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LAKE MITCHELL 2011 ANNUAL PROGRESS REPORT

AN ANNUAL ASSESSMENT OF AQUATIC VEGETATION AND WATER QUALITY IN LAKE MITCHELL WEXFORD COUNTY, MICHIGAN

JANUARY, 2012

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January, 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) and Hybrid Watermilfoil (*Myriophyllum spicatum var. M. sibiricum;* HWM*)* within Lake Mitchell, Wexford County, Michigan. In 2009, approximately 495 acres of EWM infested the lake with most of it forming a thick canopy over the lake surface. That EWM was successfully reduced to nearly 395 acres in 2010 and to less than 295 acres in 2011. Aquatic herbicide treatments for the EWM consisted of systemic herbicides such as 2,4-D (Trade name: Navigate®, originally at 120 lbs per acre in 2009-2010 and then at 150 lbs per acre in 2011 due to observed tolerance of the plants to the previous herbicide doses). In June of 2011, plants suspected of being hybrid by phenotype were sent to the GVSU Annis Water Resource Institute for genotypic diagnosis that confirmed the observed phenotype was hybrid milfoil. A mid-August post-treatment survey and early October lake survey in 2011 found that most of the EWM had been successfully killed but that HWM was beginning to fill in the niche previously occupied by the EWM. It is now estimated that Lake Mitchell contains between 100-250 acres of milfoil but less than 30 acres of that total appeared to be EWM. Staff at Lakeshore Environmental, Inc. (LEI) will continue to monitor the lake for both EWM and HWM and will re-survey the lake in the spring of 2011 to determine exact GPS coordinates for treatment. Additionally, LEI recommends that plant stems be sent to the SePRO Laboratory for analysis of plants from all areas of Lake Mitchell and their responses to various products and doses that would determine the exact dose and herbicide needed for a successful treatment of HWM and remaining EWM in the whole lake. The lake continues to recover from the previous canopy of EWM with further growth of native aquatic plants such as Fern-leaf Pondweed (*Potamogeton robbinsii*), White-Stem Pondweed (*Potamogeton praelongus*), Illinois Pondweed (*Potamogeton illinoensis*), Variable-Leaf Pondweed (*Potamogeton gramineus*), and the low-growing Slender Naiad (*Najas flexilis*). In addition, Mini-Bladderwort (*Utricularia minor*) and Water Marigold (*Megalodonta beckii*) have recently colonized the cove areas.

There are currently a total of 27 native aquatic plant species in and around Lake Mitchell. In 2011, a total of 18 submersed, 4 floating-leaved, and 5 emergent aquatic plant species were found for a grand total of 27 species. The removal of EWM has resulted in an increase of 3 native submersed aquatic plants to the lake ecosystem.

The water clarity of the lake continues to improve relative to recent years and the zebra mussel population will be monitored for possible lake clarity changes. It is unlikely that the zebra mussel would become problematic in Lake Mitchell due to the soft waters. The hard shells of the mussels generally require adequate amounts of calcium carbonate which are not abundant in the lake. Additionally, the increase in submersed native vegetation would compete with planktonic algae for nutrients and favor fewer algae since the plants utilize the nutrients.

Phytoplankton communities within the lake appear to be balanced between the diatom and green-algae communities with low quantities of blue-green algae. Nutrient levels in the lake are high enough to create algae blooms. Green algae and diatoms are the preferred food choices for zooplankton. Excessive increases in green algae can impart a green color to the lake water and also decrease water clarity. If this problem becomes an issue, then whole-lake laminar flow aeration may be a possible option to control blooms.

Staff from LEI recommend that a local Lake Mitchell riparian workshop be conducted during the 2012 season to educate lake citizens about the issues on the lake. The workshop would provide educational assistance to residents from LEI expert limnologists and watershed managers with a demonstration table that includes lake protection information on Lake Mitchell.

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 and shallow mean depth of Lake Mitchell, a bi-seasonal GPS Point-Intercept grid matrix survey is conducted to assess all aquatic species, including emergent and floating-leaved species.

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, two rake tosses are conducted and 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 May 27, 2011 and on October 16, 2011 consisted of 1,686 equidistantly-spaced grid points on Lake Mitchell, using a Humminbird® 50-satellite GPS WAAS-enabled unit (accuracy within 2 feet). A combination of rake tosses and visual data accounted for each point and the distance between points for the survey.

3.0 AQUATIC PLANT SURVEY RESULTS FOR 2011

The 2011 aquatic vegetation surveys of Lake Mitchell were necessary to record the relative abundance and locations of native aquatic plant species present and to record the current distribution of EWM and hybrid milfoil within the lake.

3.1 Lake Mitchell Exotic Aquatic Plant Species

The May 27, 2011 survey detected very little vegetation due to the low water temperatures and lack of overwintered plant growth. Some areas contained overwintered beds of scattered Fern-Leaf Pondweed (*Potamogeton robbinsii*) and White-Stem Pondweed (*Potamogeton praelongus*) growth, but little vegetation was noted during that survey.

In 2011, there were four invasive species present, including EWM (Figure 1), Hybrid milfoil (Figure 2), Curly-Leaf Pondweed (Figure 3), and Purple Loosestrife (Figure 4). Exotic species found in Lake Mitchell during 2011 are listed below in Table 1.

