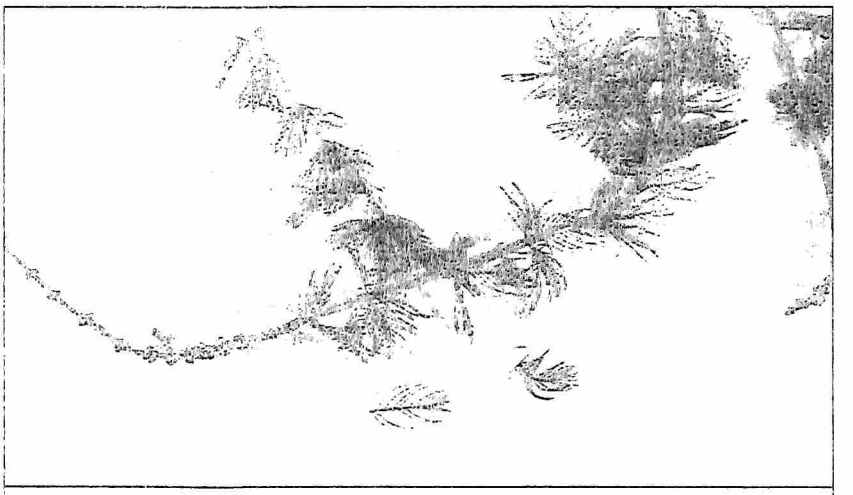


Figure 15. Eurasian Watermilfoil

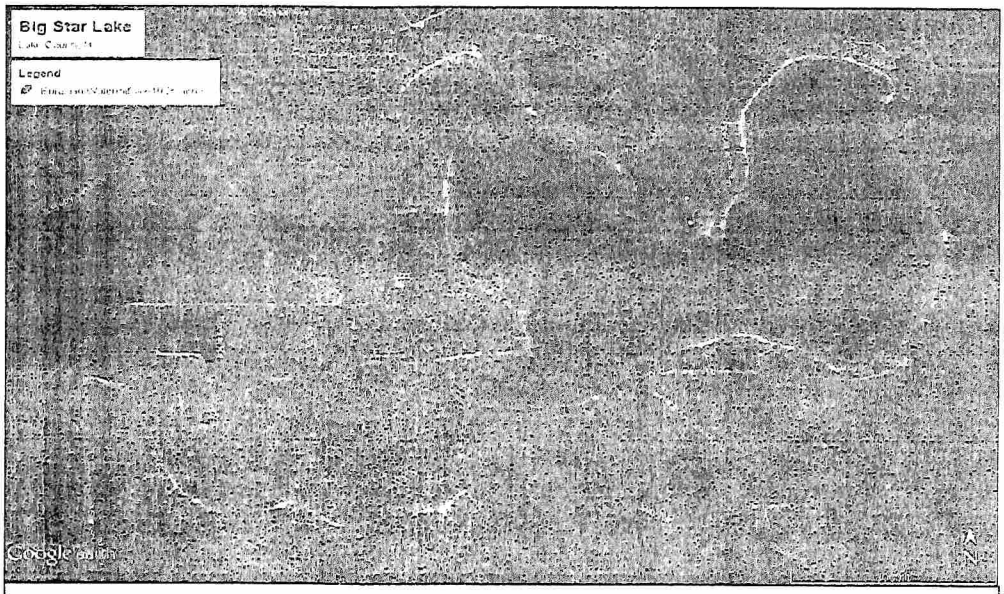


Figure 16. Eurasian Watermilfoil distribution in Big Star Lake (June, 2016).

