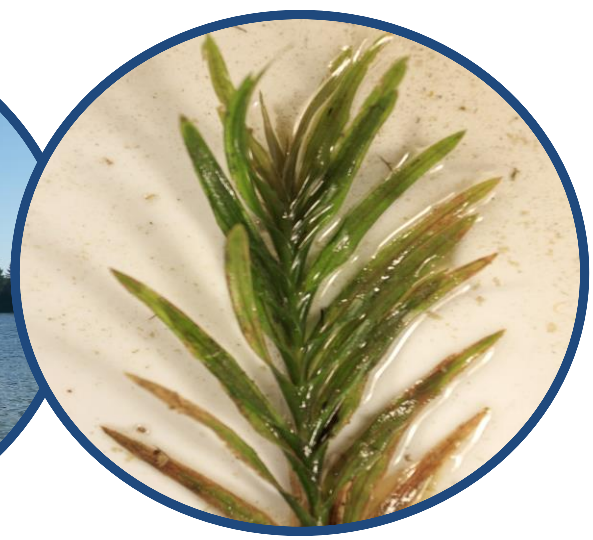
Bear Lake 2016 Aquatic Vegetation & Water Quality Report & 2017 Management Recommendations



October, 2016

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

(2016)

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1

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

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

The overall condition of Bear Lake is ranked in the top 15% of developed lakes of similar size in the state of Michigan. The water clarity in 2016 was excellent with an average of 16.0 feet. Much of this clarity is due to filtration by Zebra Mussels which extract green algae from the water for a food source and leave the water clearer. This is also why algal concentrations are low in Bear Lake. The nutrient concentrations in the lake are considered moderate and are adequate to support robust submersed aquatic plant growth. Invasive species such as Eurasian Watermilfoil are able to grow in moderate nutrient waters and thus are a challenge to the Bear Lake ecosystem. Bear Lake had nearly 16 acres of EWM in 2016 which was very effectively treated with systemic herbicides such as triclopyr and 2, 4-D. Protection of the 26 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 in East Bay).

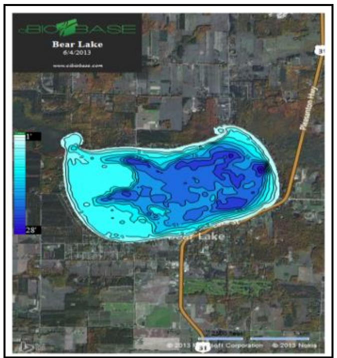
The lake did not experience depletion of dissolved oxygen with depth during spring or mid-summer sampling which is common for a large lake that minimally stratifies. Trends for most water quality parameters are shown below. Overall, Bear Lake is a very stable aquatic ecosystem with excellent aquatic vegetation biodiversity and water clarity, and neutral pH and soft water alkalinity.

Section

2

Bear Lake Water Quality Data

Water Quality Parameters Measured



Did You Know? Bear Lake has a maximum depth of 28 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 nitrogen (both in µg/L), chlorophyll-*a* (in µg/L), and algal species composition. Graphs that show some critical trends for some parameters in spring and late summer of each year are displayed below. Trend data was calculated using mean values for each parameter for each season over each sampling location. Table 1 below demonstrates how lakes are classified based on key parameters. Bear Lake would be considered mesotrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth but has excellent water clarity and moderate algal growth. 2016 water quality data for Bear Lake is shown below in Tables 2-7. Three deep basins were measured, with DB#1 located at the NW corner of the lake, DB#2 located at the central portion of the lake, and DB#3 located at the northeastern portion of the lake. These parameters are discussed below along with water quality data specific to Bear Lake which were collected on June 14 and August 17 of 2016.