Macrophyte Species and Code	***Common Name***	***Plant Growth Form***	***% Coverage Lake Area***
Myriophyllum spicatum	Eurasian Watermilfoil	Submersed; Rooted	3
M. spicatum var. sibiricum	Hybrid Watermilfoil	Submersed; Rooted	24
Potamogeton crispus	Curly-Leaf Pondweed	Submersed; Rooted	8
Lythrum salicaria	Purple Loosestrife	Emergent	6

Table 1. Exotic aquatic plant species present within or around Lake Mitchell (May and October, 2011)

Figure 1. A photograph of the EWM Phenotype & Confirmed Genotype

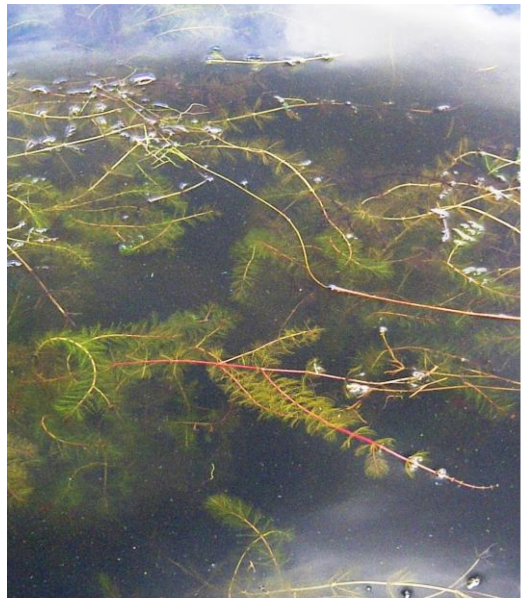


Figure 2. A photograph of the Hybrid EWM Phenotype and Confirmed Genotype

Information on Hybrid Watermilfoil

Hybrid Watermilfoil was genetically determined during June of 2011 to be related to the above-mentioned red-stemmed phenotype. Hybrid milfoil is a serious problem in Michigan inland lakes. A similar milfoil species that is considered to be exotic by some scientists (*Myriophyllum heterophyllum*) in New Hampshire was found to have significant impacts on waterfront property values (Halstead et *al*., 2003). Moody and Les (2007) were among the first to determine a means of genotypic and phenotypic identification of the hybrid milfoil variant and further warned of the potential difficulties in the management of hybrids relative to the parental genotypes. It is commonly known that hybrid vigor is likely due to increased ecological tolerances relative to parental genotypes (Anderson 1948), which would give hybrid milfoil a distinct advantage to earlier growth, faster growth rates, and increased robustness in harsh environmental conditions.

Furthermore, the required dose of 2,4-D for successful control of the hybrid milfoil is likely to be higher since there is much more water volume at greater depths it can occupy and also due to the fact that hybrid milfoil has shown increased tolerance to traditionally used doses of systemic aquatic herbicides. There has been significant scientific debate in the aquatic plant management scientific community regarding the required doses for effective control of hybrid milfoil. Glomski and Netherland (2010) found that the greatest percentage of hybrid milfoil (93-100%) was successfully killed with 2,4-D concentrations greater than or equal to 70 µg L^{-1}. Their results may vary dramatically from open-water systems; however, as they were tested in laboratory aquaria and the results in field trials would be subjected to a multitude of external environmental factors. However, the concentration of 70 µg L^{-1} yielded a desired 2,4-D residue concentration to be maintained for up to 21 days as in the study by Glomski and Netherland (2010). Thus, residue sampling intervals could be recommended at the treatment areas for 2 hours after treatment, 1 week after treatment, and 20 days post-treatment. Concentration-Exposure Time (CET) studies such as those by Glomski and Netherland (2010) and Poovey et *al.*, (2007) are important in the determination of dose requirements for hybrid milfoil; however, they were conducted in laboratory aquaria and field CET studies are therefore needed.

An additional option is to collect many stems of hybrid milfoil from Lake Mitchell in early spring and submit them to the SePRO Laboratory to determine the ideal dose and product for a successful lake-wide, open water treatment. In regards to impacts on native vegetation, hybrid milfoil possesses a faster growth rate than Eurasian milfoil or other plants and thus may effectively displace other vegetation (Les and Philbrick 1993; Vilá et *al*. 2000).

Figure 3. A photograph of the Curly-Leaf Pondweed (*Potamogeton crispus*)

Figure 4. A photograph of Purple Loosestrife (*Lythrum salicaria*)

3.2 Lake Mitchell Native Aquatic Plant Species

The native aquatic vegetation present in Lake Mitchell has shown a significant rebound since the EWM has been reduced from the 2009 densities. In 2009 with the dense EWM beds observed, there were only 15 submersed, 4 floating-leaved, and 5 emergent species. In 2011, a total of 18 submersed, 4 floating-leaved, and 5 emergent aquatic plant species were found for a grand total of 27 species (Table 2), which is perhaps the most diverse aquatic ecosystem observed by LEI staff on a Michigan inland lake. This indicates a very high biodiversity of aquatic vegetation in Lake Mitchell and also emphasizes that 3 more native species have germinated in the lake due to less light limitation from overlying EWM canopies.

Graphs 1 and 2 below show the changes in common and rare native aquatic plant species, respectively, with time in Lake Mitchell for the time period between 2009-2011. A few photographs of common species found in Lake Mitchell can be found on page 17 (Figures 5-8) and rare species are displayed on page 18 (Figures 9-12).

Macrophyte Species and Code	***Common Name***	***Plant Growth Form***	***% Coverage of Lake Area***
Chara vulgaris (macroalga)	Muskgrass	Submersed; Rooted	20
Potamogeton pectinatus	Sago Pondweed	Submersed; Rooted	11
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed; Rooted	66
Potamogeton gramineus	Variable-leaved Pondweed	Submersed; Rooted	19
Potamogeton praelongus	White-stemmed Pondweed	Submersed; Rooted	40
Potamogeton richardsonii	Clasping-leaf Pondweed	Submersed; Rooted	12
Potamogeton illinoensis	Illinois Pondweed	Submersed; Rooted	29
Potamogeton amplifolius	Large-leaf Pondweed	Submersed; Rooted	5
Myriophyllum sibiricum	Northern Watermilfoil	Submersed; Rooted	5
Ceratophyllum demersum	Coontail	Submersed; Non-rooted	6
Elodea canadensis	Common Waterweed	Submersed: Rooted	7
Utricularia vulgaris	Common Bladderwort	Submersed; Non-rooted	24
Utricularia minor	Mini Bladderwort	Submersed; Non-rooted	3
Najas guadalupensis	Southern Naiad	Submersed; Rooted	35
Najas flexilis	Slender Naiad	Submersed; Rooted	39
Potamogeton pusillus	Small-leaf Pondweed	Submersed; Rooted	35
Nymphaea odorata	White Waterlily	Floating-leaved	3
Nuphar variegata	Yellow Waterlily	Floating-leaved	5
Brasenia schreberi	Watershield	Floating-leaved	5
Lemna trisulca	Star Duckweed	Floating-Leaved; Non-rooted	3
Pontedaria cordata	Pickerelweed	Emergent	1
Typha latifolia	Cattails	Emergent	6
Scirpus acutus	Bulrushes	Emergent	41
Decodon verticillatus	Swamp Loosestrife	Emergent	4
Myriophyllum tenellum	Leafless Watermilfoil	Submersed; Rooted	53
Eleocharis acicularis	Spikerush	Emergent	28
Bidens beckii	Water Marigold	Submersed; Rooted	2

