Restorative Lake Sciences, LLC

Lake Mitchell 2012 Annual Progress Report

An Annual Assessment Of
Aquatic Vegetation And Water Quality in
Lake Mitchell
Wexford County, Michigan

January, 2013

Prepared for: Lake Mitchell Improvement Board
C/o Mike Solomon, Chair
400 Lake Street, Suite 600
Cadillac, MI 49601

Prepared by: Restorative Lake Sciences, LLC
Jennifer Jermalowicz-Jones
Water Resources Director
2714 East Hawley Road
Custer, MI 49405

TABLE OF CONTENTS

SECTION	PAGE

FIGURES

TABLES

An Annual Progress Report of Aquatic Vegetation and Water Quality in Lake Mitchell Wexford County, Michigan

January, 2013

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 June of 2012, plants suspected of being hybrid by phenotype were sent to the GVSU Annis Water Resource Institute (Muskegon, Michigan) for genotypic diagnosis that confirmed the observed phenotype was hybrid watermilfoil. 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. **On May 22-23 of 2012, approximately 250 acres of HWM were located in the main lake and coves during the whole-lake GPS Grid Matrix Survey. Treatment of approximately 239 acres of HWM occurred on June 13, 2013 by Professional Lake and Land Management of Caledonia, Michigan.** Approximately 146 acres of HWM was treated with the systemic granular Renovate Max G® at a dose of 160 lbs per acre. An additional 93 acres of HWM was treated with Renovate Max G® at a dose of 120 lbs per acre. **A post-treatment survey on July 23, 2012** that included three members of the Lake Mitchell Improvement Board, a representative from the herbicide manufacturer, SePRO, and an applicator from PLM all accompanied the consultant for the Lake Mitchell Improvement Board to assess the efficacy of the treatment throughout the lake. It was mutually determined by those stakeholders that a **re-treatment of approximately 53 acres of HWM** throughout the lake was needed with 45 acres being treated with Renovate Max G® at a dose of 160 lbs per acre and 8 acres being treated with Renovate Max G® at 120 lbs per acre. Additionally, a new 15.3 acres of HWM was noted with 2.5 acres being treated with Renovate OTF® at 120 lbs per acre and 12.5 acres being treated with Sculpin G® at a dose of 160 lbs per acre. **A total of 44,966 lbs of granular aquatic herbicide product were applied to the main lake during 2012.**

In addition to the main lake, the **coves and canal were all treated on June 11, 2012** by A&T Service, LLC based in Spring Lake, Michigan. In Little Cove, approximately 13 acres of nuisance HWM and native vegetation was treated with the contact herbicide fluxioxazin (Clipper®) at 200 ppb. Franke North and Franke South were treated with 2.5 acres of Clipper® at 400 ppb and 3 acre of Clipper® at 400 ppb, respectively. In Big Cove, approximately, 7 acres of HWM was treated with the contact herbicides diquat (Reward®), Hydrothol (Aquathol-K®), and chelated copper algaecide (Cutrine®). In the Torenta Canal, approximately 3 acres were treated with the contact herbicides diquat (Reward®), Hydrothol (Aquathol-K®), and chelated copper algaecide (Cutrine®). An additional 3 acres of the aforementioned contacts was applied to the Franke Coves on August 29, 2012 by A& T Service, LLC.

On July 15, 2012, approximately 40 pots of cultured *Galerucella* sp. beetles were transplanted into areas that contained actively growing Purple Loosestrife. In many cases, individual beetles were hand-delivered to individual florescences of Purple Loosestrife plants. Transplant areas included Little Cove, the Franke Coves, Big Cove, and the Torenta Canal. Beetles were cultured at the Kalamazoo Nature Center in Kalamazoo, Michigan. **On August 17th, 2012, approximately 3-5 florescence's on different plants were evaluated at each of the stocking sites. The mean damage index was 3.1±1.0 and the mean number of beetles observed on a given florescence was 2.5±1.3.**

A final GPS Grid matrix Survey conducted on August 17th and 19th , 2012 determined that many of the HWM areas that were treated showed significant damage. A few areas at the North side of the lake showed some resistance but a spring 2013 survey is needed to fully determine the extent of systemic herbicide damage. **The weevil activity in Big Cove continues to decline over the past three years, even despite an initially high stocking density of 10,000 weevil units in a 1-acre are during July of 2009. Due to this weak response, further stocking of milfoil weevils in Big Cove is not advised.**

Water quality sampling of the deep basins and tributaries of Lake Mitchell was conducted on July 14, 2012. Secchi transparencies were higher than average (by nearly 2 feet on average) and the water temperatures were very warm with surface temperatures near 79 degrees. **Nutrient levels continue to be in the eutrophic range for the entire lake, with elevated levels entering the lake from Brandy Brook and Mitchell Creek.**

Staff at Restorative Lake Sciences, LLC (RLS) will continue to monitor the lake for both EWM and HWM and will **re-survey the lake in the spring of 2013** to determine exact GPS coordinates for treatment. Additionally, RLS recommends that **either *in situ* test of various herbicide combinations and/or laboratory tests of the same be conducted prior to large-scale treatments in 2013. The challenge of HWM is a serious one for many inland lakes and the treatment strategies differ from site to site due to differences in water and sediment chemistry.**

There are currently a total of 27 native aquatic plant species in and around Lake Mitchell. In 2012, 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 and continued removal of HWM is needed to maintain this high biodiversity.

Staff from RLS recommend that a local **Lake Mitchell riparian workshop be conducted during the 2013 season** to educate lake citizens about the issues on the lake. The workshop would provide educational assistance to residents from RLS 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 22-23, 2012 and on August 17 and 19, 2012 consisted of 1,686 equidistantly-spaced grid points on Lake Mitchell, using a Humminbird® 50-satellite GPS WAAS-enabled unit (accuracy within 2 feet; Figure 1). The objective of the surveys is to compare the changes in both milfoil and native aquatic vegetation prior to treatment and after treatment. 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 2012

The 2012 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 HWM within the lake. Currently, the majority of the milfoil in the lake is HWM since previous infestations by EWM were successfully controlled.

3.1 Lake Mitchell Exotic Aquatic Plant Species

The May 22-23, 2012 survey detected four invasive species, including EWM (Figure 2) and Hybrid watermilfoil (Figure 3). The distribution of HWM in May (before treatment) is shown in Figure 4 and the distribution of HWM in August (after treatment) is shown in Figure 5. The other submersed exotic Curly-Leaf Pondweed (Figure 6), and emergent Purple Loosestrife (Figure 7) are also shown below. Exotic species found in Lake Mitchell during 2012 are listed below in Table 1.