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. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on June 14, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	70.1	10.1	7.5	226	0.3	141.6	0.50	60	0.010
10	65.9	9.8	7.6	229	0.5	136.1	0.50	59	0.010
21	61.7	9.8	7.6	224	1.1	111.8	0.50	58	0.026

Table 3. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on June 14, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	70.0	10.0	7.6	225	0.4	126.4	0.40	60	0.010
10	65.3	10.2	7.6	229	0.5	121.4	0.50	60	0.020
22	62.0	9.6	7.5	226	0.9	102.4	0.40	60	0.029

Table 4. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on June 14, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	70.5	10.2	7.6	228	0.5	146.9	0.40	61	0.010
10	66.9	10.0	7.5	225	0.4	133.4	0.40	60	0.022
21	63.7	9.2	7.5	226	1.0	127.7	0.40	59	0.034

Table 5. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on August 17, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	76.9	9.8	7.6	225	0.5	133.8	0.50	60	0.010
10	73.6	7.9	7.6	224	0.7	125.4	0.50	59	0.025
21	68.4	6.9	7.5	229	1.1	108.4	1.0	60	0.029

Table 6. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on August 17, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	76.0	9.8	7.5	226	0.4	156.3	0.40	60	0.010
10	73.4	7.9	7.6	226	0.4	129.6	0.40	60	0.028
22	69.0	7.5	7.6	227	1.0	107.5	1.0	59	0.035

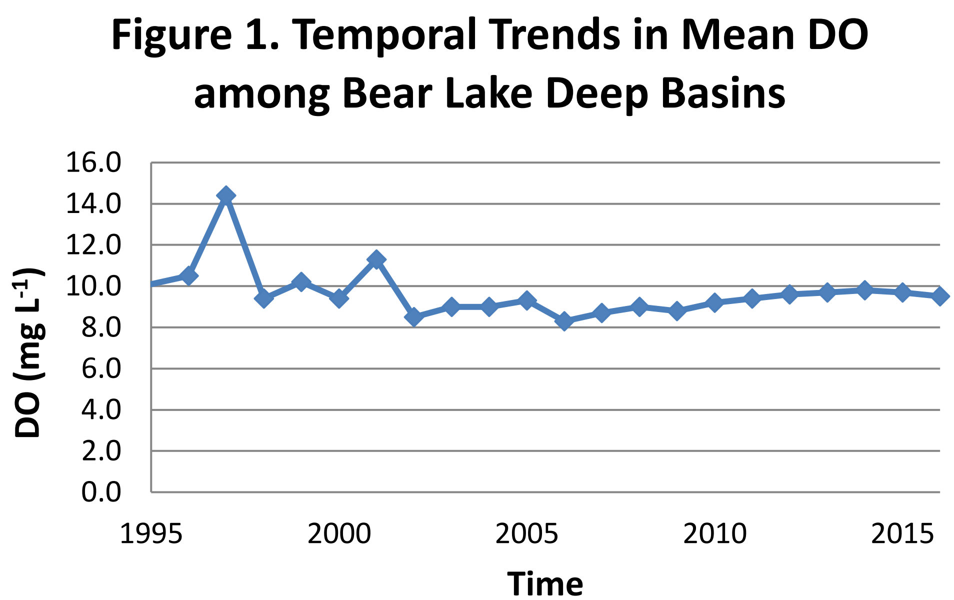
Table 7. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on August 17, 2016.

Depth ft.	*Water Temp ºF*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*ORP mV*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	75.9	9.9	7.5	226	0.5	134.2	0.50	60	0.010
10	73.6	8.9	7.6	226	0.5	120.1	0.50	60	0.026
21	69.8	6.6	7.6	227	1.1	106.4	0.65	61	0.038

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 in Bear Lake 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 is measured in milligrams per liter (mg L^{-1})