TABLE 2. Native Aquatics

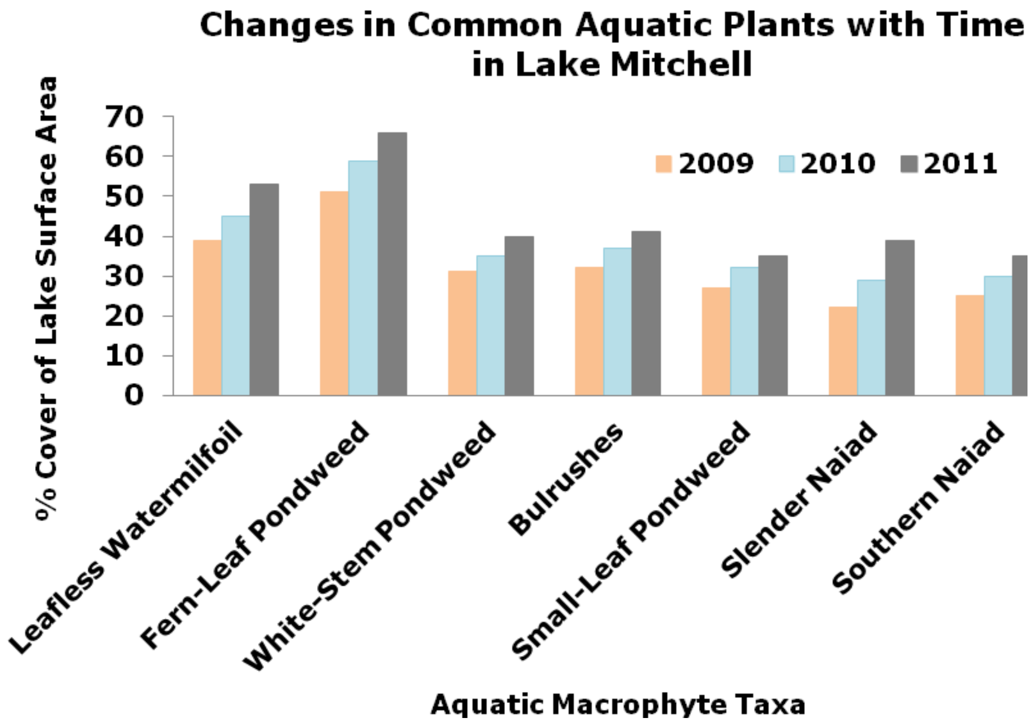


Figure 5. Common aquatic plants in Lake Mitchell, 2011.

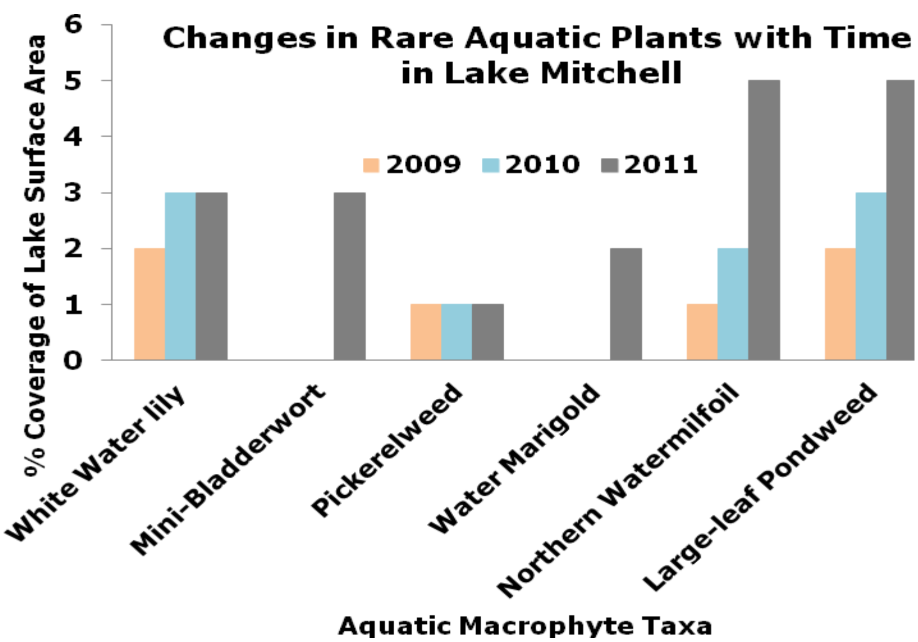


Figure 6. Rare aquatic plants in Lake Mitchell, 2011.