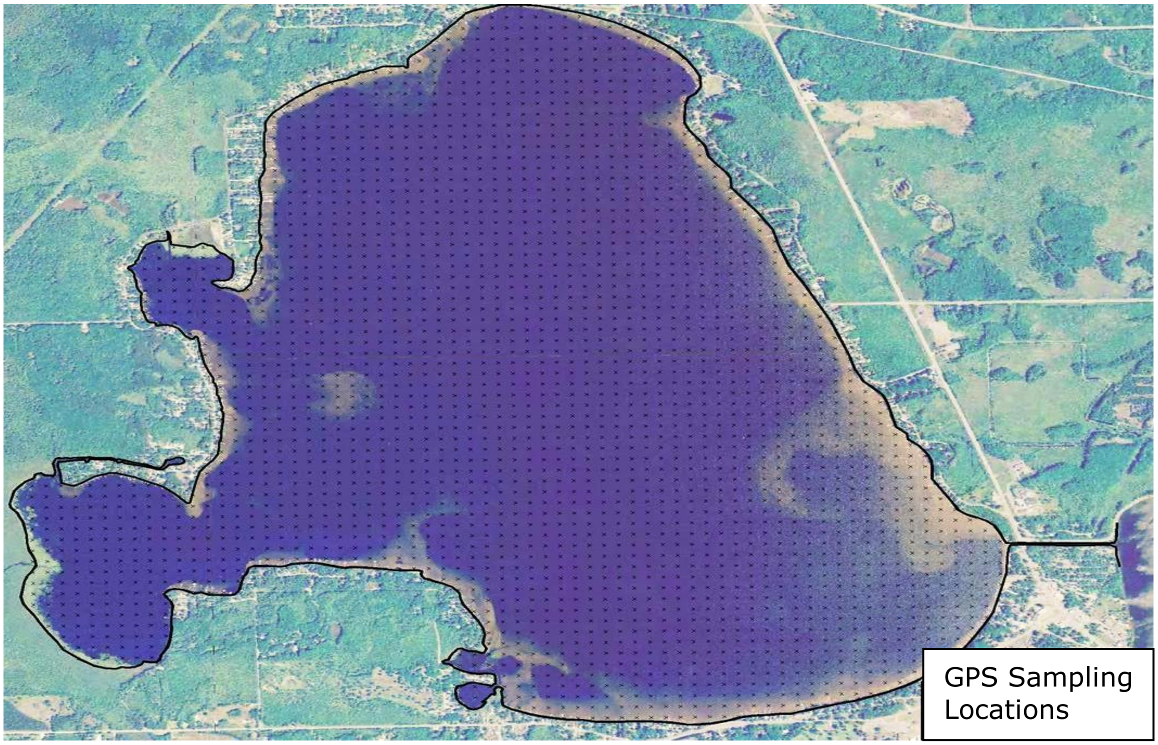


Figure 1. A map showing GPS sampling location points on Lake Mitchell, Wexford County, Michigan.

Macrophyte Species and Code	Common Name	Plant Growth Form	% Coverage Lake Area
Myriophyllum spicatum	Eurasian Watermilfoil	Submersed; Rooted	1.0
M. spicatum var. sibiricum	Hybrid Watermilfoil	Submersed; Rooted	6.0
Potamogeton crispus	Curly-Leaf Pondweed	Submersed; Rooted	0.5
Lythrum salicaria	Purple Loosestrife	Emergent	2.0

Table 1. Exotic aquatic plant species present within or around Lake Mitchell (August, 2012)

Figure 2. A photograph of the EWM Phenotype & Confirmed Genotype

Figure 3. A photograph of the Hybrid EWM Phenotype and Confirmed Genotype

Information on Hybrid Watermilfoil

Hybrid Watermilfoil was genetically determined during June of 2012 to be related to the above-mentioned red-stemmed phenotype. Hybrid watermilfoil 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 watermilfoil 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 watermilfoil 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 watermilfoil 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 watermilfoil 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 watermilfoil. Glomski and Netherland (2010) found that the greatest percentage of hybrid watermilfoil (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 watermilfoil; however, they were conducted in laboratory aquaria and field CET studies are therefore needed.

An additional option is to collect many stems of hybrid watermilfoil 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. There are limitations to this method in that laboratory testing conditions are not the same as exist in situ in Lake Mitchell (i.e. the lake water chemistry is likely different from laboratory water chemistry). Additionally, the use of certain granular products interacts with lake sediments that are not present in laboratory tests. In regards to impacts on native vegetation, hybrid watermilfoil 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).

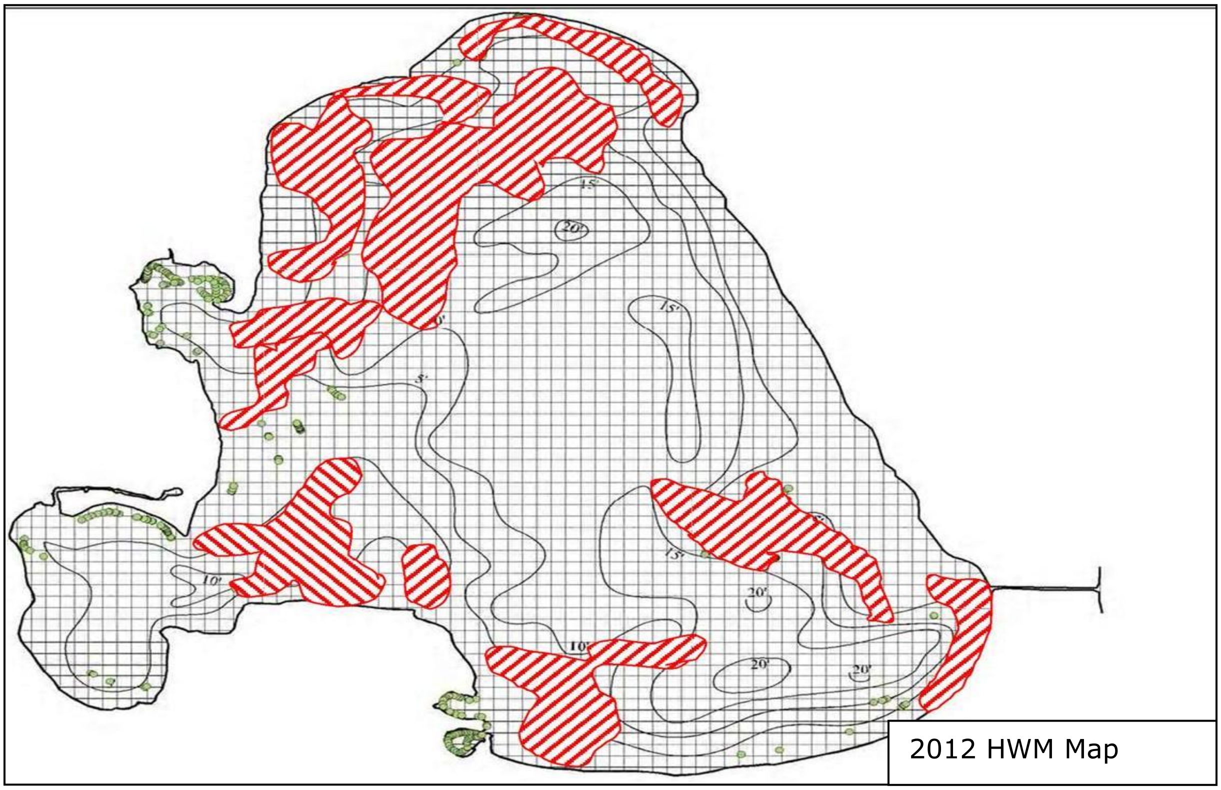


Figure 4. HWM distribution in Lake Mitchell (May, 2012).

