2010

Lake Mitchell Annual Progress Report

Lakeshore Environmental, Inc.

Water Resources

2/22/2011

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I. EXECUTIVE SUMMARY

Lake Mitchell is a natural, glacial lake located in Sections 34,35,36,1,2,3,4,10,11, and 12 of Cherry Grove and Selma Townships in Wexford County, Michigan (T. 21,22N, R. 10W). The lake has three major tributaries including Mitchell Creek which enters the lake from the west side of Big Cove, Brandy Creek which enters the lake at the north end of Little Cove, and Gyttja Creek which enters the lake at the northernmost point. **These tributaries were monitored on August 10, 2010 for water quality parameters such as total phosphorus, pH, water temperature, conductivity, oxidative reduction potential, dissolved oxygen, and turbidity. Brandy Creek contributed the highest concentration of phosphorus to the lake with a total phosphorus concentration of 0.030 mg L^{-1}, followed by Gyttja Creek at 0.025 mg L^{-1} and Mitchell Creek at 0.025 mg L^{-1}. Tributary mean values for measured parameters included a pH of 7.9, conductivity of 208 µs cm^{-1}, dissolved oxygen concentration of 8.1 mg L^{-1}, and total dissolved solids concentration of 112 mg L^{-1}.**

Water samples collected from the lake deep basins on August 9, 2010 indicated that the lake is eutrophic, with low to moderate Secchi disk transparency (mean Secchi transparency for 2010 of 6 feet), elevated nutrients such as phosphorus, and excessive aquatic macrophyte growth. Total phosphorus concentrations ranged from 0.030 mg L^{-1} to 0.035 mg L^{-1} in Deep Basins 1 and 2. The mean pH for both deep basins was 7.4, mean conductivity was 153 µs cm^{-1}, mean dissolved oxygen concentration was 6.7 mg L^{-1} and mean total dissolved solids concentration was 95 mg L^{-1}.

Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 1) was introduced to the United States in the 1950’s and has progressed to many of Michigan’s inland lakes. Currently, it occurs in over 33 of the United States. Large, shallow lakes with adequate water transparency and public access sites (such as Lake Mitchell) are most vulnerable to Eurasian Watermilfoil infestation. Eurasian Watermilfoil is among the first species to germinate in lakes after the ice melts, and quickly forms a dense surface canopy that impedes the necessary light for more favorable, native aquatic plant species. Eurasian Watermilfoil reproduces by seed and fragmentation and may even hybridize with native milfoil species in the lake. Such hybridization has been observed in various areas of Lake Mitchell. Eurasian Watermilfoil is also capable of overwintering under winter ice, although a fair amount of the previous seasonal vegetation does decay.

Rigorous lake management approaches such as the use of systemic herbicides (such as 2, 4-D and Triclopyr) used in early June and mid-July of 2010 to control approximately 357 acres of Eurasian Watermilfoil in Lake Mitchell were successfully implemented. The acreage was determined through a rigorous 1,686-point GPS aquatic vegetation survey during the week of June 8, 2010 and a post-treatment survey of the same points conducted on September 12, 2010. The survey detected 27 native aquatic plant species, which consisted of 18 submersed, 3 floating-leaved, and 6 emergent species. Four exotic species were found in and around the lake, which included Eurasian Watermilfoil (present in 17% of the grid points) and Purple Loosestrife (*Lythrum salicaria*) which was scattered on the shores of Little and Big Coves. The Giant Common Reed (*Phragmites australis)* and Yellow Iris (*Iris pseudacorus*) were found during the September 12, 2010 final post-treatment survey, although approximately 0.50 acres of *Phragmites* near the Torenta Canal was treated during late summer and was killed. Nuisance native aquatic vegetation and *Cladophora* algae growth was removed with the use of a mechanical harvester. The total acreage of *Cladophora* removed was approximately 5 acres and nuisance native vegetation in all of the four coves was approximately 23 acres. Harvesting was only conducted in areas where Eurasian Watermilfoil had been previously treated or was absent to reduce the threat of fragmentation and spread.

Although no weevils were added to the Big Cove of Lake Mitchell during 2010 (as 10,000 weevil units were in 2009), weevil damage parameters on randomly selected milfoil stems were assessed during late July of 2010**. Forty milfoil stems were collected and the average weevil damage index was 2.7±1.6 (on a 0-5 scale system where a 5 denotes complete stem and leaf destruction).**

Management objectives and activities for 2011 should include: 1.) The treatment of remaining milfoil areas (determined by the point-intercept GPS survey in late spring of 2010) with systemic herbicides, 2.) The mechanical harvesting of the coves and specific areas of the main lake (projected to be a total of 24 acres with the use of new harvesting guidelines developed by the Lake Mitchell Improvement Board (LMIB), 3.) The removal of nuisance *Cladophora* in the Canal (approximately 5 acres) with either the use of algaecides and/or careful use of a mechanical harvester, 4.) The application of the *Galerucella* beetle to areas infested with Purple Loosestrife (approximately 5 total acres), 6.) The application of systemic herbicides to the *Phragmites* located at the southern portion of the Canal in the wetlands if it reoccurs (approximately ¼ acre), 7.) The continued monitoring of water quality parameters in the Deep Basins and Main Tributaries and investigation of BMP's to reduce nutrient loads to the lake, and 8.) Oversight of all herbicide and harvesting treatments by the Consultant.