Common Aquatic Plant Species Present in Lake Mitchell

Figure 7. A photograph of White-Stem Pondweed (*Potamogeton praelongus*)

Figure 8. A photograph of Leafless Watermilfoil (*Myriophyllum tenellum*)

Figure 9. A photograph of Fern-Leaf Pondweed (*Potmageton robbinsii*)

Figure 10. A photograph of Bulrushes (*Scirpus acutus*)

Rare Aquatic Plant Species Present in Lake Mitchell

Figure 11. A photograph of Large-Leaf Pondweed (*Potamogeton amplifolius*)

Figure 12. A photograph of Northern Watermilfoil (*Myriophyllum sibiricum*)

Figure 13. A photograph of Water Marigold (*Megalodonta beckii*)

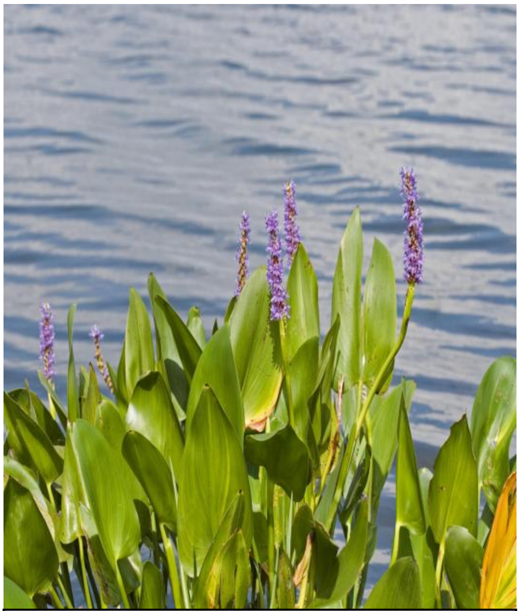


Figure 14. A photograph of Pickerelweed (*Pontedaria cordata*)

4.0 LAKE MITCHELL 2011 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 Lake Mitchell 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 3). 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**. Lake Mitchell is classified as eutrophic based on its moderately low transparency and high 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 3. Lake Trophic Status Classification Table (MDEQ)

Lake Mitchell and Tributary Water Quality Parameters

Water quality parameters such as dissolved oxygen, water temperature, conductivity, turbidity, total dissolved solids, pH, total alkalinity, total phosphorus, 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 and tributaries (Figure 15) and are discussed below along with water quality data specific to Lake Mitchell. (Tables 4-6 and assorted graphs).

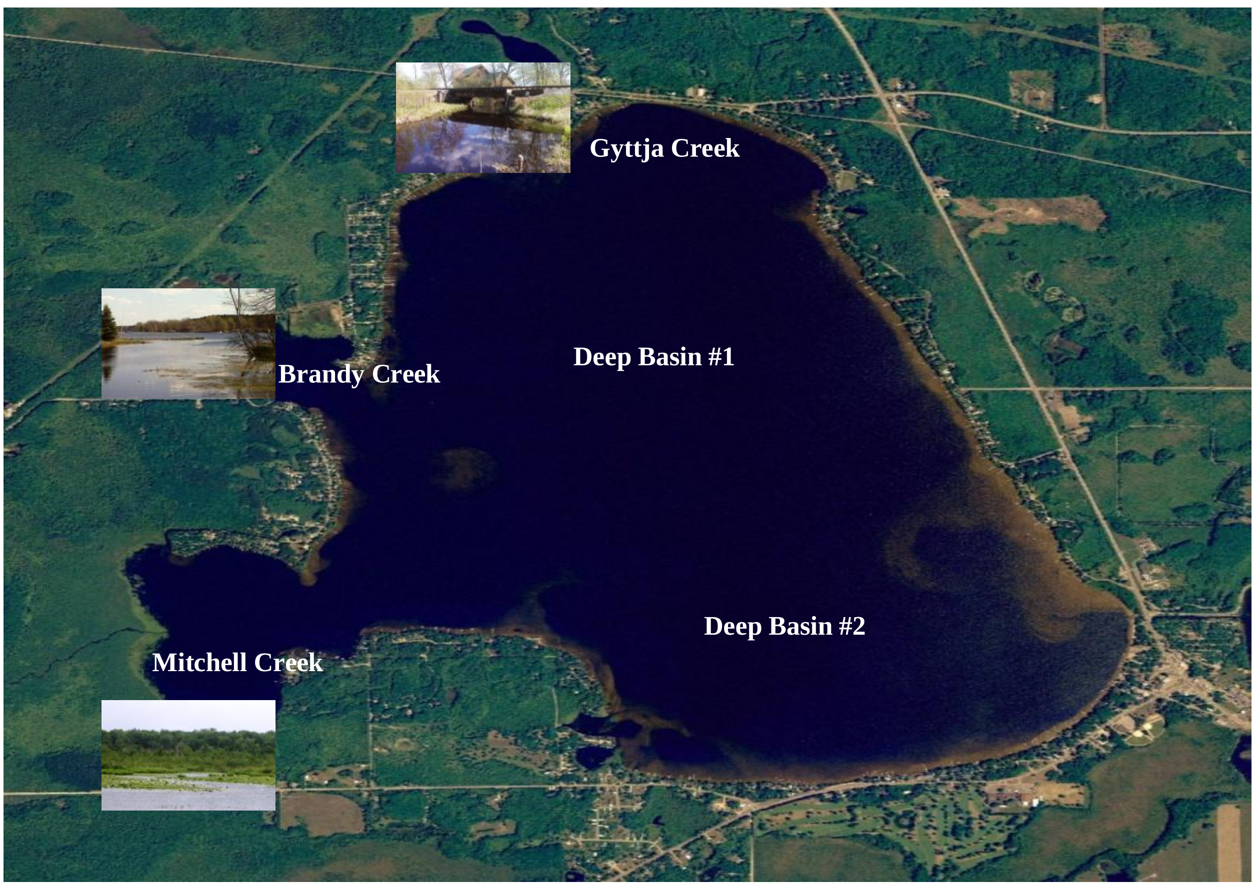


Figure 15. A location map of water quality lake and tributary sampling stations on Lake Mitchell (October, 2011)

Dissolved Oxygen

Dissolved oxygen (DO) is a measure of the amount of oxygen that exists in the water column. In general, DO levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations in Lake Mitchell 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 DO meter and/or through the use of Winkler titration methods. The October DO concentrations in Lake Mitchell were high and consistent with increased depth and ranged between 9.9 – 11.5 mg L^{-1}, with average values around 8.3 mg L^{-1} for the tributaries. A decline in DO may cause increased release rates of phosphorus (P) from Lake Mitchell bottom sediments if DO levels drop to near zero milligrams per liter. A graph showing the changes in DO was not created due to different sampling dates and inherently different DO levels. In general, DO levels measured in mid-summer are substantially lower (i.e., by 2.0 mg L^{-1}) and cannot be compared to the higher levels in spring and fall.