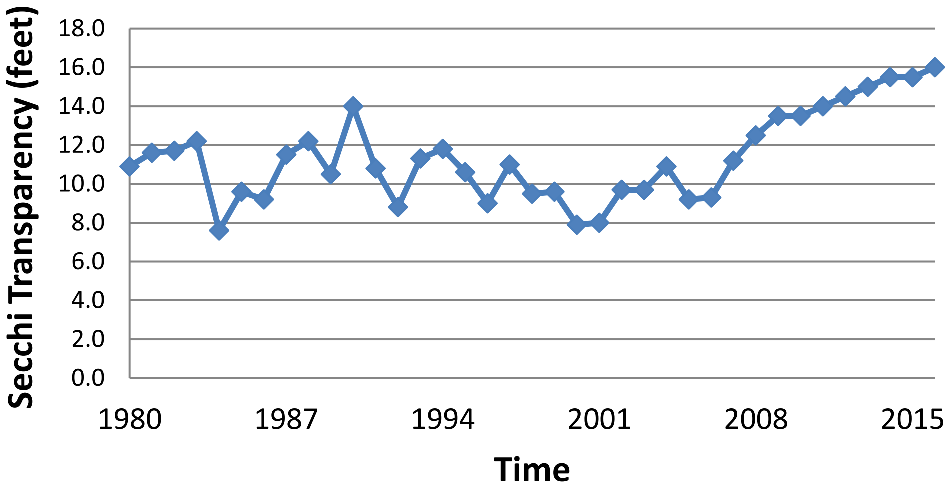
with the use of a dissolved oxygen meter and/or through the use of Winkler titration methods. The dissolved oxygen concentrations in Bear Lake were healthy and declined minimally with depth. This may be due to near isothermic conditions during the spring sampling and due to reduced stratification of the lake during summer months due to constant mixing of the lake water. The dissolved oxygen concentrations in Bear Lake support both a warm water and cool water fishery with an average concentration of around 9.5 mg L^{-1}. Figure 1 below shows the changes in mean dissolved oxygen with time in Bear Lake.



Water Clarity (Transparency) Data & Turbidity

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Bear Lake is adequate (~ 16.0 feet in 2016; Figure 2) 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 Bear Lake during the 2016 sampling events were also quite low at ≤1.1 NTU's and 48 mg/L, respectively. These values are lower than in 2015.

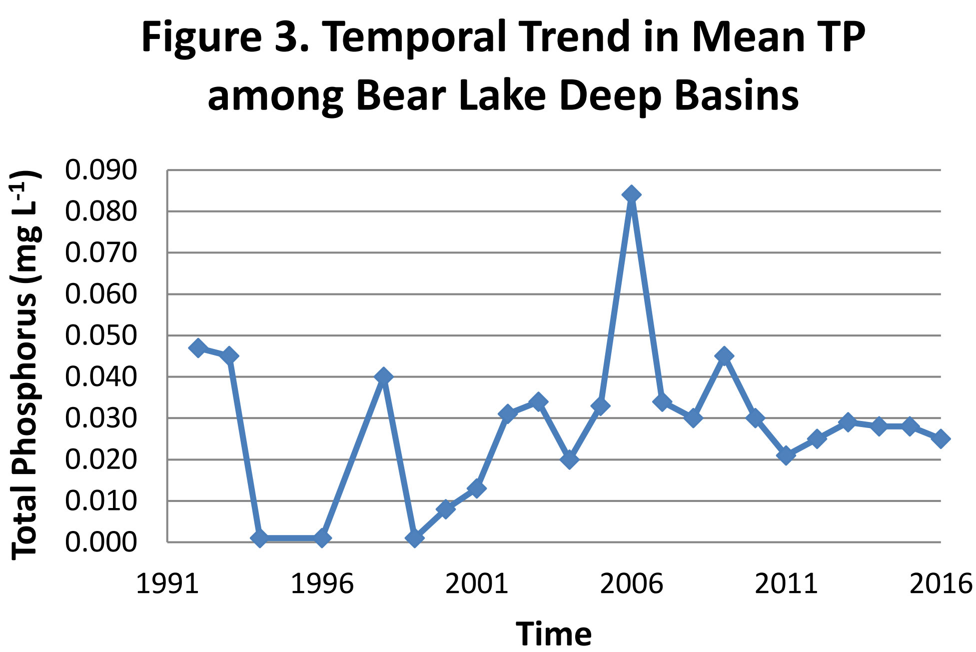
Figure 2. Temporal Trends in Mean Secchi Transparency among Bear Lake Deep Basins