II. LAKE MITCHELL WATER QUALITY DATA

A. *Water Quality Overview*

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 each 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. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 1). 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 a eutrophic lake.

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 1. Lake Trophic Status Classification Table (MDNRE)

Water Quality Parameters Measured

Water quality parameters such as dissolved oxygen, water temperature, conductivity, turbidity, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, algal species and composition, and Secchi transparency, among others, all respond to changes in water quality and consequently serve as indicators of water quality change. These parameters are discussed below along with water quality data specific to Lake Mitchell (Tables 2-3). Sampling Locations for the tributary and deep basin water quality sites are shown in Figure 1.

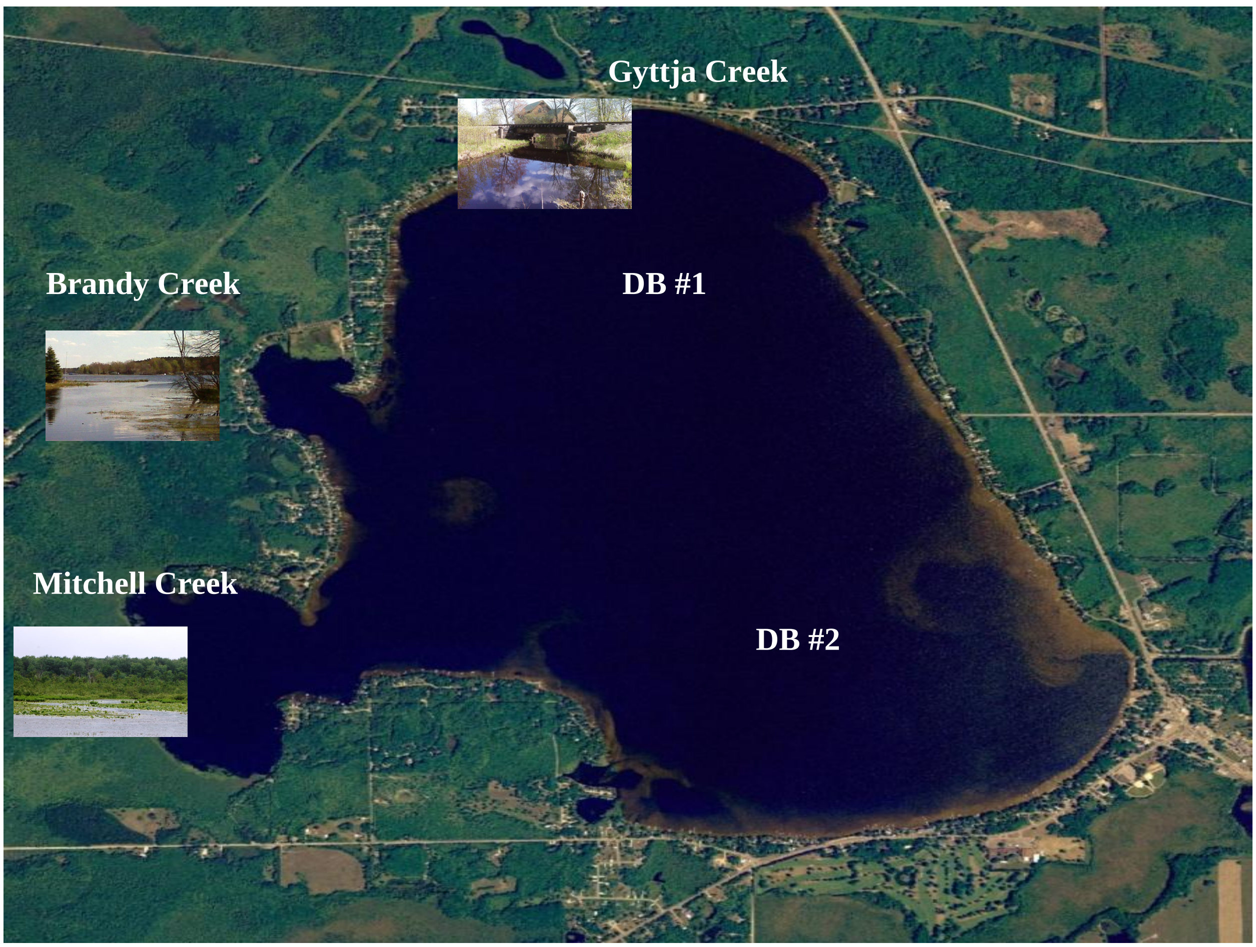

Figure 1. Tributary and Deep Basin sampling locations for Lake Mitchell (2010).

