Restorative Lake Sciences, LLC

Bear Lake: State of the Lake & 2012 Annual Report

Prepared for the Bear Lake Improvement Board, Bear Lake Township, Pleasanton Township, and the Village of Bear Lake

December, 2012

Prepared for: **Bear Lake Improvement Board**
C/o: Mr. Don Brisbin

Prepared by: **Jennifer Jermalowicz-Jones**
Water Resources Director
Restorative Lake Sciences, LLC
2714 E. Hawley Rd
Custer, MI 49405

TABLE OF CONTENTS

SECTION **PAGE**

FIGURES

TABLES

NAME	PAGE

AN ANNUAL PROGRESS REPORT OF AQUATIC VEGETATION AND WATER QUALITY IN BEAR LAKE
MANISTEE COUNTY, MICHIGAN

December, 2012

1.0 EXECUTIVE SUMMARY

This report describes the current distribution of native and exotic submersed, floating-leaved, and emergent aquatic plants, including the exotic species, Eurasian Watermilfoil (*Myriophyllum spicatum;* EWM) within Bear Lake, Manistee County, Michigan. During the original lake improvement feasibility study in 2007, Bear Lake was infested with over 300 acres of invasive EWM that was widely distributed around the lake. Over the past five years, the EWM was successfully spot-treated and reduced. On June 14, 2012, approximately 78 acres of exotic milfoil were treated. There were 70 acres of EWM in the main lake that were treated by A&T Service, LLC with 2,4-D at a dose of 120 lbs per acre and 8 acres of EWM in the West and East Bay areas that were treated with Renovate OTF® at a dose of 120 lbs per acre.

Continuous monitoring of Bear Lake for EWM, new invasives, and the changes in native aquatic plant community composition is highly recommended on an annual basis, preferably in mid to late spring and in late summer. Whole-lake grid surveys conducted on June 5 and September 5 of 2012 revealed that the native pondweed and low-growing native aquatic plant communities have flourished throughout the lake. Currently 38% of the lake remains unvegetated and 62% remains vegetated. In other words, of the 558 grid points used to monitor the lake, there were 209 grid points without vegetation and these were primarily in deep waters of over 12 feet deep and in shallow sandy areas near shore. In particular, native species such as the most abundant aquatic plant species included Variable-leaf Pondweed (*Potamogeton gramineus*), Fernleaf Pondweed (*Potamogeton robbinsii*), Leafless Watermilfoil (*Myriophyllum tenellum*), and Skunkgrass (*Chara vulgaris*). Rare species included Water Stargrass (*Zosterella dubia*), Clasping-leaf Pondweed (*Potamogeton richardsonii*), Flatstem Pondweed (*Potamogeton zosteriformis*), and Northern Watermilfoil (*Myriophyllum sibiricum*). This aquatic plant community composition is highly favorable because these plants represent a high diversity in plant structures that house different macroinvertebrate communities which feed fish.

There are currently a total of 29 native aquatic plant species in and around Bear Lake, which includes 21 submersed, 3 floating-leaved, and 5 emergent aquatic plant species. The removal of EWM has been critical for the protection of the native aquatic plant biodiversity and the fishery within Bear Lake.

The water clarity of the lake continues to be high and helps support abundant aquatic plant growth in many areas. The high Secchi transparency also supports aquatic plant growth to a depth of approximately 13 feet in Bear Lake. Levels of nutrients such as phosphorus and nitrogen have remained consistent over the past few years and are slightly lower than most lakes of similar depth. The alkalinity and pH of the lake water are indicative of neutral lake chemistry and consistent with other Michigan inland lakes.

Phytoplankton communities within the lake appear to be balanced between the diatom and green-algae communities with little evidence of blue-green algae. However, the density of filamentous *Cladophora* green algae near shore on hard substrates has increased over the past few years, presumably due to the warm water temperatures that encourage green algae growth. Nutrient levels in the lake are still low enough to prevent excessive blue green algae blooms. Green algae and diatoms are the preferred food choices for zooplankton.

A timeline of all lake management activities performed in 2012 is shown below in Table 1.

Table 1. Bear Lake Timeline of Lake Management Events in 2012

January 19, 2012: Bear Lake Improvement Board Meeting

April 19, 2012: Bear Lake Improvement Board Meeting

May 17, 2012: Bear Lake Improvement Board Meeting

May 22, 2012: Bear Lake Water Quality Sampling

June 5, 2012: Bear Lake GPS Grid Matrix Survey

June 21, 2012: Bear Lake Improvement Board Meeting

July 7, 2012: Bear Lake Water Quality Sampling

July 14, 2012: Bear Lake Days Educational Booth

July 19, 2012: Bear Lake Improvement Board Public Hearings

August 10, 2012: Bear Lake Improvement Board Conference Call

August 16, 2012: Bear Lake Improvement Board Meeting/Workshop

September 5, 2012: Bear Lake GPS Grid Matrix Survey

September 20, 2012: Bear Lake Improvement Board Meeting

October 12, 2012: Bear Lake Aquatic Herbicide Bid RFP's Released

October 18, 2012: Bear Lake Improvement Board Meeting

December 20, 2012: Bear Lake Improvement Board Meeting

2.0 AQUATIC PLANT SURVEY METHODS

The aquatic plant sampling methods used for lake surveys of macrophyte communities commonly consist of shoreline surveys, visual abundance surveys, transect surveys, AVAS surveys, and Point-Intercept Grid surveys. The Michigan Department of Environmental Quality (MDEQ) prefers that an Aquatic Vegetation Assessment Site (AVAS) Survey, or a GPS Point-Intercept survey (or both) be conducted on most inland lakes following large-scale aquatic herbicide treatments to assess the changes in aquatic vegetation structure and to record the relative abundance and locations of native aquatic plant species. Due to the large size of Bear Lake, a bi-seasonal GPS Point-Intercept grid matrix/AVAS survey is conducted to assess all aquatic species, including submersed, floating-leaved species, and emergent aquatic plants.