Total Phosphorus and Total Nitrogen

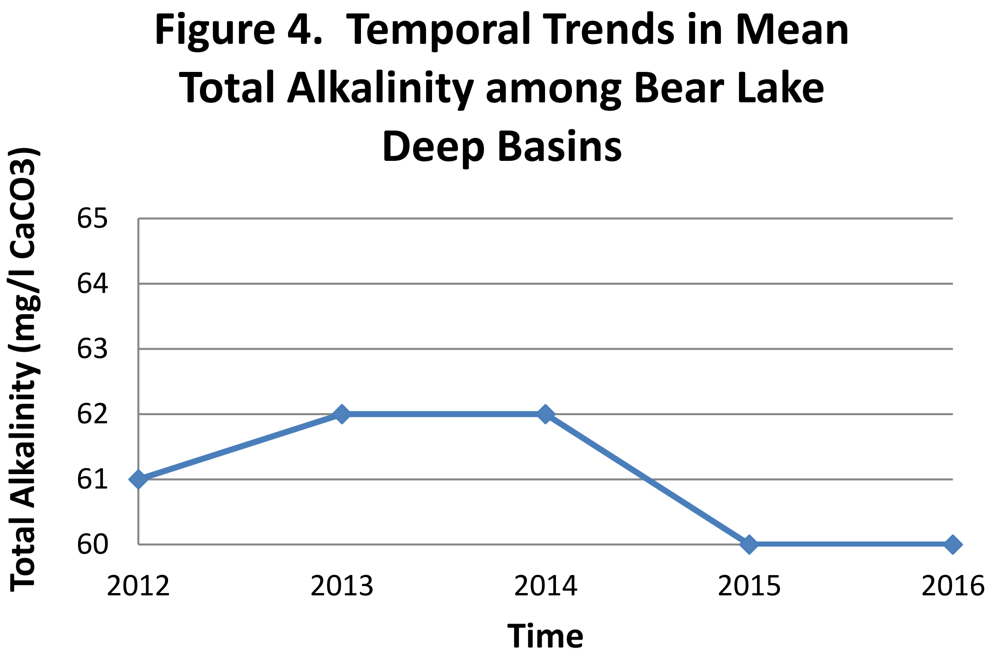
Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP concentrations are usually higher at increased depths due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Fortunately, even though the TP levels in Bear Lake are moderate, the dissolved oxygen levels are good enough at the bottom to not cause release of phosphorus from the bottom. TP concentrations have fluctuated between 0.010-0.038 mg L^{-1} during the 2016 season. The mean TP concentration was around 0.025 mg L^{-1} (Figure 3).

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 groundwater 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. Bear Lake possessed TKN concentrations between 0.40-1.0 mg L^{-1} during the 2016 sampling events which is considered oligo-mesotrophic and is desirable.