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	76.7	8.0	7.5	149	0.3	29.1	< 0.045	46	< 0.030
10	76.3	8.0	7.0	148	0.9	60.1	< 0.050	50	< 0.030
21	76.4	4.8	6.8	151	2.0	67.6	< 0.050	41	< 0.035

Table 2. Lake Mitchell Deep Basin 1 water quality data (August 9, 2010)

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	76.4	7.4	7.6	152	0.3	68.1	< 0.030	42	< 0.030
10	76.2	7.8	7.8	148	0.8	53.3	< 0.055	50	< 0.030
20	74.9	3.9	7.2	171	2.1	56.2	< 0.050	45	< 0.035

Table 3. Lake Mitchell Deep Basin 2 water quality data (August 9, 2010).

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 Lake Mitchell 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 Lake Mitchell were normal and declined with increased depth during the late summer sampling event and ranged between 8.0-3.9 mg L^{-1}, over the deep basin sampling sites.**

During summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. A decline in dissolved oxygen may cause increased release rates of phosphorus (P) from the Lake Mitchell bottom sediments if dissolved oxygen levels drop to near zero milligrams per liter.

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 late summer water temperatures of Lake Mitchell demonstrated a lack of a thermocline between the surface and a "middle depth" due to lake mixing. **Late summer water temperatures ranged between 76.7ºF at the surface and 74.9 ºF at the lake bottom among the deep basin sites.**

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 throughout the deep basins and ranged between 148 µS cm^{-1} and 171 µS cm^{-1} for late summer water samples.** Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Lake Mitchell over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading.

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 0.3 – 2.1 NTU's among the two deep basin sites during the spring sampling event.** Turbidity generally declined as zebra mussel filtration activities increase throughout the summer.

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 6.8 – 7.6 during the late summer sampling.** From a limnological perspective, Lake Mitchell is considered "neutral to slightly basic" 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 Lake Mitchell is considered "low" (< 100 mg L^{-1} of $CaCO_3$), and indicates that the water is soft. **Total alkalinity ranged from 41-52 mg L^{-1} of $CaCO_3$ during the late summer 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.

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}) with the use of a chemical autoanalyzer. The surface total phosphorus (TP) concentration for the Lake Mitchell Deep Basin sampling sites was between 29-31 µg L^{-1}. The middle depth (depth = 11.0 feet) total phosphorus concentration among the Deep Basin sites ranged between 28-31 µg L^{-1}. The total phosphorus concentration at the bottom depth (depth = 21.0 feet) among the deep basins was between 30-33 µg L^{-1}.

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. **Lake Mitchell contained highly variable values for TKN (< 0.030 – 0.055 mg L^{-1}) from surface to bottom during late summer.**

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 over 6.0 feet over the deep basins during the late summer sampling period.** This transparency is slightly higher than values recorded during 2009. 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.

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 E_h 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 29.1 mV and 68.1 mV from the surface to the bottom within the lake, and thus were within a normal range for mesotrophic lakes.**

B. Algal Analysis

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

C. Aquatic Vegetation Surveys

Aquatic vegetation communities are dynamic and are composed of plants with different structural architecture. Most aquatic systems contain floating-leaved, submersed, and emergent aquatic macrophytes. These differences in aquatic plant structure enhance biodiversity of macroinvertebrates in the lake and thus offer a more diverse food source for the fishery. Repeated vegetation surveys of the lake are critical for documenting the changes in ecosystem structure that will vary with changes in water levels, nutrient concentrations, and aquatic plant control activities. Furthermore, systems such as Lake Mitchell which are infested with exotic macrophytes such as Eurasian Watermilfoil (Figure 2), *Phragmites* (Figure 3), Purple Loosestrife (Figure 4), and Yellow Iris (Figure 5), require frequent monitoring to evaluate the progress of the selected management techniques (Table 4). **LEI staff were present to oversee all herbicide and harvesting activities during the 2010 season.** In addition a spring pre-treatment 1,686-point GPS survey and a late summer/early fall post-treatment and inventory survey of treated areas was conducted. **The recent 1,686-point GPS survey conducted on Lake Mitchell on September 12, 2010 revealed the presence of 18 native submersed species, 3 floating-leaved, and 6 emergent species for a total of 27 native species (Table 5). An abundance of the algae *Cladophora* was also found in the coves and Torenta Canal (Figure 6). The exotic species included the submersed macrophyte, Eurasian Watermilfoil and the emergent macrophytes, Purple Loosestrife, Yellow Iris, and *Phragmites* (Table 2). A graphical representation of the relative abundance of aquatic plant taxa is presented in Figure 7.**

Aquatic herbicides are an effective method for the control of nuisance native and exotic macrophytes. The Natural Resources and Environmental Protection Act, P.A. 451 of 1994 (Part 33) mandates that a permit be acquired from the Michigan Department of Environmental Quality prior to all aquatic herbicide treatments.