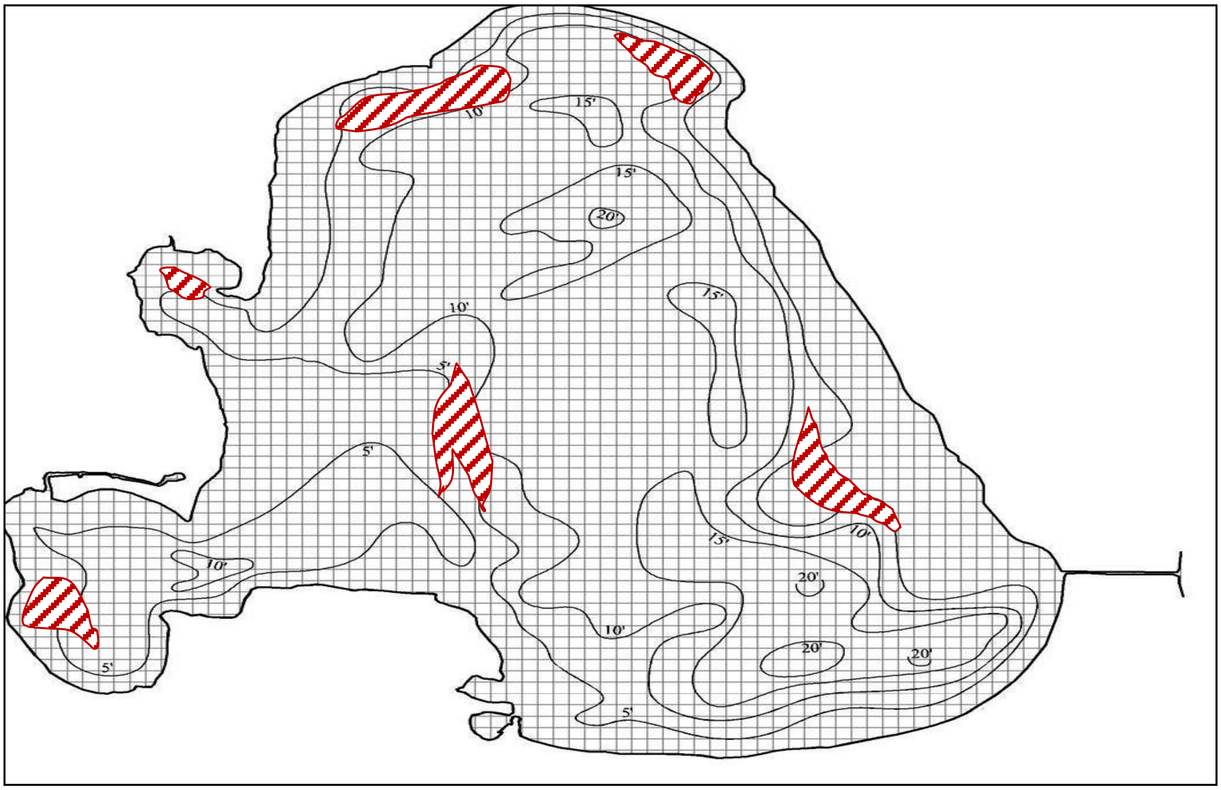


Figure 5. HWM distribution in Lake Mitchell (August, 2012).

Figure 6. A photograph of the Curly-Leaf Pondweed (*Potamogeton crispus*)

Figure 7. 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 2012, 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 RLS 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 and HWM canopies. **The numbers in Table 2 were calculated based on aquatic vegetation found among the 1,686 GPS grid points that were sampled in late May and again in mid-August of 2012.**

Graphs 1 and 2 (Figures 8 and 9) below show the changes in common and rare native aquatic plant species, respectively, with time in Lake Mitchell for the time period between 2009-2012. A few photographs of common species found in Lake Mitchell can be found on page 22 (Figures 10-13) and rare species are displayed on page 23 (Figures 14-17).

Aquatic Plant Species	***Common Name***	***Plant Growth Form***	***% Coverage of Sampled Lake Area***
Chara vulgaris (macroalga)	Muskgrass	Submersed; Rooted	23
Potamogeton pectinatus	Sago Pondweed	Submersed; Rooted	12
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed; Rooted	69
Potamogeton gramineus	Variable-leaved Pondweed	Submersed; Rooted	24
Potamogeton praelongus	White-stemmed Pondweed	Submersed; Rooted	47
Potamogeton richardsonii	Clasping-leaf Pondweed	Submersed; Rooted	18
Potamogeton illinoensis	Illinois Pondweed	Submersed; Rooted	32
Potamogeton amplifolius	Large-leaf Pondweed	Submersed; Rooted	9
Myriophyllum sibiricum	Northern Watermilfoil	Submersed; Rooted	11
Ceratophyllum demersum	Coontail	Submersed; Non-rooted	9
Elodea canadensis	Common Waterweed	Submersed: Rooted	12
Utricularia vulgaris	Common Bladderwort	Submersed; Non-rooted	28
Utricularia minor	Mini Bladderwort	Submersed; Non-rooted	5
Najas guadalupensis	Southern Naiad	Submersed; Rooted	31
Najas flexilis	Slender Naiad	Submersed; Rooted	42
Potamogeton pusillus	Small-leaf Pondweed	Submersed; Rooted	39
Nymphaea odorata	White Waterlily	Floating-leaved	5
Nuphar variegata	Yellow Waterlily	Floating-leaved	9
Brasenia schreberi	Watershield	Floating-leaved	7
Lemna trisulca	Star Duckweed	Floating-Leaved; Non-rooted	6
Pontedaria cordata	Pickerelweed	Emergent	2
Typha latifolia	Cattails	Emergent	8
Scirpus acutus	Bulrushes	Emergent	45
Decodon verticillatus	Swamp Loosestrife	Emergent	6
Myriophyllum tenellum	Leafless Watermilfoil	Submersed; Rooted	59
Eleocharis acicularis	Spikerush	Emergent	33
Bidens beckii	Water Marigold	Submersed; Rooted	6

Table 2. Native Plants

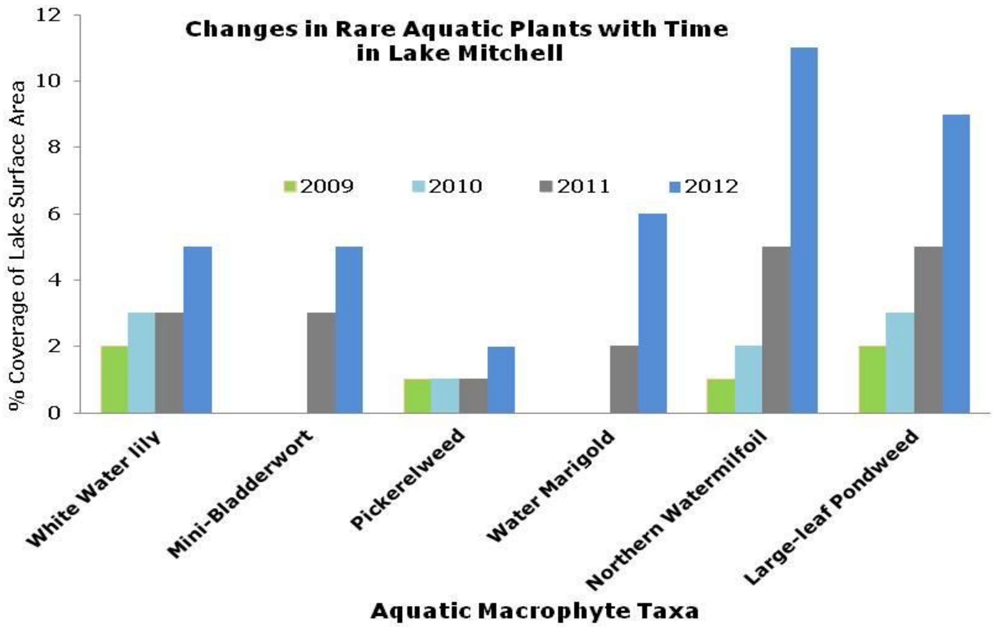


Figure 8. Common aquatic plants in Lake Mitchell, 2012.