Total Alkalinity

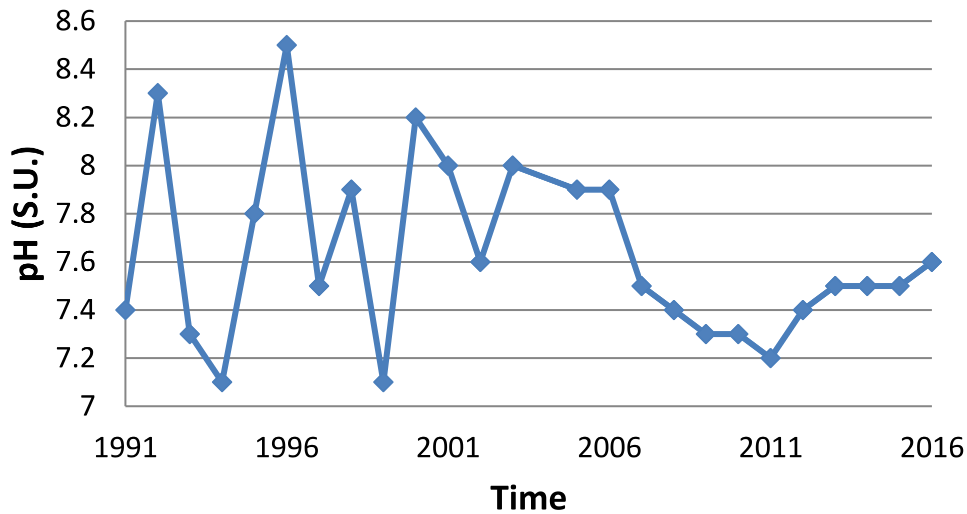
Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" water. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water. The alkalinity in Bear Lake averaged 60 mg L^{-1} of $CaCO_3$ (Figure 4) which is soft and indicates a soft water lake.



pH

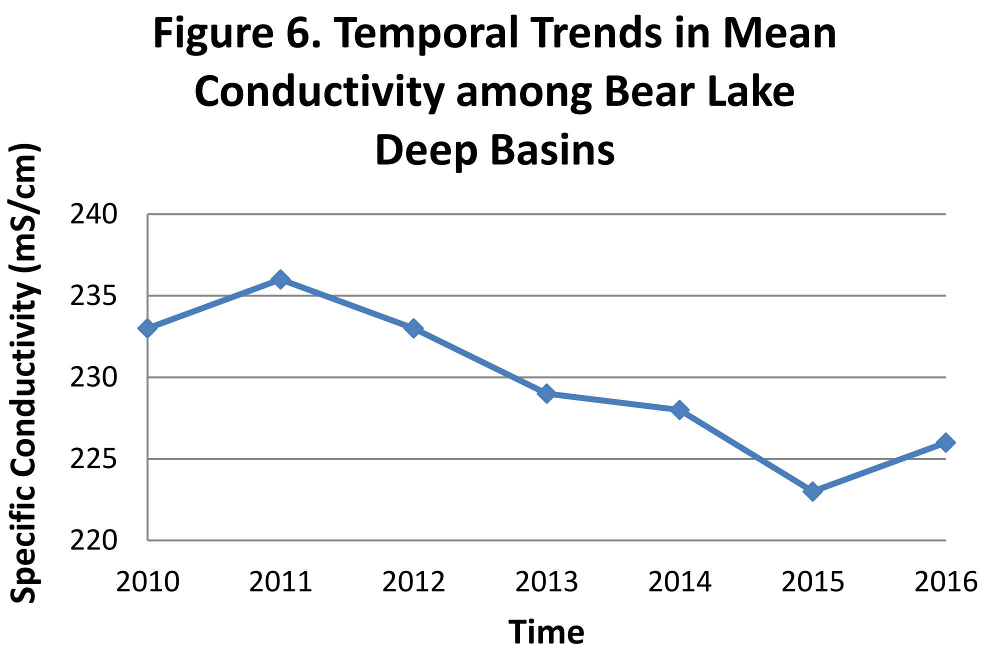
Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). Bear Lake is considered "slightly basic" on the pH scale. The mean pH of Bear Lake during the 2016 sampling events averaged 7.6 S.U. which is ideal for an inland soft water lake (Figure 5).

Figure 5. Temporal Trends in Mean pH among Bear Lake Deep Basins



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 Bear Lake during the 2016 sampling events (Figure 6) were moderate and ranged from 224-229 µS/cm. Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.



Chlorophyll-*a* and Algal Species Composition

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 μg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 μg/L are found in nutrient-poor or oligotrophic lakes. The mean chlorophyll-*a* concentrations during the 2016 sampling events in Bear Lake did not exceed 3.0 μg/L which is moderate for an inland Michigan lake and surprising given the very warm water temperatures.