There are two broad categories of aquatic herbicides; Contact and Systemic. Systemic herbicides can be applied to various areas or to an entire system and kill the entire plant. In contrast, contact herbicides kill only the shoot portion of the plant. Algaecides also fall into the herbicide category and are effective on all types of algae including filamentous (surface), planktonic (submersed), and periphytic (submersed on aquatic plants) forms. The continued use of systemic aquatic herbicides (such as 2, 4-D and Triclopyr) for Lake Mitchell is recommended to maintain good control over the Eurasian Watermilfoil for the best long-term results. **Approximately 357 acres of milfoil was treated in 2010, and it is difficult to predict what acreage may be present in 2011 since the current milfoil distribution is very patchy. Most of the algae noted in Lake Mitchell during 2010 consisted of diatoms (primarily *Navicula* sp., *Fragilaria* sp., *Tabellaria*, and *Synedra*) and planktonic blue-green algae (primarily *Microcystis* sp., and *Oscillatoria* sp).**

During early July of 2009, approximately 10,000 weevil units were placed into 2.5 acres of milfoil, located at the terminus of Mitchell Creek on Big Cove. Further weevil stockings in Lake Mitchell during 2010 did not occur but will be reevaluated in 2011 for possible stocking in 2012. Staff from Lakeshore Environmental, Inc. and will be meeting with the U.S. Forest Service in 2011 to discuss grant funding for the biological control of the emergent exotic, Purple Loosestrife, which occupies nearly 5 acres of land around the lake.

Mechanical harvesting/Weed cutting is generally preferred over herbicide use when submersed aquatic macrophyte biomass covers large areas because large quantities of decaying vegetation contribute significant organic matter to the lake bottom. Although sedimentary microbes exist to breakdown the decaying vegetation, this process is very slow and some species of macrophytes persist on the lake bottom for years. Mechanical harvesting rarely removes the plants from the roots; however, it does remove the majority of the plant biomass if conducted properly. Harvesting is usually not recommended in areas which contain Eurasian Watermilfoil. Eurasian Watermilfoil has a unique growth habit in that when cut, it breaks into small fragments that may grow into new plants. The majority of the problem areas recommended for harvesting in Lake Mitchell are in water depths less than 5 feet deep (i.e. in coves, the canal, and near shore). **Approximately 28 acres of nuisance aquatic plant and Cladophora growth was removed through mechanical harvesting in 2010.**

Macrophyte Species and MDEQ Species Code	***Common Name***	***Plant Growth Form***
Myriophyllum spicatum, 1	Eurasian Watermilfoil	Submersed; Rooted
Phragmites australis, 28	Giant Common Reed	Emergent
Lythrum salicaria, 43	Purple Loosestrife	Emergent
Iris pseudacorus, 44	Yellow Iris	Emergent

Table 4. Exotic aquatic macrophyte species found in and around Lake Mitchell (2010)

Figure 2. Eurasian Watermilfoil (*Myriopyllum spicatum*)

Figure 3. *Phragmites australis*

Figure 4. Purple Loosestrife

Figure 5. Yellow Iris

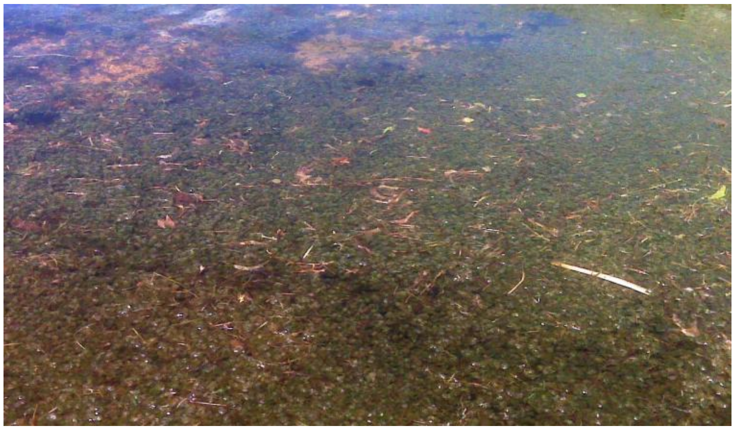

Figure 6. *Cladophora* “balls”