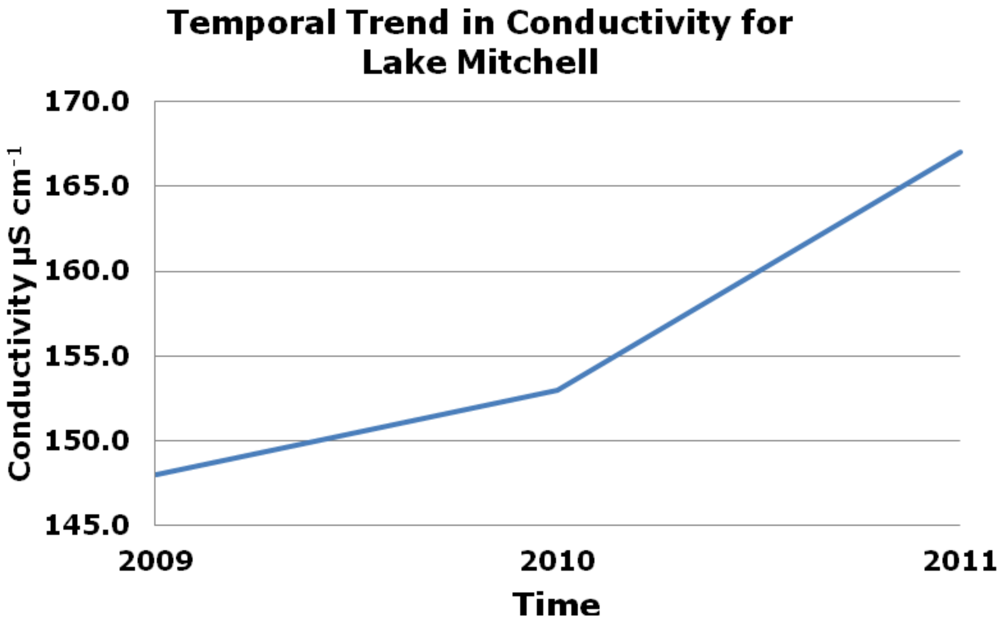
Water Temperature

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 October water temperatures of Lake Mitchell demonstrated the lack of a thermocline between the surface and a "middle depth" and bottom since the lake was sampled during a nearly isothermic period. Water temperatures ranged between 53.6 ºF at the surface and 53.9 ºF at the lake bottom. The water temperatures for all of the tributaries were lower and averaged 50.3 ºF, with the lowest temperature observed in Mitchell Creek. A graph for the water temperatures was not created since sampling dates varied along with the inherent water temperatures and an accurate comparison could not be made.

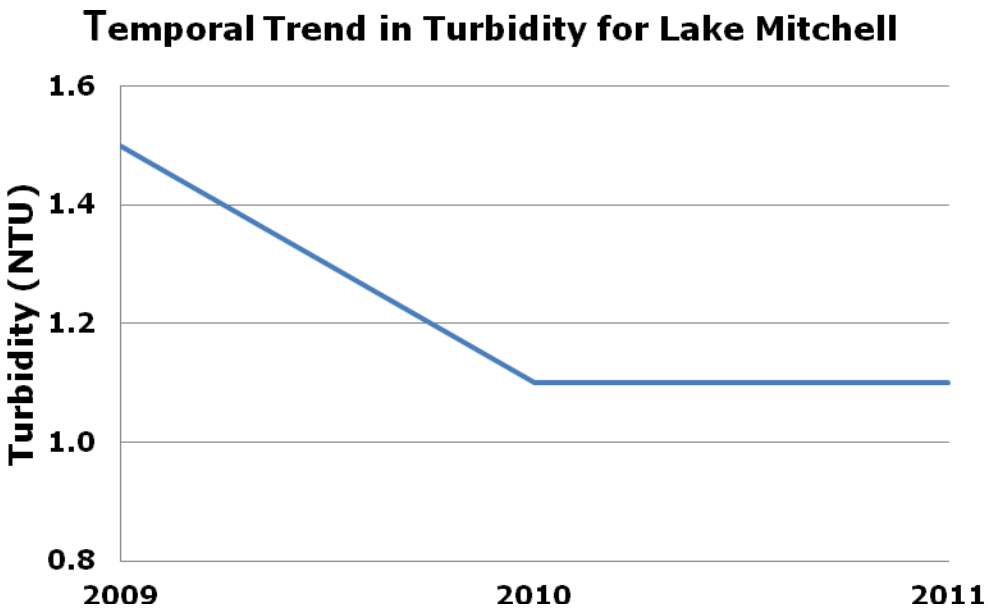
Conductivity

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 (µS cm^{-1}) with the use of a conductivity probe and meter. Conductivity values for Lake Mitchell were low and ranged between 164 µS cm^{-1} and 169 µS cm^{-1}. These values were significantly lower than for other inland lakes. The conductivity of Mitchell and Gyttja Creeks was 223 and 206 µS cm^{-1}, respectively, and indicated loading of solutes from the adjacent roads and impervious surfaces. The conductivity of Brandy Brook was only 50 µS cm^{-1}, which was very low. A graph showing the temporal trend in mean conductivity for Lake Mitchell is shown below.