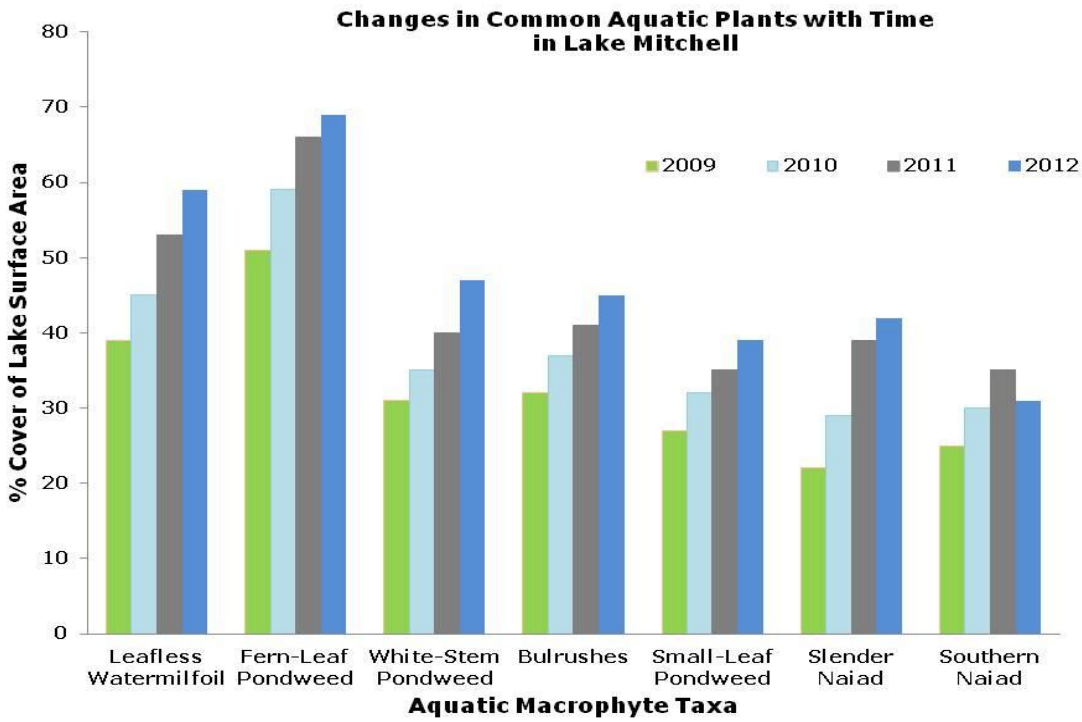


Figure 9. Rare aquatic plants in Lake Mitchell, 2012.

Common Aquatic Plant Species Present in Lake Mitchell

Figure 10. A photograph of White-Stem Pondweed (*Potamogeton praelongus*)

Figure 11. A photograph of Leafless Watermilfoil (*Myriophyllum tenellum*)

Figure 12. A photograph of Fern-Leaf Pondweed (*Potmageton robbinsii*)

Figure 13. A photograph of Bulrushes (*Scirpus acutus*)

Rare Aquatic Plant Species Present in Lake Mitchell

Figure 14. A photograph of Large-Leaf Pondweed (*Potamogeton amplifolius*)

Figure 15. A photograph of Northern Watermilfoil (*Myriophyllum sibiricum*)

Figure 16. A photograph of Water Marigold (*Megalodonta beckii*)

Figure 17. A photograph of Pickerelweed (*Pontedaria cordata*)

3.3 Lake Mitchell Big Cove Weevil Assessment

The use of the aquatic weevil, *Euhrychiopsis lecontei* to control *M. spicatum* has become a natural option for inland lakes. The weevil naturally exists in many of our lakes; however, the lack of adequate populations in many lakes requires that they be implanted or stocked for successful control of *M. spicatum*. The weevil feeds almost entirely on *M. spicatum* and will leave native aquatic species unharmed. The weevil burrows into the stems of *M. spicatum* and removes the vascular tissue, thereby reducing the plant's ability to store carbohydrates (Newman et *al.* 1996; Figure 18). Eventually, the *M. spicatum* stems lose buoyancy and the plant decomposes on the lake bottom.

Figure 18. Weevil stem damage by a pupa of the milfoil weevil

Recent research has shown that the weevils require a substantial amount of aquatic plant biomass for successful control of *M. spicatum*. Additionally, there is increasing evidence that the weevil is much less effective on HWM, which s now dominant in Big Cove. In addition, the weevils require adequate over-wintering habitat since they overwinter within shoreline vegetation.

Lakes with sparse *M. spicatum* distribution and abundant metal and concrete seawalls are not ideal candidates for the milfoil weevil. During July of 2009, approximately 10,000 weevil units were transplanted into a 1-acre area near Mitchell Creek in Big Cove. Over the past few years, staff from RLS have assessed the populations of the weevil and have determined that the population has not been adequately sustained. **Data from 2011 indicated that the average stem damage index was 1.2±1.3, while it dropped to an average of 0.2±0.4 in 2012.** Each milfoil stem was carefully investigated under a dissecting microscope and analyzed for stem diameter, number of lateral branches, an index of weevil damage, and stem length. The index of weevil damage was developed to assess the degree of stem damage associated with the weevil activity. The index ranged from 0 - 5 with a value of "0" denoting no weevil damage visible, a "2" denoting the presence of larvae or eggs on or in the stem, a "3" indicated the presence of larvae in the stem tissues and vascular tissue damage, "4" indicated the presence of larvae or pupae and severe necrosis of the stem tissue, and a "5" denoted both severe tissue necrosis, weevil pupae or larvae, and the loss of foliar leaves. Additional stocking is not recommended at this time.

3.4 Lake Mitchell Purple Loosestrife Beetle Assessment

Purple loosestrife is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as cattails (*Typha latifolia*) or native swamp loosestrife (*Decodon verticillatus*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. Biological control vectors such as the beetles *Galerucella calmariensis* (Figure 19) and *G. pusilla* have been effective on the treatment of shoreline purple loosestrife in many locations throughout the Midwest. However, these beetles usually prefer a large stand of purple loosestrife to promote their population. As a result, beetles that were cultured at the Kalamazoo Nature Center were released into areas around Lake Mitchell that had adequate stands of the plant. **A total of 40 cultured pots were released on July 15, 2012 into areas that contained significant stands of Purple Loosestrife plants.** A damage index similar to the weevil index was used to determine the degree of damage observed on individual florescences (flowers) on individual Purple Loosestrife plants. **On August 17th, 2012, approximately 3-5 florescences on different plants were evaluated at each of the stocking sites. The mean damage index was 3.1±1.0 and the mean number of beetles observed on a given florescence was 2.5±1.3.** This data indicates This project was funded by the United States Forest Service for 2012-2013. A map showing the distribution of the beetles is shown below in Figure 20.