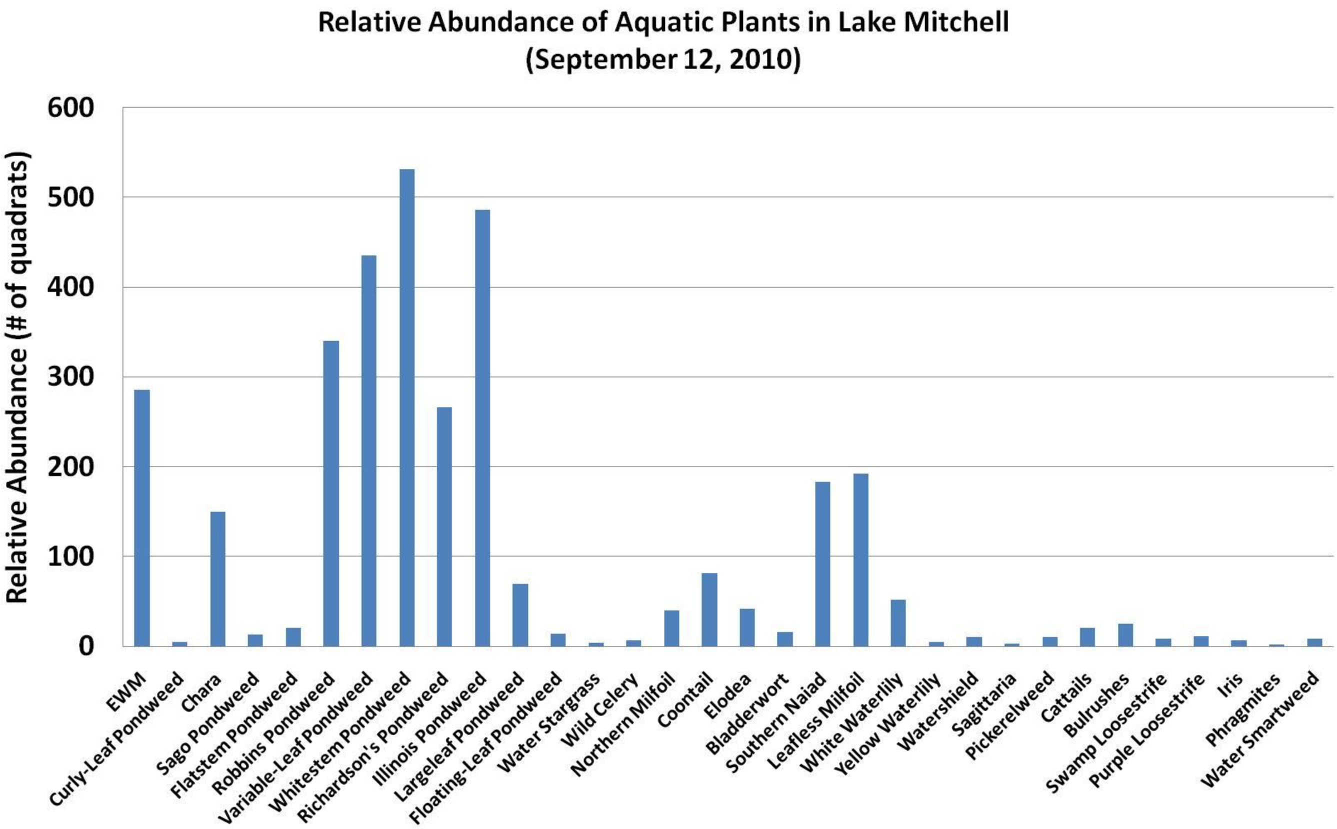

Figure 7. Relative abundance of aquatic plants in Lake Mitchell (September 12, 2010).

Macrophyte Species and Code	***Common Name***	***Plant Growth Form***
Chara vulgaris (macroalga), 3	Muskgrass	Submersed; Rooted
Potamogeton pectinatus, 4	Sago Pondweed	Submersed; Rooted
*Potamogeton zosteriformis,*5	Flat-Stem Pondweed	Submersed; Rooted
Potamogeton robbinsii, 6	Fern-leaf Pondweed	Submersed; Rooted
Potamogeton gramineus, 7	Variable-leaved Pondweed	Submersed; Rooted
Potamogeton praelongus, 8	White-stemmed Pondweed	Submersed; Rooted
Potamogeton richardsonii, 9	Clasping-leaf Pondweed	Submersed; Rooted
*Potamogeton illinoensis,*10	Illinois Pondweed	Submersed; Rooted
Potamogeton amplifolius, 11	Large-leaf Pondweed	Submersed; Rooted
Potamogeton natans, 13	Floating-Leaf Pondweed	Submersed; Rooted
Heteranthera dubia, 14	Water Stargrass	Submersed; Rooted
Vallisneria americana, 15	Wild Celery	Submersed; Rooted
Myriophyllum heterophyllum, 17	Variable Watermilfoil	Submersed; Rooted
Ceratophyllum demersum, 20	Coontail	Submersed; Non-rooted
Elodea canadensis, 21	Common Waterweed	Submersed: Rooted
Utricularia vulgaris, 22	Common Bladderwort	Submersed; Non-rooted
Najas guadalupensis, 25	Southern Naiad	Submersed; Rooted
Nymphaea odorata, 30	White Waterlily	Floating-leaved
Nuphar variegata, 31	Yellow Waterlily	Floating-leaved
Brasenia schreberi, 32	Watershield	Floating-leaved
Sagittaria sp., 36	Arrowhead	Emergent
Pontedaria cordata, 37	Pickerelweed	Emergent
Typha latifolia, 39	Cattails	Emergent
Scirpus acutus, 40	Bulrushes	Emergent
Decodon verticillatus, 42	Swamp Loosestrife	Emergent
Myriophyllum tenellum, 50	Leafless Watermilfoil	Submersed; Rooted

Table 5. Native aquatic macrophyte species found in and around Lake Mitchell (Summer 2010).