2.1 The GPS Point-Intercept Survey Method

While the MDEQ AVAS protocol considers sampling vegetation using visual observations in areas around the littoral zone, the Point-Intercept Grid Survey method is meant to assess vegetation throughout the entire surface area of a lake (Madsen et *al*. 1994; 1996). This method involves conducting measurements at Global Positioning Systems (GPS)-defined locations that have been pre-selected on the computer to avoid sampling bias. Furthermore, the GPS points are equally spaced on a map. The points should be placed together as closely and feasibly as possible to obtain adequate information of the aquatic vegetation communities throughout the entire lake. At each GPS Point location the aquatic vegetation species presence and abundance are estimated. In between the GPS points, any additional species and their relative abundance are also recorded using visual techniques. This is especially important to add to the Point-Intercept method, since EWM and other invasive plants may be present between GPS points but not necessarily at the pre-selected GPS points. Once the aquatic vegetation communities throughout the lake have been recorded using the GPS points, the data can be placed into a Geographic Information System (GIS) software package to create maps showing the distribution and relative abundance of particular species. The GPS Point- Intercept method is particularly useful for monitoring aquatic vegetation communities through time and for identification of nuisance species that could potentially spread to other previously uninhabited areas of the lake.

The GPS Point-Intercept method surveys on June 5, 2012 and on September 5, 2012 consisted of 558 equidistantly-spaced grid points on Bear Lake (Figure 1), using a Humminbird® 50-satellite GPS WAAS-enabled unit (accuracy within 2 feet). A combination of rake tosses and visual data accounted for the observations in the survey.

Figure 1. Map showing grid sampling locations on Bear Lake.

3.0 AQUATIC PLANT SURVEY RESULTS FOR 2012

Whole-lake grid surveys conducted on June 5, 2012 and September 5, 2012 revealed that the native pondweed and low-growing native aquatic plant population has flourished throughout the lake. Currently, 38% of the lake remains unvegetated and 62% remains vegetated. In other words, of the 558 grid points used to monitor the lake per acre, there were 209 grid points without vegetation and these were primarily in deep waters of over 13 feet deep and in shallow sandy areas near shore. The most abundant aquatic plant species included Variable-leaf Pondweed (*Potamogeton gramineus*), Fernleaf Pondweed (*Potamogeton robbinsii*), Leafless Watermilfoil (*Myriophyllum tenellum*), and Skunkgrass (*Chara vulgaris*). Rare species included Water Stargrass (*Zosterella dubia*), Clasping-leaf Pondweed (*Potamogeton richardsonii*), Flatstem Pondweed (*Potamogeton zosteriformis*), and Northern Watermilfoil (*Myriophyllum sibiricum*). This aquatic plant community composition is highly favorable because these plants represent a high diversity in plant structures that house different macroinvertebrate communities which feed fish.

3.1 Bear Lake Exotic Aquatic Plant Species (2012)

The June 5, 2012 survey detected approximately 78 acres of invasive milfoil (Figure 2) distributed throughout the lake. A preliminary survey on May 19, 2012 showed little growth of milfoil and other native aquatic plants. Previous laboratory results on the genotype of the milfoil indicated that none of the milfoil samples showed hybridization between exotic and native milfoils. Exotic species and their relative abundance in the lake prior to 2012 treatments are listed below in Table 2.

Figure 2. Eurasian Watermilfoil
© *Superior Photique*

Invasive Aquatic Macrophyte Species	***Common Name***	***Percent Coverage***
Myriophyllum spicatum	Eurasian Watermilfoil	0.1%

Table 2. Exotic aquatic plant species present within or around Bear Lake (June and September, 2012)

Figure3. EWM locations within Bear Lake in May 2012.

3.2 Bear Lake Native Aquatic Plant Species (2012)

During the late summer survey in 2012, a total of 21 submersed, 3 floating-leaved, and 5 emergent aquatic plant species were found for a grand total of 29 species (Table 5). The table shows the relative abundance in percentage of littoral zone cover for each species (# GPS points out of 558 that contained vegetation). This indicates a high biodiversity of aquatic vegetation in Bear Lake. Photographs of the most common aquatic plant species found in Bear Lake can be found on page 15 (Figures 4-7) and less common species are found on page 16 (Figures 8-11).

