Restorative
Lake Sciences

Marcellus Lakes 2014 Annual Progress Report

An Annual Assessment of
Aquatic Vegetation & Water Quality in
Big Fish, Saddlebag, and Finch Lakes
Cass County, Michigan

October, 2014

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October, 2014

1.0 EXECUTIVE SUMMARY

This report describes the current distribution of the exotic aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*), additional nuisance aquatic plant species such as Starry Stonewort (*Nitellopsis obtusa*), and other native aquatic vegetation within Big Fish Lake, Saddlebag Lake, and Finch Lake, located in Cass County, Michigan.

Aquatic vegetation surveys were conducted on May 31, 2014 (Pre-treatment, initial), July 23, 2014 (Post-treatment), and again on September 18, 2014 (Post-treatment and Post-harvest). Aquatic herbicide treatments were conducted on June 16, 2014 and again on August 18, 2014. **All aquatic vegetation growth was behind this year due to the extreme winter weather conditions during 2013, but was present by the end of May, 2014. The initial aquatic herbicide treatment conducted on June 16, 2014 consisted of approximately 11 acres of contact herbicides for exotic Curly-leaf Pondweed and algae and 15 acres of systemic herbicide for milfoil in Finch Lake, 11.5 acres of contact herbicides for exotic Curly-leaf Pondweed and Chara/Starry Stonewort algae and 24 acres of systemic herbicide for milfoil in Big Fish Lake, and 3.1 acres of contact herbicides for exotic Curly-leaf Pondweed and 10 acres of systemic herbicide for milfoil in Saddlebag Lake.** The mixture of contact herbicides consisted of chelated copper (Cutrine®) and hydrothol (Aquathol-K®) and the systemic herbicide used was Triclopyr (Navitrol®).

On August 18, 2014, approximately 34 acres of nuisance re-growth of assorted pondweeds and 3 acres of new Starry Stonewort growth were treated on the east shore of Big Fish Lake. In Finch Lake, 3 acres of new milfoil growth were treated with systemic liquid triclopyr and chelated copper algaecide.

The final survey on September 18, 2014 determined that the milfoil and Starry Stonewort had responded favorably to the treatment and the nuisance native aquatic vegetation growth was controlled in many areas. **In fact, there were approximately 140 acres of**

milfoil and 125 acres of Wild Celery in 2011 before the improvement program began and recent estimates are at 49 acres of milfoil and 95 acres of Wild Celery. This is a successful reduction of two of the most problematic aquatic plant species. Now that the milfoil and Wild Celery are reduced in many areas, other nuisance native aquatic plant species such as Flat-stem Pondweed are now growing in those once-occupied locations. Future treatment will be able to focus on reduction of these nuisance natives since budget will be available for their removal due to less need for exotic species control. The MDEQ will not permit treatment of nuisance natives in certain zones after June 15 of the season. This is very problematic since both the Flat-stem Pondweed and Wild Celery grow after that period. Due to this rule, the implementation of mechanical harvesting to reduce this nuisance growth is recommended for 2015 and beyond unless the MDEQ rules are changed. **Finch Lake cannot have any nuisance native aquatic plants treated due to the previous finding of the Pug nose Shiner that is present in the lake. Finch Lake was harvested in 2014 with great success. Due to the highly degraded nature of all of the lakes prior to the start of the weed treatment program, it will require multiple years to provide effective control of these highly herbicide resistant exotic aquatic plants and the nuisance native aquatic plant biomass.**

These lakes provide for a remarkably diverse aquatic ecosystem with 18 native submersed, 3 floating-leaved, and 6 emergent aquatic plant species for a total of 27 native species.