III. LAKE MITCHELL TRIBUTARY WATER QUALITY DATA

A. Water Quality Parameters

The lake has three major tributaries including Mitchell Creek which enters the lake from the west side of Big Cove, Brandy Creek which enters the lake at the north end of Little Cove, and Gyttja Creek which enters the lake at the northernmost point. These tributaries were monitored on August 10, 2010 for water quality parameters such as total phosphorus, pH, water temperature, conductivity, oxidative reduction potential, dissolved oxygen, and turbidity (Table 6). Brandy Creek (Figure 8) contributed the highest concentration of phosphorus to the lake with a total phosphorus concentration of 0.030 mg L^{-1}, followed by Gyttja Creek (Figure 9) at 0.025 mg L^{-1} and Mitchell Creek at 0.025 mg L^{-1}.

Figure 8. Brandy Brook tributary

Figure 9. Gyttja Creek tributary

Figure 10. Mitchell Creek tributary

Tributary	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***TDS mgL^{-1}***	***ORP mV***	***Turbidity NTU***	***Total Phos. mg L^{-1}***
Mitchell	70.0	8.3	7.6	257	112	27.5	0.6	0.025
Brandy	65.6	7.9	8.4	149	125	31.2	1.2	0.030
Gyttja	74.9	8.1	7.8	218	98	45.6	0.9	0.025

Table 6. Lake Mitchell Tributary water quality data (August 10, 2010).

IV. LAKE MITCHELL SOILS ANALYSIS AND BMP'S

The five major soil series types immediately surrounding Lake Mitchell may have impacts on the water quality of the lake and may also dictate the particular land use activities associated within a location. A map (created with data from the United States Department of Agriculture and Natural Resources Conservation Service, 1977) with the soil types and locations can be found in Appendix A. The map demonstrates the precise soil types and locations around Lake Mitchell. There are ten major classes of soils that are found in large quantities around the Lake Mitchell. **Problematic soils include the Loxley Peats, Lupton Mucks, and Tawas-Roscommon Association which are all poorly drained and prone to**

ponding. These soil series comprise the majority of soils around the Lake Mitchell shoreline and are not conducive to septic systems or building since they are associated with high water tables and loosely consolidated material.

Many point and non-point sources are responsible for nutrient loads to aquatic systems. The Lake Mitchell Watershed is approximately 23,315 acres in size, which is nine times larger than the size of the lake (2,580 acres). Water entering Lake Mitchell from the three major tributaries can contribute significant nutrient loads to the lake.

In addition, many residential lawns are regularly enriched with fertilizers that contain phosphorus (P). Many counties within Michigan are introducing P-bans and P-free fertilizers and dishwashing detergents are becoming more available. Storm drains may also contribute nutrients to aquatic systems; however, if nutrient sources are dramatically reduced in proximity to the drains, the effluent is generally not nutrient-enriched and not a threat to the system. Riparian zone (shoreline) vegetation should also be preserved to act as a filter of nutrients that originate in the watershed and eventually enter the lake.

These guidelines include: 1) maintenance of brush cover on lands with steep slopes (ideal for many lakefront lots on Lake Mitchell, 2) development of a vegetation buffer zone 25-30 feet from the land-water interface with approximately 60-80% of the shoreline bordered with vegetation, 3) limiting boat traffic to reduce wave energy and thus erosion potential, 4) avoiding the use of retaining walls and encouraging the growth of dense shrubs or rip-rap to control erosion, and 5) using only native genotype plants (those native to Lake Mitchell) around the lake since they are most likely to establish and thrive than those not acclimated to growing in the area soils, and 6) restricting boat access via the consideration of a township ordinance (i.e. carry-down access sites, or electric motor only at various launch sites).

Any additional inputs of phosphorus Lake Mitchell are likely to create further algal blooms throughout the lake. This is especially problematic given the high amount of nutrient-rich soils in the surrounding watershed which contribute abundant nutrient loads to the lake, in addition to riparian properties which may contribute fertilizers or other nutrient inputs to the lake.