Native Aquatic Plant Species	***Common Name***	***Relative Abundance***	***Growth Habit***
Chara vulgaris, 3	Muskgrass	4.5%	Submersed, Rooted
Potamogeton illinoensis, 10	Illinois Pondweed	3.4%	Submersed, Rooted
Potamogeton pusillus, 29	Small-leaf Pondweed	1.7%	Submersed, Rooted
Potamogeton robbinsii, 6	Fern-leaf Pondweed	12.1%	Submersed, Rooted
Stuckenia pectinatus, 4	Sago Pondweed	1.0%	Submersed, Rooted
Potamogeton amplifolius, 11	Large-leaf Pondweed	1.8%	Submersed, Rooted
Potamogeton praelongus, 8	White-stemmed Pondweed	2.1%	Submersed, Rooted
Potamgeton richardsonii, 9	Clasping-leaf Pondweed	0.5%	Submersed, Rooted
Potamogeton gramineus, 7	Variable-leaf Pondweed	14.1%	Submersed, Rooted
Potamogeton natans, 13	Floating-leaf Pondweed	1.5%	Submersed, Rooted
Zosterella dubia, 14	Water Stargrass	0.4%	Submersed, Rooted
Potamogeton zosteriformis, 5	Flat-stemmed Pondweed	0.7%	Submersed, Rooted
Vallisneria americana, 15	Wild Celery	1.2%	Submersed, Rooted
Myriophyllum sibiricum, 18	Northern Watermilfoil	0.6%	Submersed, Rooted
Najas guadalupensis, 25	Southern Naiad	3.3%	Submersed, Rooted
Myriophyllum tenellum, 27	Leafless Watermilfoil	9.4%	Submersed, Rooted
Megalodonta beckii, 28	Water Marigold	0.8%	Submersed, Rooted
Ceratophyllum demersum, 20	Coontail	0.9%	Submersed, Non-Rooted
Elodea canadensis, 21	Common Elodea	1.2%	Submersed, Rooted
Utricularia vulgaris, 22	Common Bladderwort	1.6%	Submersed, Non-Rooted
Utricularia minor, 23	Small Bladderwort	0.1%	Submersed, Non-Rooted
Nymphaea odorata, 30	White Waterlily	1.7%	Floating-Leaved, Rooted
Nuphar variegata, 31	Yellow Waterlily	0.1%	Floating-Leaved, Rooted
Pontedaria cordata, 37	Pickerelweed	0.1%	Emergent
Brasenia schreberi, 32	Watershield	0.9%	Floating-Leaved, Rooted
Typha latifolia, 39	Cattails	0.5%	Emergent
Scirpus acutus, 40	Bulrushes	0.5%	Emergent
Iris versicolor, 44	Blueflag Iris	0.1%	Emergent
Decodon verticillatus, 42	Swamp Loosestrife	0.6%	Emergent

Table 3. Native aquatic plant species found in and around Bear Lake, 2012.

Figure 4. A photograph of Variable-leaf Pondweed (*Potamogeton gramineus*) © *Superior Photique*

Figure 5. A photograph of Fern-leaf Pondweed (*Potamogeton robbinsii*) © *Superior Photique*

Figure 6. A photograph of Leafless Watermilfoil (*Myriophyllum tenellum*) © *Superior Photique*

Figure 7. A photograph of Skunkgrass (*Chara vulgaris*)

Figure 8. A photograph of Water Stargrass (*Zosterella dubia*)
© Superior Photique

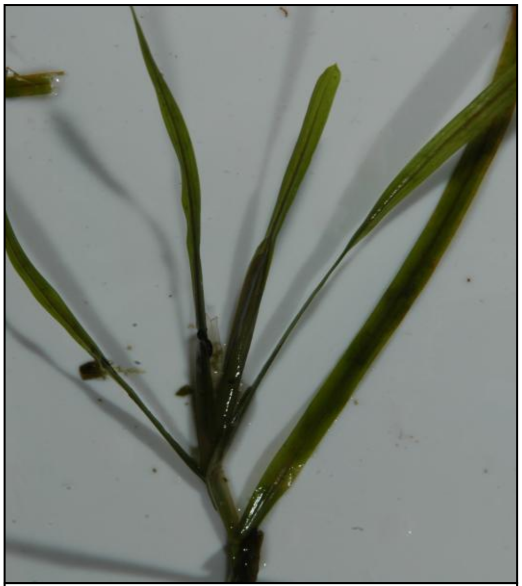


Figure 9. A photograph of Flat-stem Pondweed (*Potamogeton zosteriformis)* *© Superior Photique*

Figure 10. A photograph of Northern Watermilfoil (*Myriophyllum sibiricum*)
© Superior Photique

Figure 11. A photograph of Illinois Pondweed

4.0 BEAR LAKE 2012 AND HISTORICAL WATER QUALITY RESULTS

The quality of water is highly variable among Michigan inland lakes, although some characteristics are common among particular lake classification types. The water quality of Bear Lake is affected by both land use practices and climatic events. Climatic factors (i.e., spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use) alter water quality over longer time periods. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 4). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as **eutrophic**; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as **oligotrophic**. Lakes that fall in between these two categories are classified as **mesotrophic**. **Bear Lake is classified as mesotrophic based on its high transparency and moderate nutrient and chlorophyll-*a* concentrations.**