Overall **management recommendations for the control of milfoil include spot-treating milfoil with EPA-registered systemic aquatic herbicides during mid to late spring and throughout the summer in calm conditions with oversight. In addition, Wild Celery is proposed to be treated in mid-July with the use of granular Harpoon® herbicide.** Post-treatment surveys will then proceed around three weeks post-treatment to evaluate the efficacy of the treatments. Lastly, **the use of mechanical harvesting is recommended for areas with herbicide restrictions (i.e. Finch Lake and after mid-June in certain zones).**

2.0 AQUATIC PLANT SURVEY METHODS

The aquatic plant sampling methods used for lake surveys of aquatic plant communities consisted of shoreline surveys, visual abundance surveys, transect surveys, AVAS surveys, and GPS 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 Grid 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.

2.1 MDEQ AVAS Survey Method

The Aquatic Vegetation Assessment Site (AVAS) Survey method was developed by the MDEQ to quickly assess the presence and relative abundance of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of Michigan lakes. With this survey method, the littoral zone areas of the lake are divided into lakeshore sections approximately 100-300 feet in length. The species of aquatic plants present and relative abundance of each aquatic plant are recorded onto an MDEQ AVAS data sheet. Each aquatic plant species corresponds to an assigned number designated by the MDEQ. In addition to the particular species observed (via assigned numbers), a relative abundance scale is used to estimate the percent coverage of each species within the AVAS site (Table 1). If shallow areas are present in the open waters of the lake, then individual AVAS segments can be sampled at those locations to assess the aquatic plant communities in offshore locations. This is particularly important since EWM and other exotics often expand in shallow island areas located offshore in some lakes.

MDEQ Species Abundance Code	*Abundance Meaning Interpretation*	*% Coverage of AVAS Surface Area*
a	**Found**	**< 2**
b	**Sparse**	**2 - 20**
c	**Common**	**21 – 60**
d	**Dense**	**> 60**

Table 1. MDEQ AVAS species relative abundance codes used in AVAS surveys.

2.2 The GPS Point-Intercept Grid 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). At each GPS Point location, the aquatic vegetation species presence and abundance are estimated. In between the GPS points, any additional species and their relative abundance are also recorded using visual techniques. This is especially important to add to the GPS Point Intercept method, since EWM and other invasive plants may be present between GPS points but not necessarily at the 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.

Precise GPS Point-Intercept Grid Surveys of the lakes were conducted on May 31, 2014 and September 18, 2014 and consisted of 162 sampling points as was developed in 2010-2011.

3.0 2014 BIG FISH, SADDLEBAG, AND FINCH LAKES AQUATIC PLANT COMMUNITIES

Aquatic Vegetation survey results collected on May 31, 2014 and September 18, 2014, showed the presence of 18 native submersed, 3 floating-leaved, and 6 emergent aquatic plant species, which is a total of 27 native species. In addition, there were 5 exotic, invasive aquatic plant species found which are discussed below. This aquatic ecosystem contains one of the most diverse aquatic vegetation communities in the state since it contains most of the aquatic plant species listed on the state aquatic ecosystem vegetation list. **Additionally, the September, 2014 survey revealed adequate control of treated areas, although many new areas of growth emerged and will require intense treatment during the spring of 2015.**

3.1 Big Fish, Saddlebag, and Finch Lakes Exotic Aquatic Plant Species

Eurasian Watermilfoil (EWM; Figure 1) is a non-native (i.e. exotic), invasive, submersed, perennial aquatic plant which was introduced into the United States in the 1880’s (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was discovered in the 1940’s. Exotic aquatic plants are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem. EWM has since spread to thousands of inland lakes in various states through the use of boats and

trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. EWM is a major threat to the ecological balance of aquatic ecosystems through causation of significant declines in favorable native vegetation within lakes (Madsen et *al*. 1991), and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979). The aquatic plant frequently forms dense surface canopies on inland lakes (Figure 2).
Additionally, EWM can alter the macro invertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985). The biodiversity of native aquatic plant species is strongly threatened in areas where the EWM is common to dense, and since the plant propagates by fragmentation, many areas that are currently sparse in density may become more infested, especially in areas not well-vegetated with native aquatic plant species.