Thus, the following recommendations are advised to protect the water quality of Lake Mitchell:

1) Avoid the use of lawn fertilizers that contain phosphorus (P). P is the main nutrient required for aquatic plant and algae growth, and plants grow in excess when P is abundant. When possible, water lawns with lake water that usually contains adequate P for successful lawn growth. If you must fertilize your lawn, assure that the middle number on the bag of fertilizer reads "0" to denote the absence of P.
2) Preserve riparian vegetation buffers around lake (such as those that consist of Cattails, Bulrushes, and Native Swamp Loosestrife), since they act as a filter to catch nutrients and pollutants that occur on land and may run off into the lake. As an additional bonus, Canadian geese (*Branta canadensis*) usually do not prefer lakefront lawns with dense riparian vegetation because they are concerned about the potential of hidden predators within the vegetation.
3) Do not burn leaves near the lake shoreline since the ash is a high source of P. The ash is lightweight and may become airborne and land in the water eventually becoming dissolved and utilized by aquatic vegetation and algae.

In addition to the contribution of *E. coli* from runoff sources, waterfowl populations should also be controlled since they may contribute bacteria and nutrients to the lake and also contribute to the problem of swimmer's itch. It is recommended that the residents of Lake Mitchell prevent the feeding of waterfowl that visit lakefront properties. Waterfowl populations may be controlled by following these guidelines:

- Do not feed the waterfowl as it only encourages them to reside on lakefront lawns. There is adequate food for them within the watershed area.
- Plant tall grasses near the shoreline or stop mowing the lawn in areas adjacent to shore. Geese in particular are less likely to visit a lawn with tall grasses due to the possibility of a potential predator residing there. In addition, the vegetation buffer may help to absorb some of the fecal matter (and consequently the *E. coli* bacteria and nutrients) and prevent it from leaching into the water at the shoreline-water interface. Since geese will likely not visit the edge of this buffer if it directly abuts the water's edge, they may visit the other side of the buffer and it may filter the fecal inputs from the geese.

- Contact the Michigan Department of Natural Resources (MDNR) for permit applications for egg-replacement strategies of Geese, which usually nest in March and April. The MDNR may also participate in nest destruction practices in selected areas.
- Purchase sound alarms, whistles, or loud devices to deter waterfowl from lakefront properties. Construction of a pyramidal configuration (designed with four strings attached to a central wooden stake) on swimming rafts along with the addition of reflective compact disks (CD's) tied to the center of the pyramid, has been shown to repel the Geese from the rafts.
- Plastic birds of prey or predatory mammals (i.e. coyotes) may have some effects on the prevention of waterfowl from entering some beach areas.

An exotic species is a non-native species that does not originate from a particular location. When international commerce and travel became prevalent, many of these species were transported to areas of the world where they did not originate. Due to their small size, insects, plants, animals, and aquatic organisms may escape detection and be unknowingly transferred to unintended habitats. The first ingredient to successful prevention of unwanted transfer of exotic species to Lake Mitchell is awareness and education. Invasive species prevention signs are available from the Minnesota Department of Natural Resources, Exotic Species Program at: 500 Lafayette Rd., St. Paul, MN 55155-4025, Phone: 612-296-2835, Fax: 612-296-1811, Email: debbie.hunt@dnr.state.mn.us. The signs (size: 18"x24") are intended for posting at exits of public and private water accesses, and read: "Please stop and remove all aquatic plants and drain water from boat and trailer." They are free to water access owners in MN; however, a fee may apply in other states.

Zebra Mussels

Zebra mussels (*Dreissena polymorpha*) were first discovered in Lake St. Clair in 1988 (Herbert et al. 1989) and likely arrived in ballast water or on shipping vessels from Europe (McMahon 1996). They are easily transferred to other lakes because they inherit a larval (nearly microscopic) stage where they can easily avoid detection. The mussels then grow into the adult (shelled) form and attach to substrates (i.e. boats, rafts, docks, pipes, aquatic plants, and lake bottom sediments) with the use of byssal threads. The fecundity (reproductive rate) of female zebra mussels is high, with as many as 40,000 eggs laid per reproductive cycle and up to 1,000,000 in a single spawning season (Mackie and Schlosser 1996).

Although the mussels only live 2-3 years, they are capable of great harm to aquatic environments. In particular, they have shown selective grazing capabilities by feeding on the preferred zooplankton food source (green algae) and expulsion of the non-preferred blue green algae (cyanobacteria). Additionally, they may decrease the abundance of beneficial diatoms in aquatic ecosystems (Holland 1993). Such declines in favorable algae can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations. Zebra mussels are viewed by some as beneficial to lakes due to their filtration capabilities and subsequent contributions to increased water clarity. However, such water clarity may allow other photosynthetic aquatic plants to grow to nuisance levels (Skubinna et al. 1995). The recommended prevention protocols for introduction of zebra mussels includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into Lake Mitchell. Boat transom wells must always be steam-washed and emptied prior to entry into the lake. Excessive waterfowl should also be discouraged from the lake since they are a natural transportation vector of the microscopic zebra mussel larvae or mature adults. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in Lake Mitchell. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed.