The algal genera were determined from composite water samples collected over the deep basins of Bear Lake in 2016 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae): *Scenedesmus* sp., *Chlorella* sp., *Haematococcus* sp., *Euglena* sp., *Radiococcus* sp., *Cladophora* sp., *Pediastrum* sp., *Mougeotia* sp., *Pandorina* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): G*leocapsa* sp., the Bascillariophyta (diatoms): *Stephanodiscus sp.*, *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.

Section 3

Aquatic Vegetation Data (2016)

Status of Native Aquatic Vegetation in Bear Lake

The native aquatic vegetation present in Bear Lake is essential for the overall health of the lake and the support of the lake fishery. **The most recent survey in September of 2016 determined that there were a total of 26 native aquatic plant species in Bear Lake. These include 19 submersed species, 3 floating-leaved species, and 4 emergent species. This indicates a high biodiversity of aquatic vegetation in Bear Lake.** The overall % cover of the lake by native aquatic plants is low relative to the lake size and thus these plants should be protected unless growing near swim areas at nuisance levels.

The most common native aquatic plants included: 1) Leafless Watermilfoil (Figure 7) which lies close to the lake bottom and creates a "sod" appearance; 2) Fern-leaf Pondweed (Figure 8) which lies close to the lake bottom and has green fern-like leaves. The plant is largely responsible for carpeting the lake bottom and lowering the probability for milfoil fragments to re-root, and 3) Variable-leaf Pondweed (Figure 9) which is a bright green, small-leaved pondweed with slightly curled leaf margins that tends to grow nearshore. A list of all native aquatic plants and their relative abundance in 2016 is found in Table 8 below.

Figure 7. Leafless Watermilfoil

Figure 8. Fern-leaf Pondweed

Figure 9. Variable-leaf Pondweed

Table 8. 2016 Bear Lake Native Aquatic Plant Species and Relative Abundance.

Native Aquatic Plant Species	***Aquatic Plant Common Name***	***% cover in/around Bear Lake (June 2016)***	***% cover in/around Bear Lake (Sept. 2016)***
Chara vulgaris	Muskgrass	4.5	5.5
Potamogeton illinoensis	Illinois Pondweed	4.0	9.0
Potamogeton pusillus	Small-leaf Pondweed	2.8	6.0
Potamogeton robbinsii	Fern-leaf Pondweed	8.1	16.7
Stuckenia pectinatus	Sago Pondweed	0.9	3.3
Potamogeton amplifolius	Large-leaf Pondweed	0.9	7.0
Potamogeton praelongus	White-stem Pondweed	2.0	8.8
Potamogeton gramineus	Variable-leaf Pondweed	6.5	13.7
Potamogeton natans	Floating-leaf Pondweed	3.0	4.0
Potamogeton zosteriformis	Flat-stem Pondweed	0.5	3.0
Vallisneria americana	Wild Celery	8.0	8.9
Najas guadalupensis	Southern Naiad	5.5	9.4
Najas flexilis	Slender Naiad	0.2	1.4
Myriophyllum tenellum	Leafless Watermilfoil	19.0	24.7
Megalodonta beckii	Water Marigold	4.0	5.6
Ceratophyllum demersum	Coontail	2.0	2.0
Elodea canadensis	Common Elodea	5.8	9.0
Utricularia vulgaris	Common Bladderwort	4.0	6.6
Utricularia minor	Small Bladderwort	0.1	0.1
Nymphaea odorata	White Waterlily	0.4	0.4
Nuphar variegata	Yellow Waterlily	0.6	0.7
Brasenia schreberi	Watershield	0.5	1.9
Typha latifolia	Cattails	0.9	0.9
Scirpus acutus	Bulrushes	0.7	1.2
Iris versicolor	Blueflag Iris	0.1	0.2
Decodon verticillatus	Swamp Loosestrife	0.9	1.0

Status of Invasive (Exotic) Aquatic Plant Species in Bear Lake

Figure 10. Eurasian Watermilfoil

The amount of Eurasian Watermilfoil (Figure 10) present in Bear Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. 2016 was amongst the hottest years on record and many lakes experienced nuisance milfoil and algal outbreaks even given the two consecutive harsh winters.