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

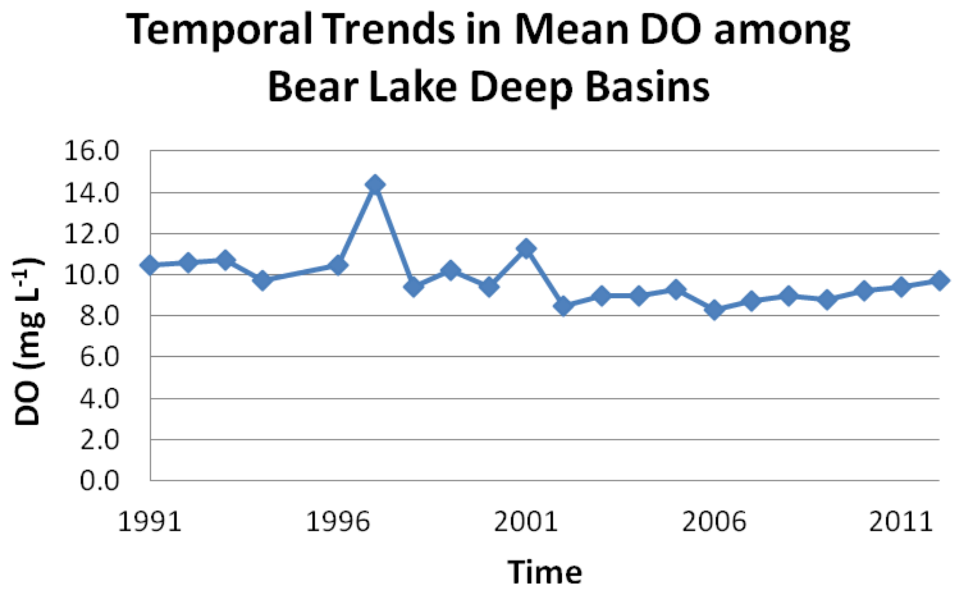
Table 4. Lake Trophic Status Classification Table (MDEQ)

4.1 Bear Lake Deep Basin Water Quality Data

Water quality parameters such as dissolved oxygen, water temperature, conductivity, turbidity, total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, Secchi transparency, chlorophyll-*a*, among others, all respond to changes in water quality and consequently serve as indicators of water quality change. These parameters were collected at the deep basins of Bear Lake during the spring and late summer of 2012. Water quality data collected over the three deep basins are shown below in tables 7-10.

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 spring 2012 dissolved oxygen concentrations in Bear Lake were high and ranged from 10.2-11.9 mg L^{-1}. Late summer values ranged from 9.2-6.0 from the surface to the bottom, which indicated that oxygen depletion was present but not to a level that would be detrimental to the fishery.



Water Temperature

The water temperature of lakes varies within and among seasons and is nearly uniform with depth under winter ice cover because lake mixing is reduced when waters are not exposed to wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover". In general, lakes with deep basins will stratify and experience turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer. The mid-May water temperatures of Bear Lake in 2012 at the deep basins demonstrated the lack of a thermocline from the surface to the bottom and thus the temperature ranged from 50.1 ºF to 56.6ºF. The late summer 2012 water temperatures, however, varied by nearly 12.3ºF from the surface to the bottom and thus a thermocline was noted. Surface water temperatures in late summer were up to 78.7 ºF, which was very high. Other inland lakes around the United States also exhibited record high water temperatures due to the excessive heat.

Conductivity

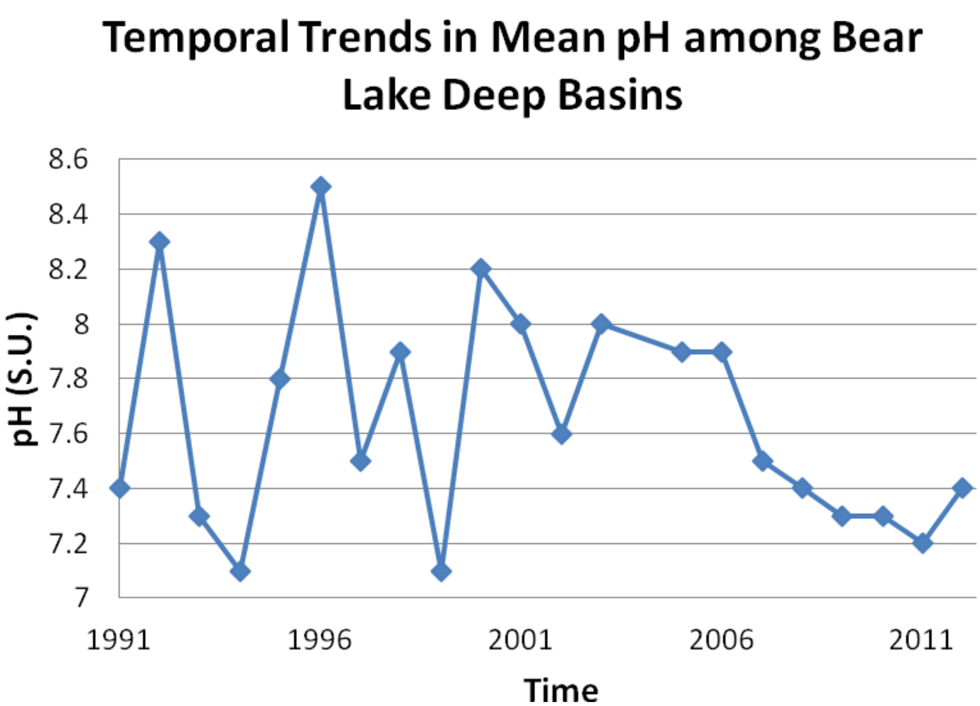
Conductivity is a measure of the amount of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. Conductivity is measured in microsiemens per centimeter ($\mu S\ cm^{-1}$) with the use of a conductivity probe and meter. Conductivity values for Bear Lake were moderate and ranged from 209-229 $\mu S\ cm^{-1}$ in spring and late summer. These values are slightly lower than in previous years.