Other Invasive Aquatic Plants

In addition to *Phragmites* and Eurasian Watermilfoil (*M. spicatum*), many other invasive aquatic plant species are being introduced into waters of the North Temperate Zone. The majority of exotic aquatic plants do not depend on high water column nutrients for growth, as they are well-adapted to using sunlight and minimal nutrients for successful growth. These species have similar detrimental impacts to lakes in that they decrease the quantity and abundance of native aquatic plants and associated macroinvertebrates and consequently alter the lake fishery. Such species include *Hydrilla verticillata* (Figure 11) and *Trapa natans* (Water Chestnut).

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Figure 11. *Hydrilla verticillata* in Lake Apopka, Florida.

Hydrilla was introduced to waters of the United States from Asia in 1960 (Blackburn et al. 1969) and is a highly problematic submersed, rooted, aquatic plant in tropical waters. Recently, *Hydrilla* was found in Lake Manitou (Indiana, USA) and the lake public access sites were immediately quarantined in an effort to eradicate it. *Hydrilla* retains many physiologically distinct reproductive strategies which allow it to colonize vast areas of water and to considerable depths, including fragmentation, tuber and turion formation, and seed production. Currently, the methods of control for *Hydrilla* include the use of chemical herbicides, rigorous mechanical harvesting, and Grass Carp (*Ctenopharyngodon idella* Val.), with some biological controls currently being researched. However, use of the Grass Carp in Michigan is currently not permitted by the Michigan Department of Natural Resources (MDNR). Methods of control involve the use of mechanical removal and chemical herbicides. Biological controls are not yet available for the control of this aquatic plant.

Viral Hemorrhagic Septicemia (VHS) Fish Virus

Viral Hemorrhagic Virus (VHS) is a fish disease caused by a rhabdovirus, which has spread to the Great Lakes region and has caused great harm to the fishery in the Great Lakes waters and a few inland lakes.

The VHS virus is deadly to fish and once it has entered into a waterbody, there is no way to remove it. VHS is most active in colder waters (i.e. water temperatures < 15ºC), which is why the virus is most active during the spring season. The virus has two possible ways of entering into an inland lake waterbody; 1.) attached to a vessel 2.) and/or through infected bait fish. The MDNR recommends that boats going from lake to lake be sprayed with a solution of Chlorox® or Virkon® prior to entering a waterbody. The solution of Chlorox® and water required to kill the virus is a very weak concentration (one-half ounce of Chlorox® per gallon of water). The MDNR has also been inspecting bait sellers and issuing virus-free bait permits. Live wells or bilge pumps should be drained prior to entering Lake Mitchell. Some Lake Associations and Boards throughout the state are supplying their boat launches with the proper gear to stop the spread of VHS. The recommended materials needed include instructions on how to disinfect your boat, safety goggles, rubber gloves, and a hand-held garden sprayer containing the Chlorox® water solution. Visit the Michigan Lake and Streams Association website at: http://www.mlswa.org for more information.

V. LAKE MITCHELL 2011 MANAGEMENT RECOMMENDATIONS AND PROPOSED BUDGET

The efficacy of the 2010 aquatic herbicide treatments of Eurasian Watermilfoil and *Phragmites* were evaluated in fall of 2010 and seemed to be successful. It is likely that further spot-treatments with the use of selective, systemic aquatic herbicides may be necessary for further control of both exotic species during the 2011 season. Thus, a detailed GPS grid/AVAS survey of Lake Mitchell will be conducted again during the spring of 2011 to detect both Eurasian Watermilfoil and *Phragmites* growth locations and ascertain accurate treatment locations. Additionally, LEI scientists will continue to investigate specific BMP's that may be site-specific to individual tributaries and therefore decrease nutrient inputs to the lake. A proposed budget for lake management activities in Lake Mitchell is shown in Table 7 below.

Lake Mitchell Proposed 2011 Management Budget

Improvement Strategy	Estimated Costs
Mechanical Harvesting	$7,020
(Approximately 27 acres @$260/acre)	
Aquatic Herbicide Treatments	$92,400
(250 acres@$350 per acre)	
(10 acres@$490 per acre)	
Weed Pickup Service	$8,000
Biocontrol (***Galerucella*** beetles)	$8,000
***Phragmites* Treatment** (0.25 acres@$300 per acre)	$300
Publications/Website	$10,000
Newsletter (mailed by LMIB)	$1,000
Consulting Fees	$16,000
(Administration, surveys, sampling, meetings, representation)	
Contingency (15% of total project)	$21,408
Total 2011 Program Cost	$164,128

Table 7. Lake Mitchell proposed lake management costs for 2011. Note: Aquatic herbicide budget may be allocated towards control of remaining EWM and *Phragmites*.

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APPENDIX A

LAKE MITCHELL SHORELINE SOILS MAP AND DATA