The June 14, 2016 survey revealed that approximately 12.3 acres of milfoil were found throughout the lake and it was treated with granular 2, 4-D (Sculpin®) at a dose of 180 lbs. per acre on June 22, 2016. On August 29, 2016 an additional 6.5 acres of milfoil were treated with various doses of Renovate OTF and Sculpin G systemic granular herbicides for nearshore and offshore areas, respectively. The treatments were successful overall with minimal regrowth of the milfoil. The 2016 surveys revealed that there was a total of 2 invasive species in and around the lake which included non-hybrid watermilfoil and the emergent, Purple Loosestrife (see photo below; Figure 11).

Maps showing the locations of all milfoil are shown on the next page. The milfoil in the West Bay was not treated in front of one residence due to request for non-treatment (Figures 12-13).

Figure 11. Purple Loosestrife as found in the West Bay of Bear Lake. This plant should be hand-removed if possible.

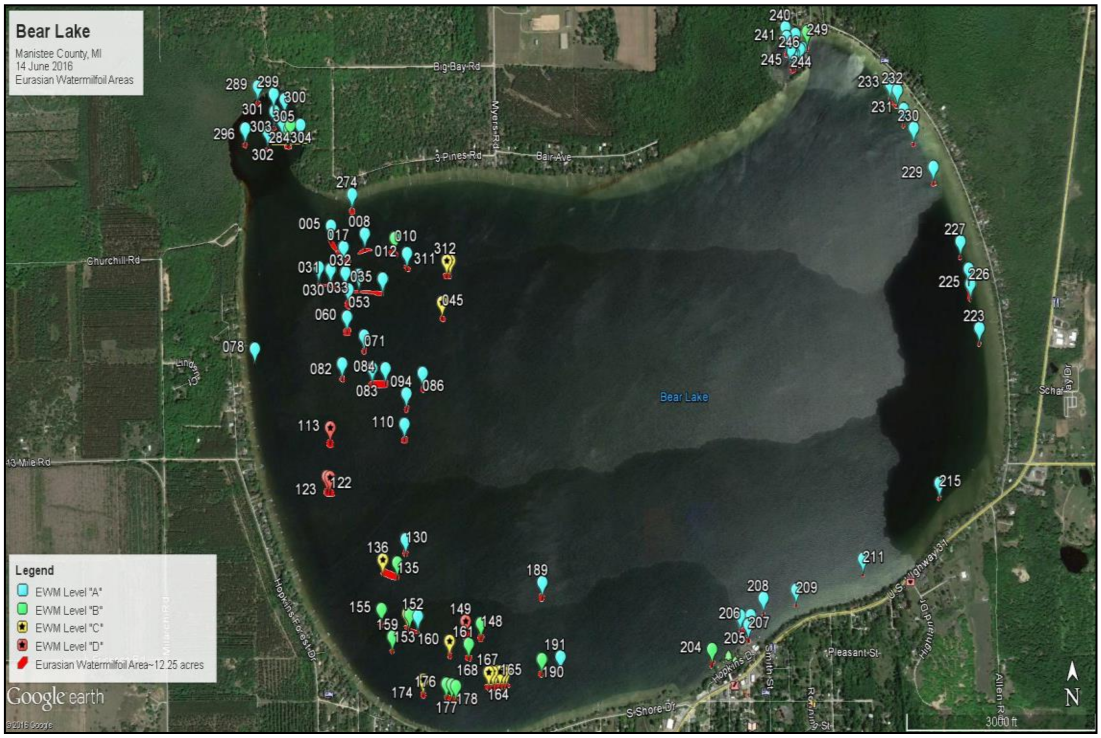


Figure 12. Distribution of EWM in Bear Lake (June, 2016).