Turbidity

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 from erosion inputs, phytoplankton blooms, stormwater discharge, urban runoff, re-suspension of bottom sediments, and by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise the water temperature. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity is measured in Nephelometric Turbidity Units (NTU's) with the use of a turbimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that. Turbidity ranged from 0.2-2.5 and was highest near the lake bottom due to increased suspension of sediments into the water column that increase turbidity. The lake bottom is predominately sandy substrate with some marl and silt, which increases the turbidity values near the lake bottom.

pH

pH is the measure of acidity or basicity of water. The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. 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). pH is measured with a pH electrode and pH-meter in Standard Units (S.U). The pH of Bear Lake water ranged from 7.2-7.6 during the spring and late summer sampling. From a limnological perspective, Bear Lake is considered "neutral" on the pH scale.

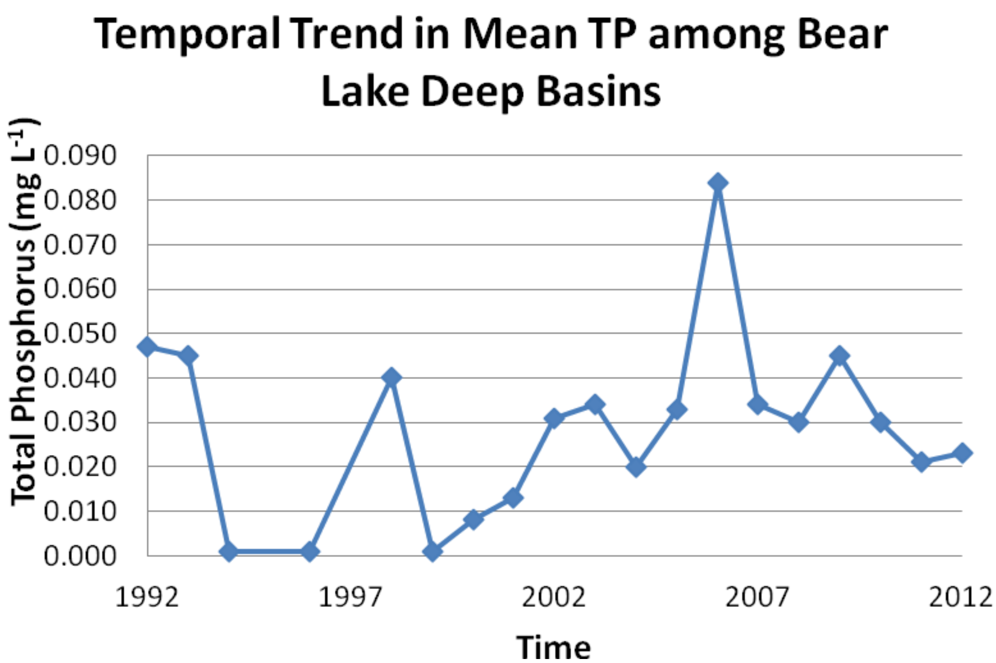


Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of lake water. 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 is measured in milligrams per liter of $CaCO_3$ through an acid titration method. The total alkalinity of Bear Lake is considered "low" (< 150 mg L^{-1} of $CaCO_3$), and indicates that the water is not hard or highly alkaline. Total alkalinity ranged from 66-73 mg L^{-1} of $CaCO_3$ among both deep basins during the sampling periods in 2012. 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.

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. Lakes which contain greater than 20 µg L^{-1} of TP are defined as eutrophic or nutrient-enriched. 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. Total phosphorus is measured in micrograms per liter (µg L^{-1}) or in milligrams per liter (mg L^{-1}) with the use of a chemical autoanalyzer. Mean TP concentrations were calculated for each deep basin and consisted of surface, middle-depth, and bottom values for each deep basin during both spring and late summer of each year. The range of TP for the 2012 sampling period ranged from a low of below 0.010 µg L^{-1} in the spring to a high of 0.055 µg L^{-1} in the late summer. The mean TP concentrations for each deep basin and season are graphed below.

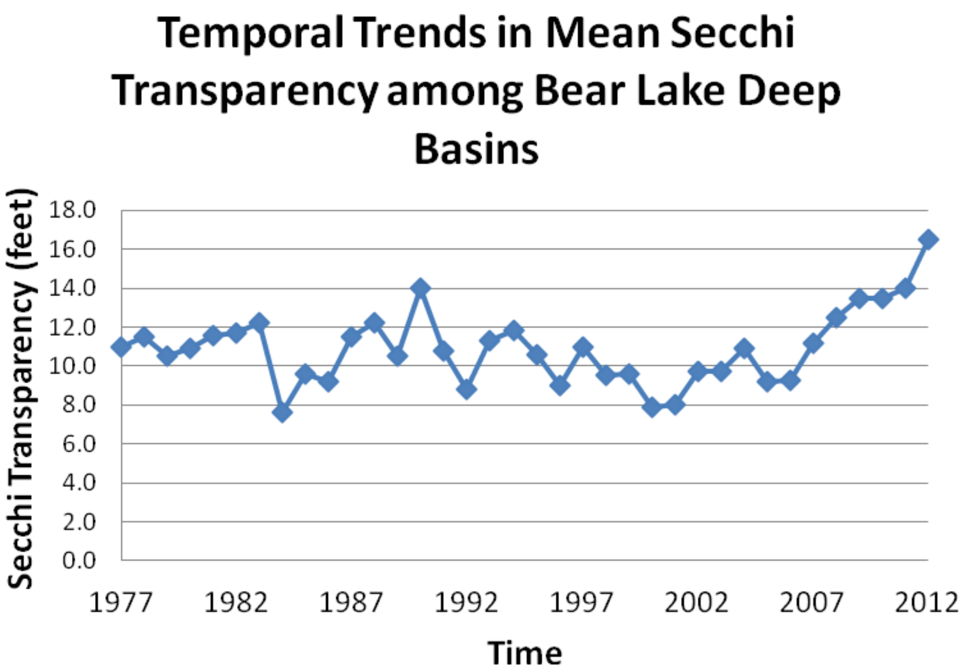


Total Kjeldahl Nitrogen

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 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 contained highly variable values for TKN (= 0.10 – 0.80 mg L^{-1}) in 2012, which was similar to previous years.

Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk. Secchi disk transparency is measured in feet (ft) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. The Secchi transparency of Bear Lake varied among deep basins and among seasons and averaged 16.5 feet which is considerably higher than in previous years. In fact, this trend was noted on many other inland lakes this year, presumably due to less runoff which limits suspended particles in the water that decrease clarity. These Secchi transparency values are adequate 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. The mean annual Secchi values are graphed below along with historical values collected with the same measurement methods.



Total Dissolved Solids

Total Dissolved Solids (TDS) is the 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. Total dissolved solids are often measured with the use of a calibrated meter in mg L^{-1}. Spring values would likely be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The concentration of TDS in Bear Lake ranged from 72-91 mg L^{-1}.

Oxidative Reduction Potential

The oxidation-reduction potential (E_h) of lake water describes the effectiveness of certain atoms to serve as potential oxidizers and indicates the degree of reductants present within the water. In general, the Eh level (measured in millivolts) decreases in anoxic (low oxygen) waters. Low E_h values are therefore indicative of reducing environments where sulfates (if present in the lake water) may be reduced to hydrogen sulfide (H_2S). Decomposition by microorganisms in the hypolimnion may also cause the E_h value to decline with depth during periods of thermal stratification. The E_h (ORP) values for Bear Lake were highly variable and change rapidly. The ORP values ranged between 199.2 mV-92.4 mV from the surface to the bottom within the lake, and indicated oxidized rather than reduced conditions. Due to the excessively high variability in these values and the fact that they can change thousands of times daily, these values were not graphed.

Chlorophyll-a and Phytoplankton Communities

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-*concentrations* are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6.0 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg L^{-1} are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* is measured in micrograms per liter (µg L^{-1}) with the use of an acetone extraction method and a spectrometer. The chlorophyll-*a* concentrations in Bear Lake were determined by collecting a composite sample of the algae throughout the water column at each of the three deep basin sites from just above the lake bottom to the lake surface in spring and late summer of 2012. The chlorophyll-*a* concentrations ranged from a low of 0.98 μg L^{-1} to a high of 4.61 μg L^{-1}, with the highest value being present at Deep Basin #2 during late summer. Overall values for chlorophyll-*a* are higher in late summer than in spring due to increased water temperatures that create more algal growth.

Algal genera from a composite water sample collected over the deep basins of Bear Lake in spring and late summer of 2012 were analyzed under a compound bright field microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Zygnema* sp., *Euglena* sp., *Scenedesmus* sp., *Ankistrodesmus* sp., *Dictyosphaerium* sp., *Pediastrum* sp., *Botryococcus* sp., *Synechococcus* sp., *Chroococcus* sp., *Aphanothece* sp., *Ulothrix* sp., *Mougeotia* sp., *Rhizoclonium* sp., *Closterium* sp., *Cladophora* sp., *Spirogyra* sp., and *Chloromonas* sp; The Cyanophyta (blue-green algae): *Oscillatoria* sp., and *Spirogyra* sp.; The Bascillariophyta (diatoms): *Stephanodiscus* sp., *Cymbella* sp., *Navicula* sp., *Cyclotella* sp., *Fragilaria* sp., *Nitzschia* sp., *Synedra* sp., *Asterionella* sp., *Tabellaria* sp., and *Opehora* sp. The aforementioned species indicate a diverse algal flora and represent a relatively balanced freshwater ecosystem, capable of supporting a strong zooplankton community in favorable water quality conditions.

Blue-green algae such as *Oscillatoria* sp. are capable of producing microtoxins (Rinehart et *al*. 1994) that can cause neurologic or hepatic (liver) dysfunction in animals or humans if ingested in large quantities. Blue-green blooms are usually visible as a bluish tinted surface “scum layer” on lake waters when they are a threat and these areas should be avoided when obvious surface layer blooms are present. The waters of Bear Lake are rich in the diatoms and small green algae, which are indicators of good water quality and also support a robust fishery. Additionally, the quantity of blue-green algae was very low in the water.