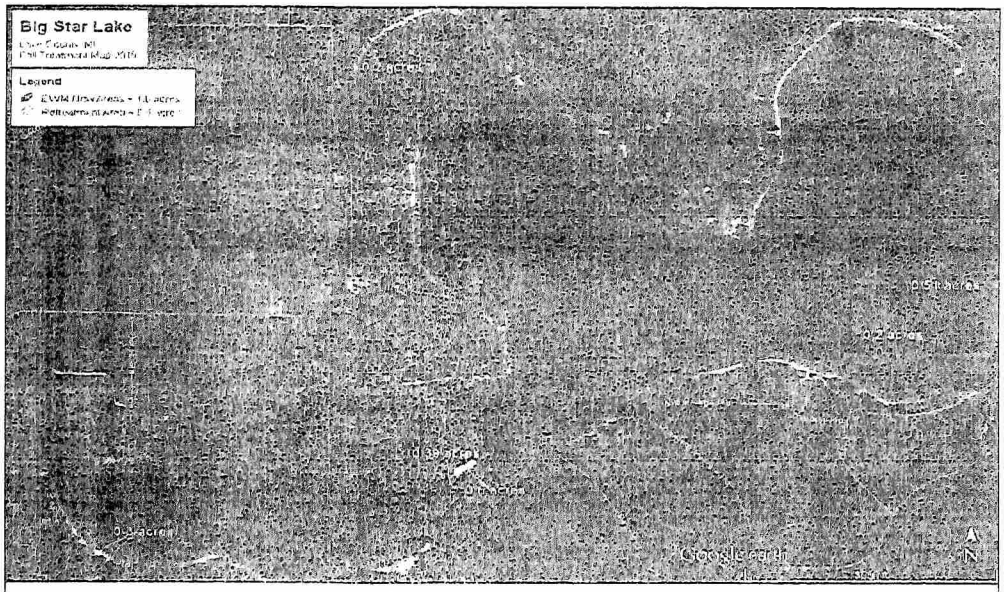


Figure 17. Eurasian Watermilfoil distribution in Big Star Lake (September, 2016).

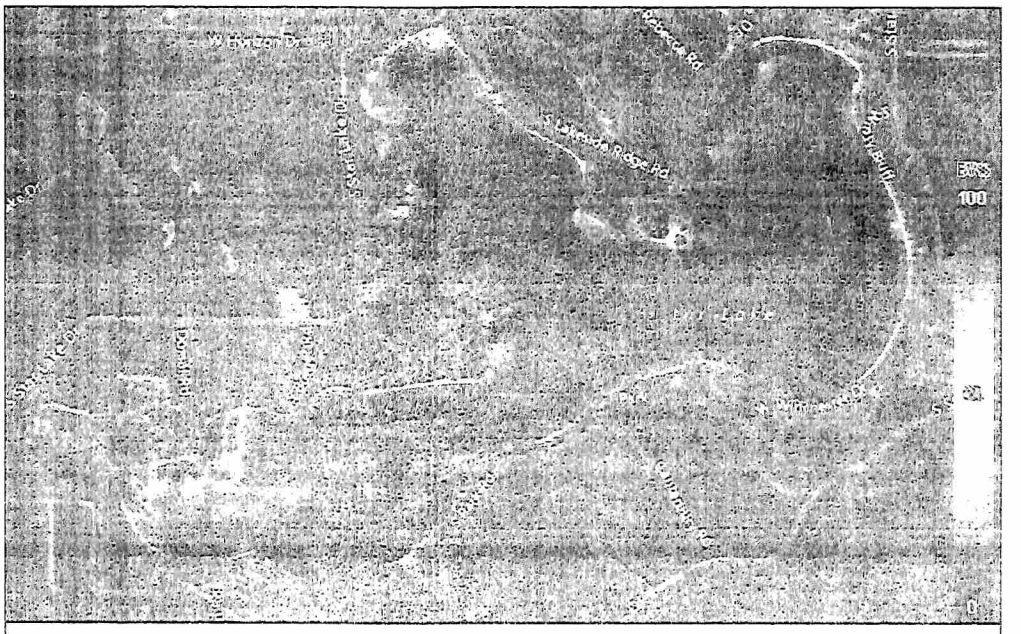


Figure 18. Aquatic Vegetation Biovolume in Big Star Lake (June, 2016).

Management Recommendations for 2017

Continuous aquatic vegetation surveys are needed to determine the precise locations of Eurasian Watermilfoil, Curly-leaf Pondweed, or other problematic invasives in or around Big Star Lake. These surveys should occur in late-May to early-June and again post-treatment in 2017. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2017 as in previous years.

Due to the relative scarcity of native aquatic vegetation in Big Star Lake, the treatment of these species with aquatic herbicides is not recommended (one exception is the overgrowth of nuisance pondweeds and in a few select areas of the lake and shallow area near the main public access site). The plan for 2017 includes the use of higher doses of systemic aquatic herbicides (such as tricopyr nearshore and 2, 4-D offshore) for the milfoil that may be present. Nuisance pondweeds will respond well to Aquathol-K® at 1-2 gallons per acre if present.

Water quality parameters in the lake will also be monitored and graphed with historical data to observe long-term trends.

In conclusion, Big Star Lake is a healthy lake with excellent aquatic plant biodiversity, excellent water clarity, moderate nutrients, and a healthy lake fishery. Management of the invasives 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) 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.