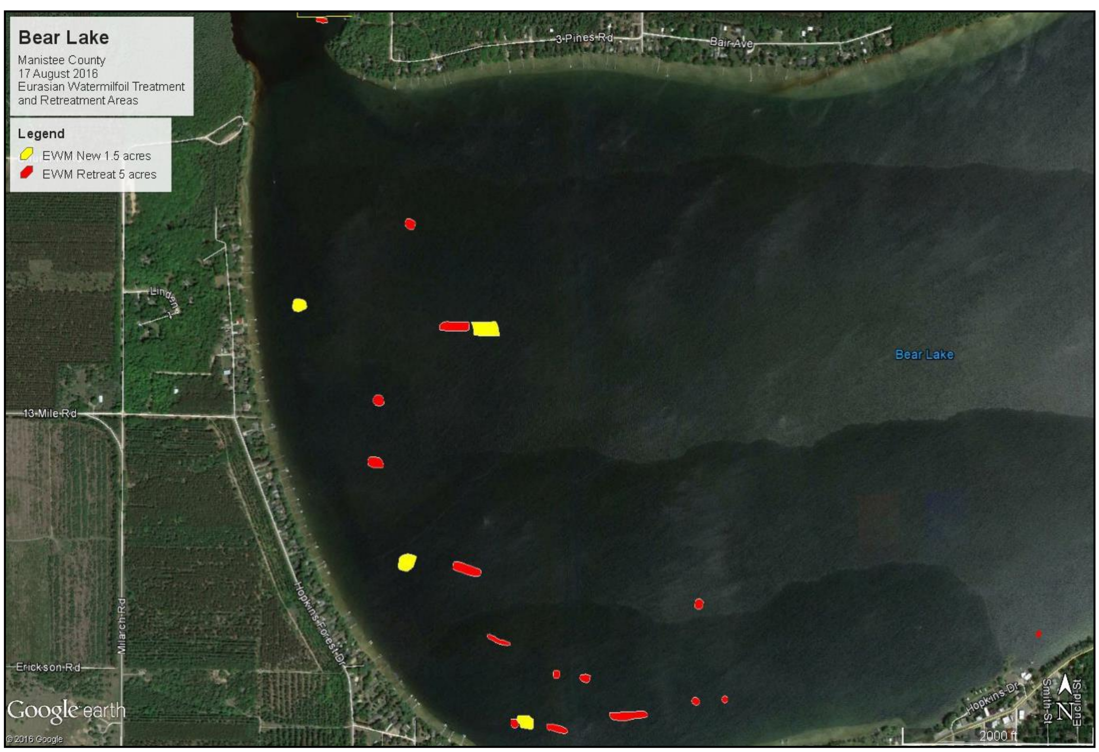


Figure 13. Distribution of EWM in Bear Lake (August, 2016).

Section

4

Management Recommendations for 2017

Continuous aquatic vegetation surveys are needed to determine the precise locations of EWM or other problematic invasives in and around Bear Lake. These surveys should occur in June and again post-treatment in 2017. As in previous years, scientists from RLS will be present to oversee all aquatic herbicide applications.

Due to the relative scarcity of native aquatic vegetation in Bear Lake, the treatment of these species with aquatic herbicides is not recommended (one exception is the overgrowth of lily pads in the East Bay. Note: That Bay would be best served with aeration to reduce encroachment of the lily pads). The plan for 2017 includes the use of high dose systemic aquatic herbicides as used in recent years. Products such as Sculpin G® at a dose of 200-250 lbs. /acre would be recommended offshore and a dose of 200-250 lbs. /acre of Renovate OTF® nearshore for effective control of the milfoil.

Water quality parameters in the main lake will also be monitored and graphed with historical data to observe long-term trends. This has been important since the nutrient concentrations and other parameters have shown a stable aquatic ecosystem.

In conclusion, Bear Lake is a very healthy lake with excellent aquatic plant biodiversity, very good water clarity, moderate nutrients, and a healthy lake fishery. Management of the EWM 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.