Figure 19. *Galerucella*, the Purple Loosestrife-eating beetle.

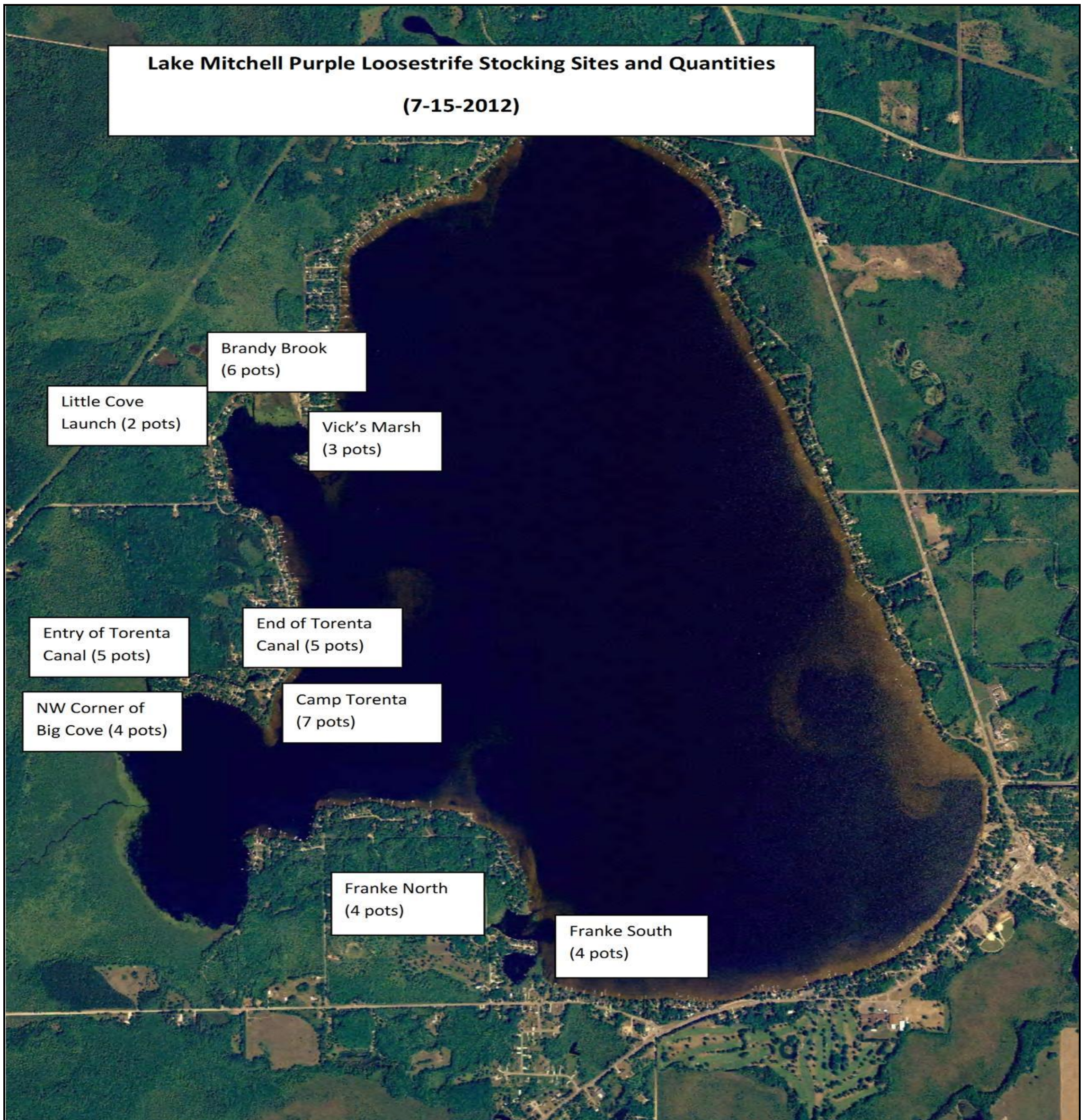


Figure 20. Purple Loosestrife beetle stocking sites around Lake Mitchell in July, 2012

4.0 LAKE MITCHELL 2012 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 moderate 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)

4.1 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 21) and are discussed below along with water quality data specific to Lake Mitchell. (Tables 4-6 and assorted graphs).