In addition to EWM, three other exotic species were found in the lakes, including the three emergent exotics Purple Loosestrife (*Lythrum salicaria*; Figure 3), Yellow Iris (*Iris pseudacorus*; Figure 4), the Giant Common Reed (*Phragmites australis*; Figure 5), and the invasive Starry Stonewort (*Nitellopsis obtusa;* Figure 6). It is estimated that the acreage of the 3 exotic emergent species is relatively low (approximately 5 acres total) in comparison to the EWM growth.

Figure 1. Eurasian Watermilfoil with seed head and lateral branches.
© Superior Photique, 2008

Figure 2. Eurasian Watermilfoil forming a dense canopy which once covered over 70% of the surface of Round Lake, Mason County, Michigan.

Figure 3. Purple Loosestrife along a shoreline.

Figure 4. Yellow Iris around a lake shoreline.

Figure 5. Phragmites australis

Figure 6. Starry Stonewort

3.2 Big Fish, Saddlebag, and Finch Lakes

Native Aquatic Plant Species

During the 2014 surveys, a total of 18 native submersed, 3 floating-leaved, and 6 emergent aquatic plant species were found in the lakes on May 31, 2014 and on September 18, 2014 (Table 2). The most dominant native aquatic plant species within the lakes included the native submersed aquatic plant, Wild Celery (*Vallisneria americana*; Figure 7) and the macro alga, Chara (*Chara vulgaris*), which grows close to the bottom and offers excellent fish spawning habitat. Other dominant vegetation included pondweeds which serve as excellent fish habitat are also an important substrate for macroinvertebrates. Care should be taken to preserve the low-growing pondweeds and Chara that helps stabilize bottom sediments and offers good fish habitat, which is why selective aquatic herbicide treatments are proposed and only during specific times of the season.

In addition, many of the floating-leaved species such as the lily pads should also be preserved since they do not pose a recreational threat and are also a critical component of the ecosystem.

Emergent aquatic plants are plentiful and create a natural "soft" shoreline that should be maintained as a buffer to absorb wave activity from boats and currents. This also applies to the high abundance of Sagittaria plants (Figure 8) that surround the shoreline.

Figures 9-16 show comparisons of aquatic vegetation biovolume for last year and in 2014. The highest biovolume of native vegetation is represented by dark red and orange color, whereas the green color denotes low-growing vegetation and the blue areas do not contain vegetation.

Figure 7. Wild Celery

Figure 8. Sagittaria on the Marcellus Lakes

Aquatic Plant Species	Common Name	Growth Form	Frequency (%)
Chara vulgaris	Muskgrass	Submersed	71
Potamogeton pectinatus	Thin-leaf Pondweed	Submersed	31
Potamogeton zosteriformis	Flat-stem Pondweed	Submersed	38
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed	22
Potamogeton richardsonii	Richardson’s Pondweed	Submersed	14
Potamogeton illinoensis	Illinois Pondweed	Submersed	20
Potamogeton amplifolius	Large-leaf Pondweed	Submersed	42
Potamogeton nodosus	American Pondweed	Submersed	15
Potamogeton natans	Floating-leaf Pondweed	Submersed	25
Heteranthera dubia	Water Stargrass	Submersed	41
Vallisneria americana	Wild Celery	Submersed	50
Myriophyllum verticillatum	Whorled Watermilfoil	Submersed	5
Ceratophyllum demersum	Coontail	Submersed	17
Elodea canadensis	Common Waterweed	Submersed	29
Utricularia vulgaris	Bladderwort	Submersed	7
Najas guadalupensis	Southern Naiad	Submersed	44
Scirpus subterminalis	Watergrass	Submersed	5
Nymphaea odorata	White Water lily	Floating-Leaved	47
Nuphar sp.	Yellow Water lily	Floating-Leaved	37
Brasenia schreberi	Water shield	Floating-Leaved	10
Polygonum amphibium	Smartweed	Emergent	15
Sagittaria sp.	Arrowhead	Emergent	44
Pontedaria cordata	Pickerelweed	Emergent	21
Typha latifolia	Cattails	Emergent	53
Scirpus sp.	Bulrushes	Emergent	22
Decodon verticillata	Swamp Loosestrife	Emergent	44

Table 2. Native aquatic plants found in Big Fish, Saddlebag, and Finch Lakes (May, 2014).