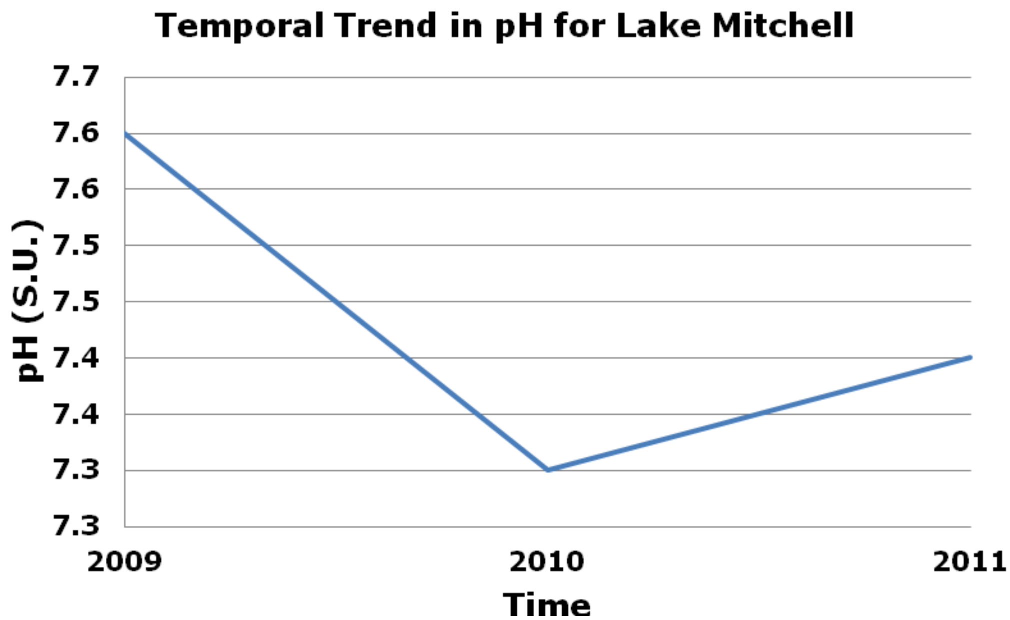
Turbidity

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. The turbidity of Lake Mitchell was low and ranged from 0.5 – 1.8 NTU's during the October sampling event, which was low for the high waves encountered during the sampling event. High wave action re-distributes lake bottom sediments throughout the water column and leads to increased turbidity. A graph showing the temporal trends in mean turbidity for Lake Mitchell is shown below.



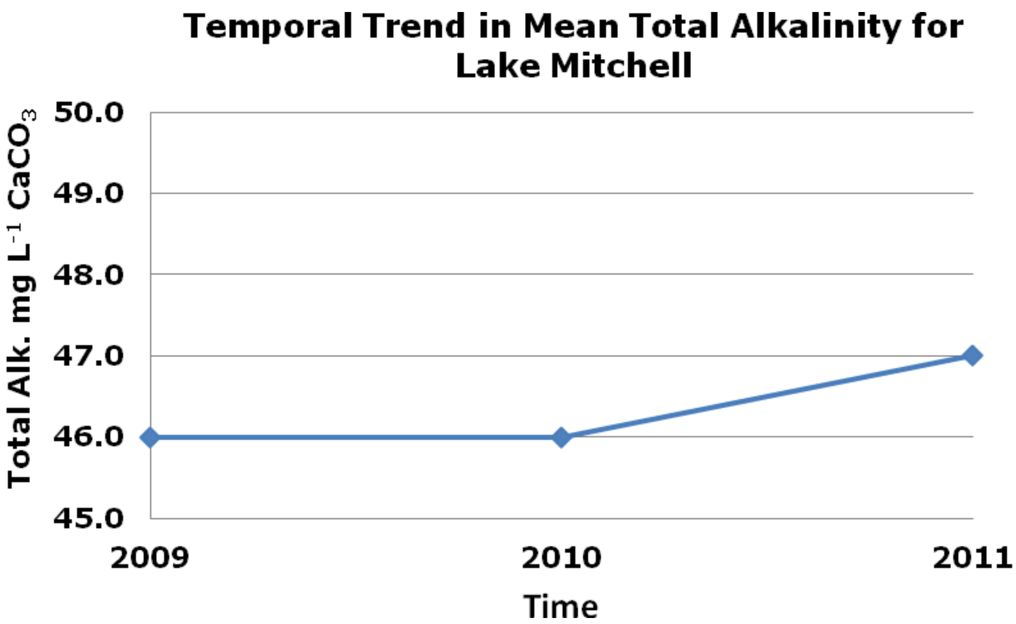
pH

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 Lake Mitchell water ranged from 7.3–7.4 during the October sampling. The mean pH of the tributaries was 7.2 which was only slightly lower than the lake water, probably due to inputs of tannic and acidic watershed substances that reduce pH. The graph below shows the trends in mean pH in Lake Mitchell over a three year period.