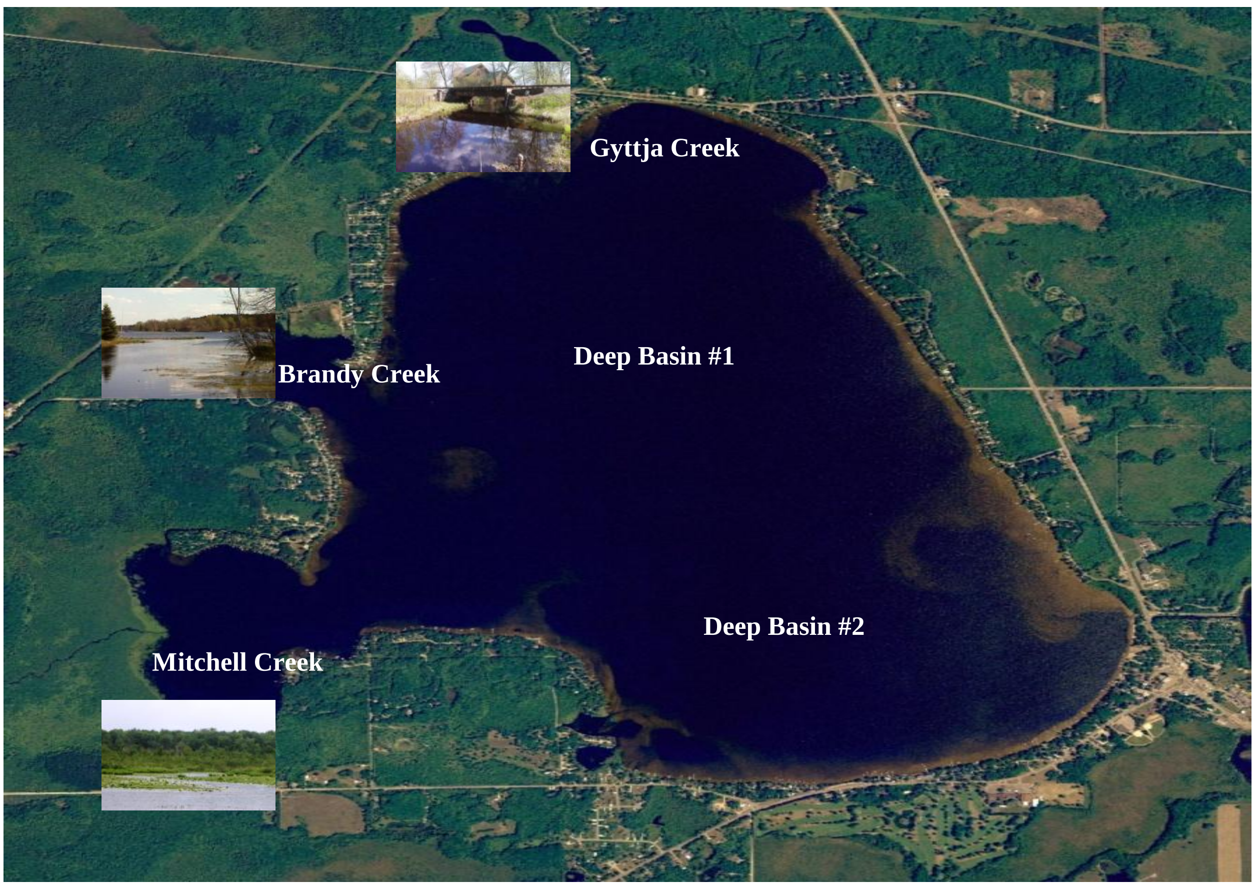


Figure 21. A location map of water quality lake and tributary sampling stations on Lake Mitchell (July, 2012)

Dissolved Oxygen

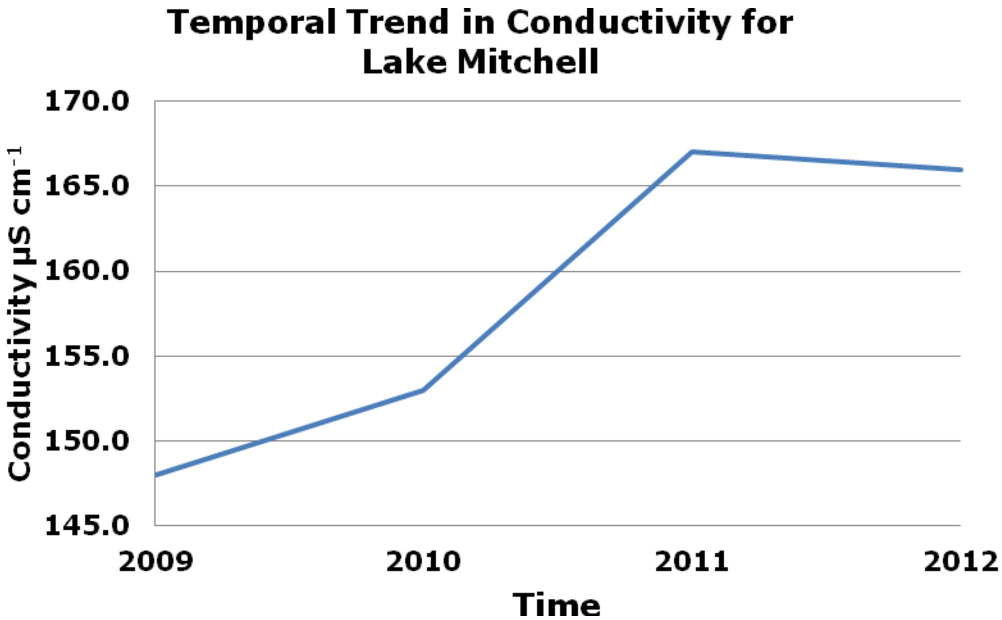
Dissolved oxygen (DO) is a measure of the amount of oxygen that exists in the water column. In general, DO levels should be greater than 5 mg L^{-1} to sustain a healthy warm-water fishery. Dissolved oxygen concentrations in Lake Mitchell may decline if there is a high biochemical oxygen demand (BOD) 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 July DO concentrations in Lake Mitchell were high at the surface and slightly lower at the lake bottom. **DO ranged from 3.99 – 9.91 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.

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 July, 2012 water temperatures of Lake Mitchell demonstrated a notable thermocline between the surface and a “middle depth” and bottom since the lake was sampled during a stratified period. **Water temperatures ranged from 78.2 ºF at the surface and 60.9 ºF at the lake bottom. The water temperatures for all of the tributaries were higher and averaged 81.2 ºF, with the lowest temperature observed in Mitchell Creek.**

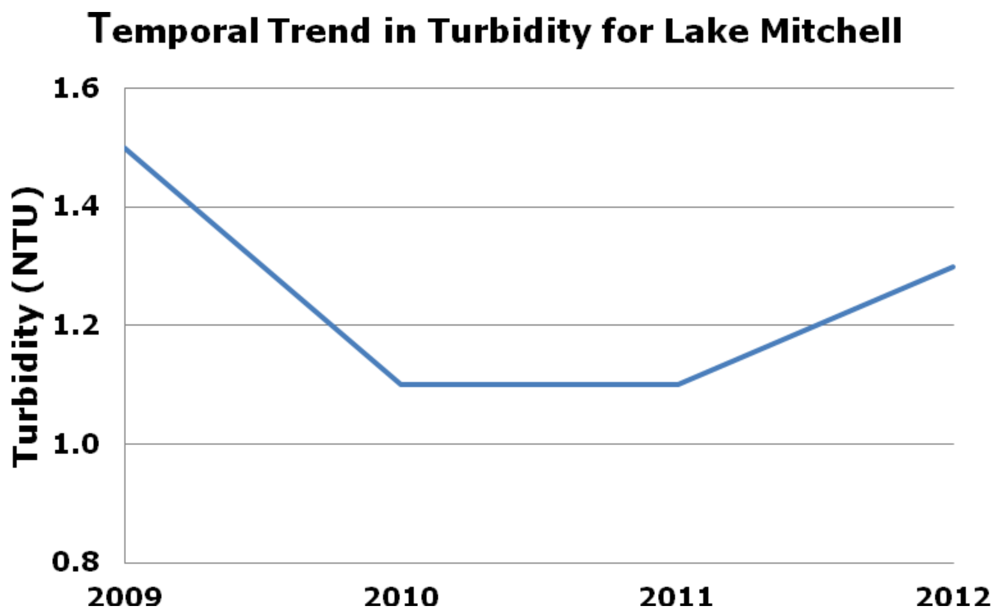
Conductivity

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 Lake Mitchell were low and ranged from 161 $\mu S\ cm^{-1}$ and 171 $\mu S\ cm^{-1}$. These values were significantly lower than for other inland lakes. The conductivity of Mitchell and Gyttja Creeks was 227 and 210 $\mu S\ cm^{-1}$, respectively, and indicated loading of solutes from the adjacent roads and impervious surfaces. The conductivity of Brandy Brook was 102 $\mu S\ cm^{-1}$, which was slightly lower than the other two tributaries.** A graph showing the temporal trend in mean conductivity for Lake Mitchell is shown below.