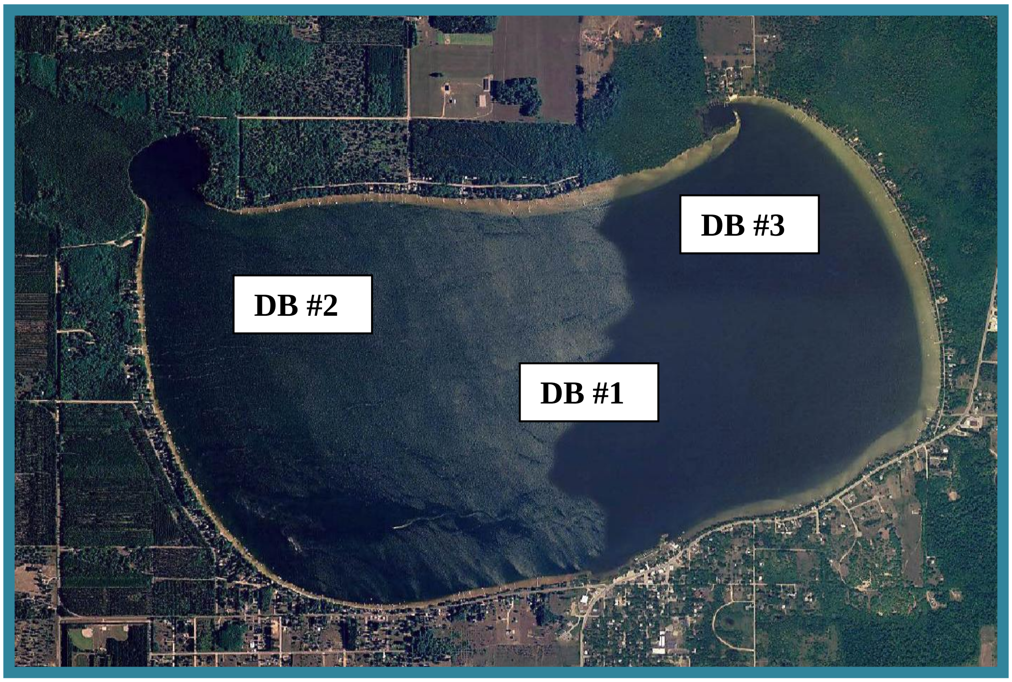


Figure 12. Water quality sampling locations in Bear Lake 2012.

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	56.5	11.8	7.5	224	0.3	195.1	< 0.100	66	< 0.010
10	54.1	11.5	7.5	221	0.9	168.2	< 0.100	70	< 0.010
21	50.7	10.9	7.6	220	2.2	177.3	< 0.100	72	< 0.010

Table 5. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on May 19, 2012.

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	56.2	11.9	7.6	218	0.4	188.4	< 0.100	69	< 0.010
10	54.0	11.7	7.5	229	0.8	180.3	< 0.100	71	< 0.010
22	50.1	10.2	7.5	219	1.8	153.6	< 0.100	70	< 0.020

Table 6. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on May 19, 2012.

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	56.6	11.4	7.6	221	0.2	199.2	< 0.100	70	< 0.010
10	54.7	11.8	7.5	219	0.6	183.7	< 0.100	66	< 0.010
21	50.8	10.9	7.2	229	2.5	187.0	< 0.100	72	< 0.020

Table 7. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on May 19, 2012.

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	78.2	9.2	7.3	204	0.9	119.8	< 0.500	72	< 0.020
10	72.0	8.7	7.2	211	1.0	106.2	< 0.500	69	< 0.035
21	65.9	6.0	7.3	209	1.5	92.4	< 0.850	73	< 0.055

Table 8. Bear Lake Water Quality Parameter Data Collected over Deep Basin 1 on July 7, 2012.

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	78.7	9.0	7.2	212	0.6	148.9	< 0.500	70	< 0.015
10	74.9	8.9	7.2	218	0.9	152.1	< 0.500	71	< 0.025
22	68.4	6.7	7.3	209	0.8	101.8	< 0.550	73	< 0.055

Table 9. Bear Lake Water Quality Parameter Data Collected over Deep Basin 2 on July 7, 2012.

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	78.4	9.0	7.3	218	0.5	160.8	< 0.500	71	< 0.020
10	73.6	8.4	7.2	210	0.8	151.6	< 0.650	69	< 0.025
21	70.1	7.0	7.2	226	1.4	120.1	< 0.650	70	< 0.045

Table 10. Bear Lake Water Quality Parameter Data Collected over Deep Basin 3 on July 7, 2012.

5.0 BEAR LAKE 2013 MANAGEMENT RECOMMENDATIONS

5.1 Bear Lake Open Water Improvements

The use of aquatic chemical herbicides is regulated by the MDEQ under Part 33 (Aquatic Nuisance) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a permit. The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions. Wherever possible, it is preferred to use a systemic aquatic herbicide for longer-lasting plant control. There are often restrictions with usage of some systemic herbicides around shoreline areas that contain shallow drinking wells (such as with 2,4-D).

In the past, systemic herbicides such as 2, 4-D and Triclopyr have been used to control EWM in Bear Lake and continued spot-treatments with both herbicides are recommended as needed. The September 5, 2012 survey indicated that the June 2012 treatment was successful with little viable EWM found in the lake. The native aquatic plant communities such as the pondweeds and low-growing plants and naiads continue to thrive in areas once dominated by EWM.

Water quality parameters as noted above should be monitored during 2013.
Table 11 below shows the proposed budget for the continuation of the Bear Lake Improvement Program (2013).

Bear Lake Improvement Strategy	***Estimated Annual Cost***
Herbicides for Control of Invasive Aquatic Plants (approx. 100 acres)@ $500 per acre	$50,000
Professional Management Services[3] (water sampling, oversight of treatments, mapping, management)	$12,500
Contingency Funds (necessary for additional costs that may arise due to unpredictable circumstances)	$6,250
TOTAL ANNUAL ESTIMATED COST	$68,750

Table 11. Proposed lake management budget for Bear Lake in 2013.

6.0 LITERATURE CITED

Madsen, J.D., J.A. Bloomfield, J.W. Sutherland, L.W. Eichler, and C.W. Boylen. 1996. The aquatic macrophyte community of Onondaga Lake: Field survey and plant growth bioassays of lake sediments, *Lake and Reservoir Management* 12:73-79.