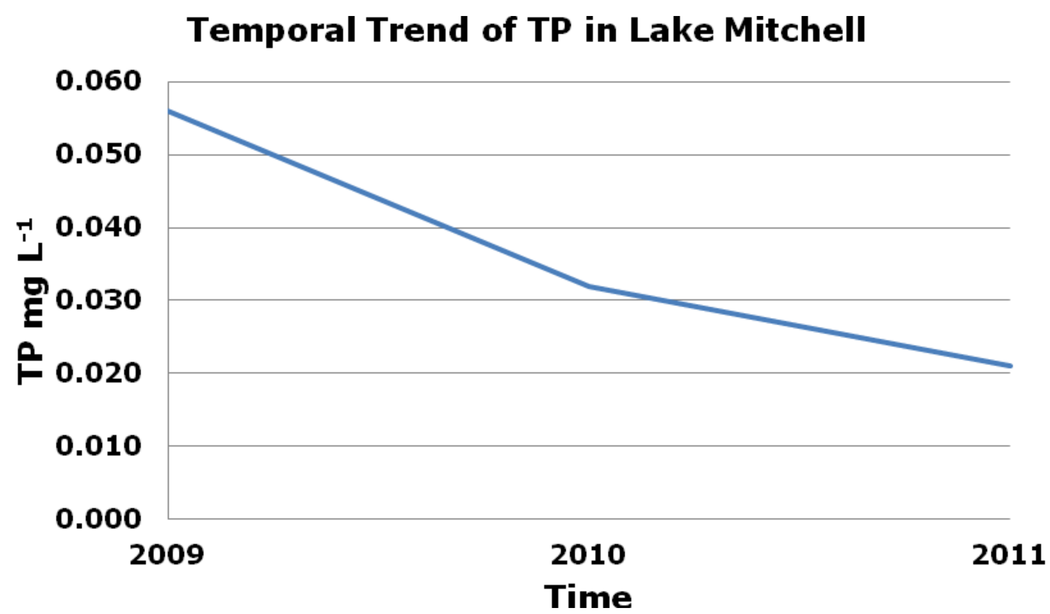
Total Alkalinity

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 Lake Mitchell is considered "low" (< 50 mg L^{-1} of $CaCO_3$), and indicates that the water is soft. Total alkalinity ranged from 42-50 mg L^{-1} of $CaCO_3$ during the October, 2011 sampling. 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 graph below shows the trends in mean total alkalinity in Lake Mitchell over the past three years.



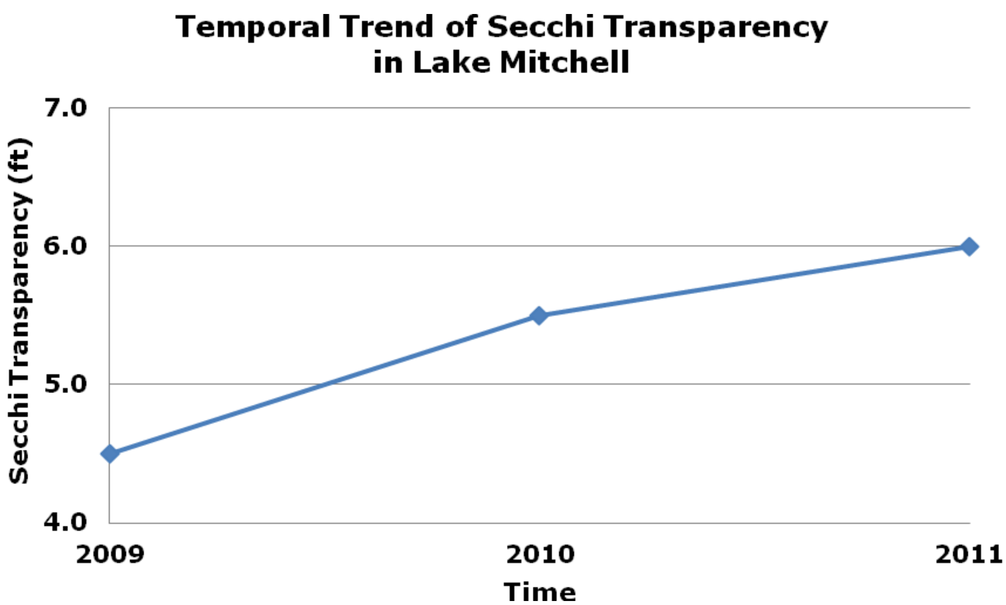
Total Phosphorus

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 0.025 mg 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. The mean surface total phosphorus (TP) concentration for the Lake Mitchell deep basin sampling sites during the October sampling event was 0.012 mg L^{-1}. The mean mid-depth TP concentration for both deep basins was 0.020 mg L^{-1}. The mean bottom TP concentration for both deep basins was 0.030 mg L^{-1}. The mid and bottom depth TP concentrations indicated that enough TP is present to cause abundant algae and aquatic plant growth. The mean TP concentration for the tributaries was 0.027 mg L^{-1}, with Gyttja Creek possessing the highest TP value. The graph below shows the trends in mean TP in Lake Mitchell over the past three 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 Lake Mitchell averaged 6.0 feet over the deep basin during the October 2011 sampling period, which may have been lower than summer levels due to heavy wave action on the date of sampling. This transparency is adequate though 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 graph below shows the trends in Secchi transparency for Lake Mitchell over that past three years.



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 Lake Mitchell during the October sampling event ranged from 82 mg L^{-1} to 89 mg L^{-1}. The TDS of tributary waters ranged from 50 mg L^{-1} to 112 mg L^{-1}, with two of the tributaries possessing values over 100 mg L^{-1}, which denoted higher TDS levels from the tributaries than in the lake itself.

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 Lake Mitchell ranged between 72.1 mV and 101.5 mV from the surface to the bottom within the lake, and indicated oxidized rather than reduced conditions. The ORP of tributary waters ranged between 78.9 mV and 104.1 mV.

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-*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^{-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 Lake Mitchell were determined by collecting a composite sample of the algae throughout the water column at the deep basins from just above the lake bottom to the lake surface. The chlorophyll-*a* concentration of Deep Basin #1 was 5.4 µg L^{-1} and the concentration for Deep Basin #2 was 4.2 µg L^{-1}, which indicated an abundance of green algae in the water column.

A composite sample of the Lake Mitchell water column was collected over both deep basins during the October 16, 2011 sampling date and also analyzed for algal species composition. Sub-samples from the collected deep basin samples were analyzed under a bright field compound microscope and identified to the genus level. The dominant genera present included *Ulothrix* sp., *Haematococcus* sp., *Scenedesmus* sp., *Melosira* sp., *Fragillaria* sp., and *Synedra* sp. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Pediastrum* sp., *Scenedesmus* sp., *Cladophora* sp., *Ulothrix* sp., *Micrasterias* sp., *Hydrodictyon* sp., *Chloromonas* sp., *Chlorella* sp., *Gleocystis* sp., *Staurastrum* sp., *Quadrigula* sp., and *Euglena* sp.; the Cyanophyta (blue-green algae): *Oscillatoria* sp., *Microcystis* sp., and *Gleocapsa* sp.; the Bascillariophyta (diatoms): *Synedra* sp., *Navicula* sp., *Cymbella* sp., *Pinnularia* sp., *Fragilaria* sp., *Eunotia* sp., *Asterionella* sp., *Biddulphia* sp., *Rhoicosphenia* sp., *Gomphonema* sp., *Diatomella* sp., and *Opehora* sp.