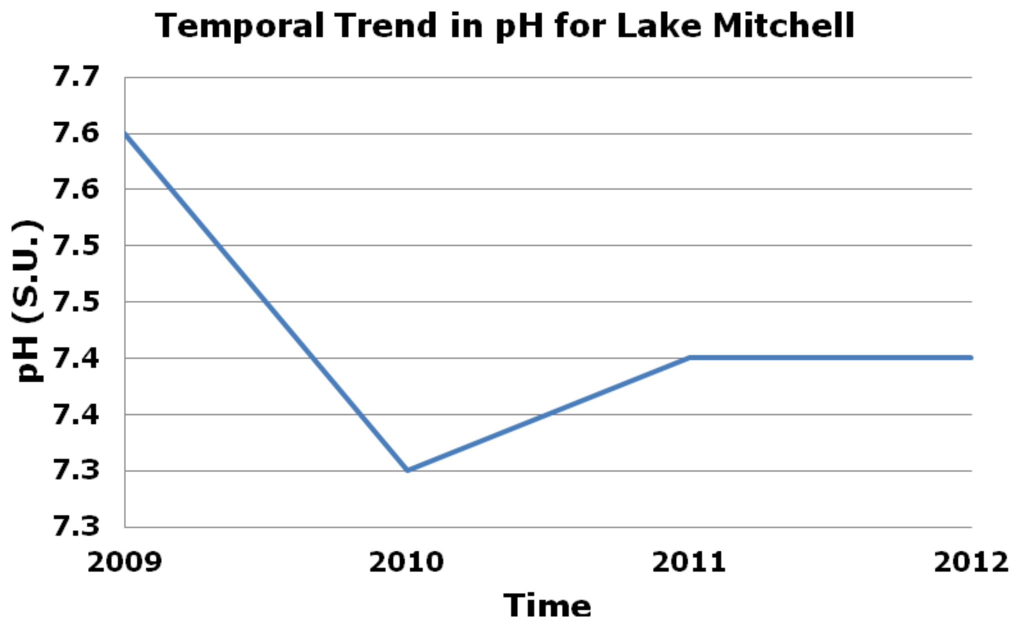
Turbidity

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 0.6 – 2.1 NTU's during the July sampling event which was low.** 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.



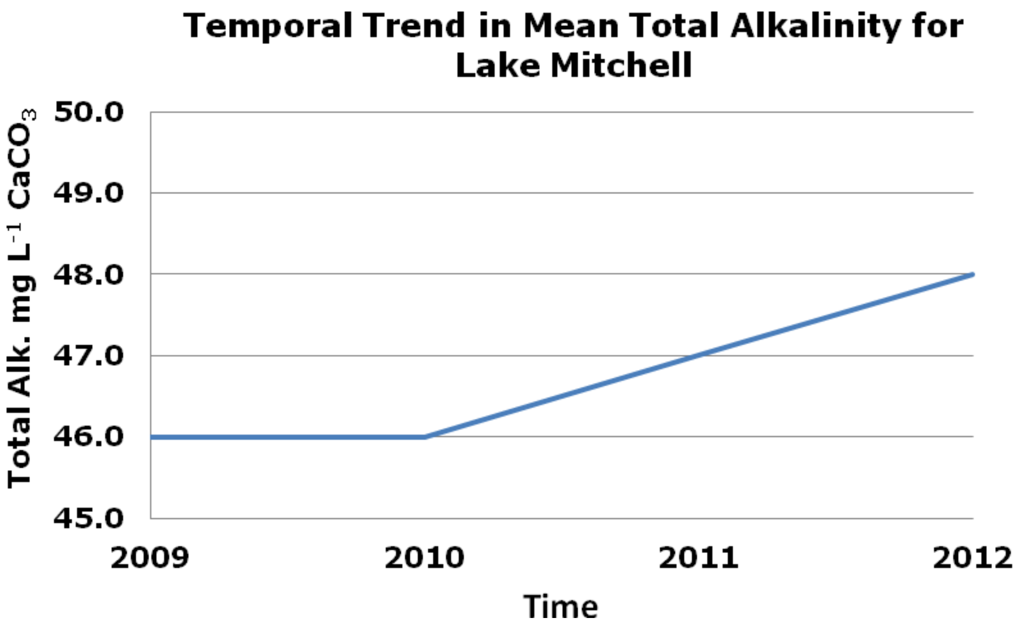
pH

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 July sampling. The mean pH of the tributaries was 7.3 which were 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 four year period.



Total Alkalinity

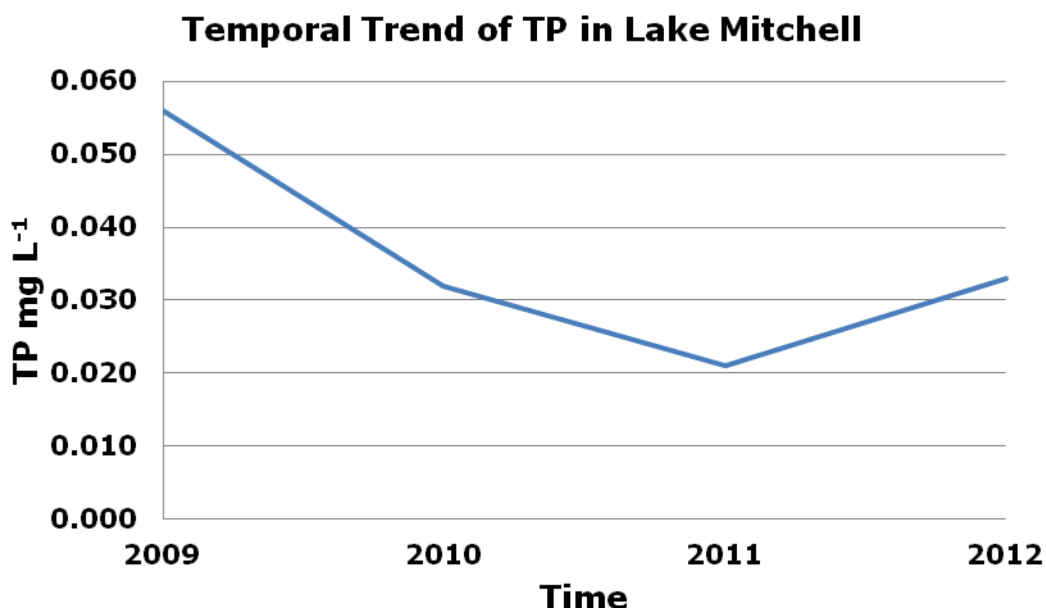
Total alkalinity is the measure of the pH-buffering capacity of lake water. Lakes with high alkalinity (> 150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having "hard" 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 46-49 mg L^{-1} of $CaCO_3$ during the July, 2012 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 four years.