Wetzel, R. G. 2001. Limnology: Lake and River Ecosystems. Third Edition. Academic Press, 1006 pgs.

LAKE NAME- BEAR LAKE **COUNTY- MANISTEE** **SURVEY DATE: September 5, 2012**

Standard Aquatic Vegetation Summary Sheet SURVEY BY: GLJ,KVS

		Total number of AVAS's 558 for each Density Catagory					Calculations				Sum of Previous Four Columns	Total Number of AVAS's	Quotient of Column 9 divided by Column 10		
		A	B	C	D		Catagory A x 1	Catagory B x10	Catagory C x 40	Catagory D x 80					
Code No	Plant Name	1	2	3	4		5	6	7	8	9	10	11	Code No	Plant Name
1	Eurasian milfoil		2	1			0	20	40	0	60	558	0.1	1	Eurasian milfoil
2	Curly leaf pondweed						0	0	0	0	0	558	0.0	2	Curly leaf pondweed
3	Chara	30	170	19			30	1700	760	0	2490	558	4.5	3	Chara
4	Thinleaf pondweed	7	38	4			7	380	160	0	547	558	1.0	4	Thinleaf pondweed
5	Flatstem pondweed	1	19	5			1	190	200	0	391	558	0.7	5	Flatstem pondweed
6	Robbins pondweed	3	25	23	70		3	250	920	5600	6773	558	12.1	6	Robbins pondweed
7	Variable pondweed	28	162	31	62		28	1620	1240	4960	7848	558	14.1	7	Variable pondweed
8	Whitestem pondweed	12	46	17			12	460	680	0	1152	558	2.1	8	Whitestem pondweed
9	Richardsons pondweed	4	19	2			4	190	80	0	274	558	0.5	9	Richardsons pondweed
10	Illinois pondweed	17	75	20	4		17	750	800	320	1887	558	3.4	10	Illinois pondweed
11	Large leaf pondweed	18	43	10	2		18	430	400	160	1008	558	1.8	11	Large leaf pondweed
12	American pondweed						0	0	0	0	0	558	0.0	12	American pondweed
13	Floating leaf pondweed	15	40	6	2		15	400	240	160	815	558	1.5	13	Floating leaf pondweed
14	Water stargrass	2	4	5			2	40	200	0	242	558	0.4	14	Water stargrass
15	Wild Celery	13	40	5	1		13	400	200	80	693	558	1.2	15	Wild Celery
16	Sagittaria						0	0	0	0	0	558	0.0	16	Sagittaria
17	Northern milfoil	2	18	2	1		2	180	80	80	342	558	0.6	17	Northern milfoil
18	M. verticillatum						0	0	0	0	0	558	0.0	18	M. verticillatum
19							0	0	0	0	0	558	0.0	19	
20	Coontail	9	35	3			9	350	120	0	479	558	0.9	20	Coontail
21	Elodea	7	25	10			7	250	400	0	657	558	1.2	21	Elodea
22	Utricularia spp.	22	65	6			22	650	240	0	912	558	1.6	22	Utricularia spp.
23	Bladderwort-mini	2					2	0	0	0	2	558	0.0	23	Bladderwort-mini
24	Buttercup						0	0	0	0	0	558	0.0	24	Buttercup
25	Najas guadalupensis	13	75	25	1		13	750	1000	80	1843	558	3.3	25	Najas guadalupensis
26	Brittle naiad						0	0	0	0	0	558	0.0	26	Brittle naiad
27							0	0	0	0	0	558	0.0	27	
28							0	0	0	0	0	558	0.0	28	
29	Pusillus	10	35	15			10	350	600	0	960	558	1.7	29	Pusillus
30	Nymphaea		3	1			0	30	40	0	70	558	0.1	30	Nymphea
31	Nuphar	2	4				2	40	0	0	42	558	0.1	31	Nuphar
32	Brasenia	2	6	3	4		2	60	120	320	502	558	0.9	32	Brasenia
33	Lemna minor						0	0	0	0	0	558	0.0	33	Lemna minor
34	Spirodella						0	0	0	0	0	558	0.0	34	Spirodella
35	Watermeal						0	0	0	0	0	558	0.0	35	Watermeal
36	Arrowhead						0	0	0	0	0	558	0.0	36	Arrowhead
37	Pickerelweed	1					1	0	0	0	1	558	0.0	37	Pickerelweed
38	Arrow Arum						0	0	0	0	0	558	0.0	38	Arrow Arum
39	Cattails	2	5	4	1		2	50	160	80	292	558	0.5	39	Cattails
40	Bulrushes	4	10	3	1		4	100	120	80	304	558	0.5	40	Bulrushes
41	Iris	1					1	0	0	0	1	558	0.0	41	Iris
42	Swamp Loosestrife	2	5	5	1		2	50	200	80	332	558	0.6	42	Swamp Loosestrife
43	Purple Loosestrife						0	0	0	0	0	558	0.0	43	Purple Loosestrife
44	Water Marigold	5	4	2	4		5	40	80	320	445	558	0.8	44	Water Marigold
45							0	0	0	0	0	558	0.0	45	
46	M. tenellum	20	91	44	32		20	910	1760	2560	5250	558	9.4	46	M. tenellum
47															
													65.6		

C:\Users\JJJ\Desktop\BLAVAS2012