These genera indicate a favorable balance of green algae, diatoms and blue-green algae to serve as the autotrophic base of the Lake Mitchell aquatic ecosystem food chain.

Depth ft	***Water Temp °F***	***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	53.6	11.5	7.4	167	0.7	97.1	83	42	0.015
10	53.4	10.0	7.4	167	0.9	101.5	84	50	0.020
18	53.1	10.0	7.3	169	1.7	82.9	89	46	0.025

Table 4. Lake Mitchell Water Quality Parameter Data Collected over Deep Basin 1 on October 16, 2011.

Depth ft	***Water Temp °F***	***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	54.0	10.1	7.3	164	0.5	92.9	82	45	0.010
9	53.9	10.0	7.3	168	1.0	89.6	82	48	0.020
19	53.9	9.9	7.4	168	1.8	72.1	84	49	0.035

Table 5. Lake Mitchell Water Quality Parameter Data Collected over Deep Basin 2 on October 16, 2011.

Tributary	Water Temp ^oF	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	TDS mg L^{-1}	ORP mV	Total Phos. mg L^{-1}
Mitchell	48.6	8.6	7.2	223	112	78.9	0.025
Brandy	49.6	8.4	7.2	97	50	82.9	0.021
Gyttja	52.7	7.8	7.2	206	103	104.1	0.035

Table 6. Lake Mitchell Tributary Water Quality Parameter Data Collected on October 16, 2011.

5.0 LAKE MITCHELL 2012 MANAGEMENT RECOMMENDATIONS

The use aquatic chemical herbicides are 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. Due to the high quantity of hybrid milfoil observed throughout the lake during the October 2011 survey, use of a strong 2,4-D product (Navigate® or Renovate Max G® at ≥ 150+ lbs per acre) is recommended. Furthermore, individual, healthy plants should be sent to the SePRO laboratory for testing on the ideal dose and herbicide to be used on a large scale in Lake Mitchell to control the hybrid milfoil. This testing should be conducted in early spring well in advance of the early summer/late spring milfoil treatment(s).

The coves should be managed for both navigability and aesthetics and thus a strong contact herbicide that offers season-long control is recommended. Clipper® contains the active ingredient, flumioxazin, which works best for actively growing submersed vegetation of all types including EWM, Hydrilla, Pondweeds, and even some types of algae. LEI recommends treating all of the areas that would normally be mechanically harvested with Clipper® at 400 ppb (the maximum permitted dose) since harvesting will cause further fragmentation of the widespread hybrid milfoil. **The Torenta Canal** will be treated with chelated copper to control *Cladophora* and contact herbicides such as Reward® and Aquathol-K® to decrease growth of nuisance native plants. **Care must be taken wherever possible to protect the diversity of native aquatic vegetation in Lake Mitchell which is so pivotal to the fishery and overall lake health.**

LEI limnologists have been monitoring the efficacy of the milfoil weevil, *Euhrychiopsis lecontei* on the milfoil population in Big Cove. Over 10,000 weevil units were placed in the cove during the summer of 2009 and LEI collected 40 stems in 2010 and 63 stems in 2011 from various areas north, south, and directly in front of the buoys. **The 2010 stem data revealed a mean stem damage index of 2.7±1.6 and stem diameter of 2.0±0.4. The 2011 milfoil stem data revealed a mean stem index of 1.2±1.9 and a stem diameter of 1.9±0.3.** The stem damage index ranges from 0-5, with 5 indicating complete damage of the stem. **The average stem diameters were similar for both years which indicated little change in the vascular diameter. In addition, the mean stem damage index was higher in 2010 than in 2011.** It appears that the rigorous stocking efforts in July of 2009 have led to less than desirable results for long-term milfoil control. As a result of this finding, **LEI recommends utilizing USFS funds for placement of the Purple Loosestrife Beetle, *Galerucella* sp. in the patches of loosestrife found in the coves and along the Torenta Canal.**

Water quality parameters as noted above will be monitored in the lake and tributaries during 2012. Additionally, LEI will refine its recommendations for a **Phase II Watershed Improvement Plan** that the Board should consider for future years.

Lastly, expert limnologists and watershed managers from LEI will participate in a **Lake Mitchell 2012 workshop** that displays an educational/outreach booth with information on the state of Lake Mitchell and assists riparians with their lake concerns. The time and place of the workshop is still being considered and a newspaper article will discuss the workshop materials and details so that as many people as possible can participate in the learning process.

A proposed lake improvement budget for 2012 is shown in Table 7 below and includes specific activities for the coves, canal, and main lake, as well as associated costs for all management activities.

Lake Mitchell Proposed 2012 Management Budget

Improvement Strategy	Estimated Costs
Clipper for Coves @$900/acre	$11,700
(Approximately 13 acres @$11,700 for season-long control of ALL coves)	
Canal Algal and Contact Treatment	$1,300
Aquatic Herbicide Treatments	$133,750
(250 acres@$535 per acre)	
Weed Pickup Service	$8,000
Biocontrol (***Galerucella*** beetles)	GRANT FUNDED
Publications/Website/Newsletter	$2,500
Consulting Fees	$16,000
(Administration, surveys, sampling, meetings, representation)	
Contingency (10% of total project)	$17,323
Total 2012 Program Cost	$190,553

Table 7. Proposed budget for the 2012 Lake Mitchell management program.

6.0 LITERATURE CITED

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