Total Phosphorus

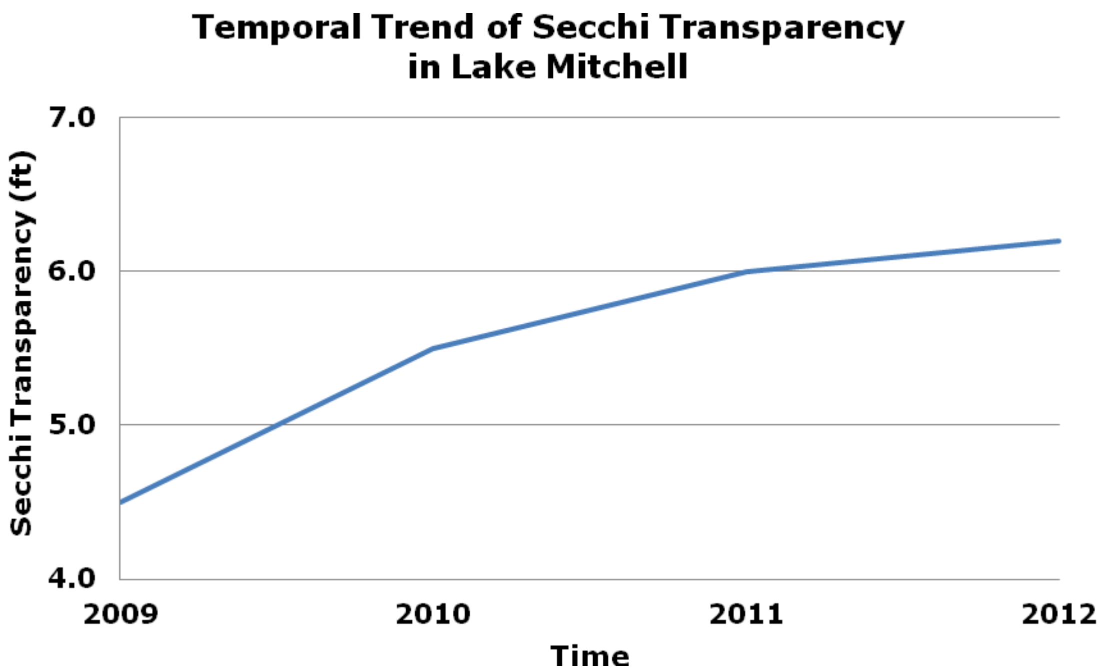
Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. Lakes which contain greater than 0.025 mg L^{-1} of TP are defined as eutrophic or nutrient-enriched. TP concentrations 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 July sampling event was 0.013 mg L^{-1}. The mean mid-depth TP concentration for both deep basins was 0.028 mg L^{-1}. The mean bottom TP concentration for both deep basins was 0.060 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 0.033 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 four 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 6.2 feet over the deep basins during the 2012 sampling period (based on n=11 measurements courtesy of Dave Foley).** 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 four 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 July sampling event ranged from 52 mg L^{-1} to 76 mg L^{-1}, which was slightly lower than in 2011. The TDS of tributary waters ranged from 109 mg L^{-1} to 129 mg L^{-1}, with all 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 from 201.6 mV and 115.7 mV from the surface to the bottom within the lake, and indicated oxidized rather than reduced conditions. The ORP of tributary waters ranged from 112.9 mV and 189.9 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 4.1 μg L^{-1} and the concentration for Deep Basin #2 was 5.2 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 July 14, 2012 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 *Haematococcus* sp., *Euglena* sp., *Scenedesmus* sp., *Melosira* sp., *Fragillaria* sp., and *Synedra* sp. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Euglena* 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., *Asterionella* 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	78.2	9.9	7.4	169	0.9	201.6	76	48	0.015
10	76.9	7.2	7.3	171	1.0	172.2	72	46	0.025
19.5	62.6	3.9	7.3	162	1.7	162.8	66	49	0.035

Table 4. Lake Mitchell Water Quality Parameter Data Collected over Deep Basin 1 on July 14, 2012.

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	77.9	9.3	7.4	166	0.6	115.7	70	49	0.010
9	74.2	8.0	7.4	169	1.2	176.1	52	47	0.030
20	60.9	6.2	7.3	161	2.1	153.5	59	47	0.085

Table 5. Lake Mitchell Water Quality Parameter Data Collected over Deep Basin 2 on July 14, 2012.

Tributary	Water Temp °F	DO mg L^{-1}	pH S.U.	Cond. µS cm^{-1}	TDS mg L^{-1}	ORP mV	Total Phos. mg L^{-1}
Mitchell	80.1	8.7	7.3	227	119	189.9	0.030
Brandy	80.9	8.5	7.3	102	129	189.2	0.025
Gyttja	82.7	7.6	7.3	210	107	112.9	0.045

Table 6. Lake Mitchell Tributary Water Quality Parameter Data Collected on July 14, 2012.

5.0 LAKE MITCHELL 2013-2015 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 hybrid watermilfoil observed throughout the lake during the August 2012 survey, use of a strong 2,4-D product (Navigate® or Renovate Max G® at ≥ 160+ lbs per acre) is recommended. Whenever possible, a systemic herbicide is preferred for long-term control. If the nuisance native aquatic plant growth is desired to be treated in future years, the use of strong contact herbicides to prevent further spread of the HWM and reduce native aquatic plant biomass may be considered.** 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 watermilfoil. 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, HWM, Elodea, Pondweeds, and even some types of algae. RLS 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 HWM. **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.**

RLS limnologists will continue to monitor the Purple Loosestrife beetle efficacy in all of the previously stocked areas. Additional stocking will occur during the summer of 2013 and beetles will be applied to all previously stocked areas. No additional stocking of the milfoil weevil, *Euhrychiopsis lecontei* is recommended for 2013 due to the observed low efficacy over the past few years.

Water quality parameters as noted above will be monitored in the lake and tributaries during 2013. Lastly, expert limnologists and watershed managers from RLS will participate in a **Lake Mitchell 2013 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 2012-2015 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. Public hearings will be held in February of 2013 to present the potential options for future management of Lake Mitchell.

Lake Mitchell Proposed 2013-2015 Management Budget

Improvement Strategy	Estimated Costs
Coves & Canal	$18,000
Main Lake Herbicide Treatments	$158,000
Administration	$31,000
Biocontrol (***Galerucella*** beetles)	GRANT FUNDED
Contingency (10% of total project)	$24,000
Total 2013 Program Cost	$231,000
Approximate Lakefront Assessment	$326
Approximate back lot Assessment	$163

Table 7. Proposed budget for the 2013 Lake Mitchell management program.

6.0 LITERATURE CITED

Anderson, E. 1948. Hybridization of the habitat. *Evolution* 2:1-9.

Glomski, L.M., and M.D. Netherland. 2010. Response of Eurasian and hybrid watermilfoil to low use rates and extended exposures of 2,4-D and Triclopyr. *Journal of Aquatic Plant Management* 48:12-14.

Les, D.H., and C.T. Philbrick. 1993. Studies of hybridization and chromosome number variation in aquatic angiosperms: Evolutionary implications. *Aquatic Botany* 44: 181-228.

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.

Madsen, J.D. G.O. Dick, D. Honnell, J. Schearer, and R.M. Smart. 1994. Ecological assessment of Kirk Pond, Miscellaneous Paper A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Moody, M.L., and D.H. Les. 2007. Geographic distribution and genotypic composition of invasive hybrid watermilfoil (*Myriophyllum spicatum* x *M. sibiricum*) populations in North America. *Biological Invasions* 9: 559-570.

Poovey, A. G., J.G. Slade, and M.D. Netherland. 2007. Susceptibility of Eurasian watermilfoil (*Myriophyllum spicatum*) and a milfoil hybrid (*Myriophyllum spicatum* x *M. sibiricum*) to Triclopyr and 2,4-D amine. *Journal of Aquatic Plant Management* 45:111-115.

Vilá, M., E. Weber, and C.M. D'Antonio. 2000. Conservation implications of invasion by plant hybridization. *Biological Invasions* 2:207-217.