Aquatic Plant Species	Common Name	Growth Form	Frequency (%)
Chara vulgaris	Muskgrass	Submersed	66
Potamogeton pectinatus	Thin-leaf Pondweed	Submersed	34
Potamogeton zosteriformis	Flat-stem Pondweed	Submersed	42
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed	26
Potamogeton richardsonii	Richardson's Pondweed	Submersed	18
Potamogeton illinoensis	Illinois Pondweed	Submersed	28
Potamogeton amplifolius	Large-leaf Pondweed	Submersed	40
Potamogeton nodosus	American Pondweed	Submersed	11
Potamogeton natans	Floating-leaf Pondweed	Submersed	23
Heteranthera dubia	Water Stargrass	Submersed	37
Vallisneria americana	Wild Celery	Submersed	18
Myriophyllum verticillatum	Whorled Watermilfoil	Submersed	4
Ceratophyllum demersum	Coontail	Submersed	18
Elodea canadensis	Common Waterweed	Submersed	25
Utricularia vulgaris	Bladderwort	Submersed	9
Najas guadalupensis	Southern Naiad	Submersed	43
Scirpus subterminalis	Watergrass	Submersed	11
Nymphaea odorata	White Water lily	Floating-Leaved	45
Nuphar sp.	Yellow Water lily	Floating-Leaved	39
Brasenia schreberi	Water shield	Floating-Leaved	11
Polygonum amphibium	Smartweed	Emergent	12
Sagittaria sp.	Arrowhead	Emergent	45
Pontedaria cordata	Pickerelweed	Emergent	24
Typha latifolia	Cattails	Emergent	56
Scirpus sp.	Bulrushes	Emergent	24
Decodon verticillata	Swamp Loosestrife	Emergent	44

Table 3. Native aquatic plants found in Big Fish, Saddlebag, and Finch Lakes (September, 2014).

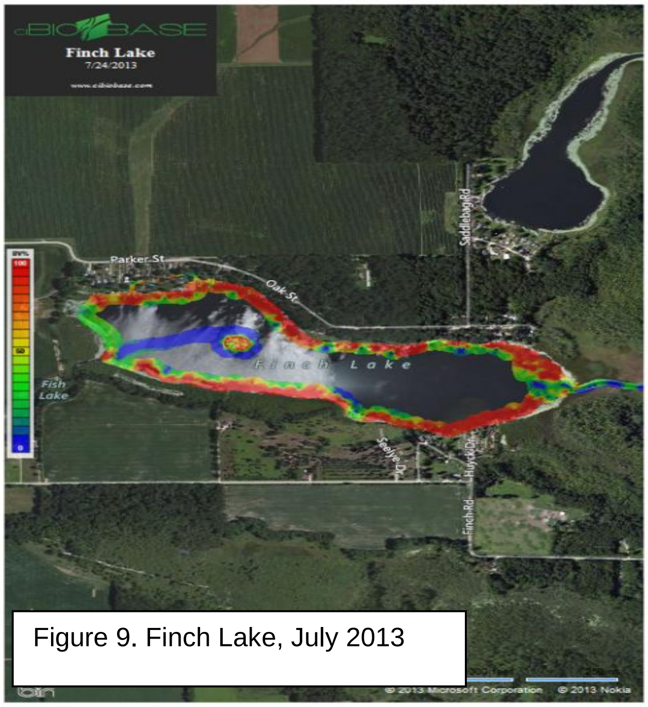

Figure 9. Finch Lake, July 2013

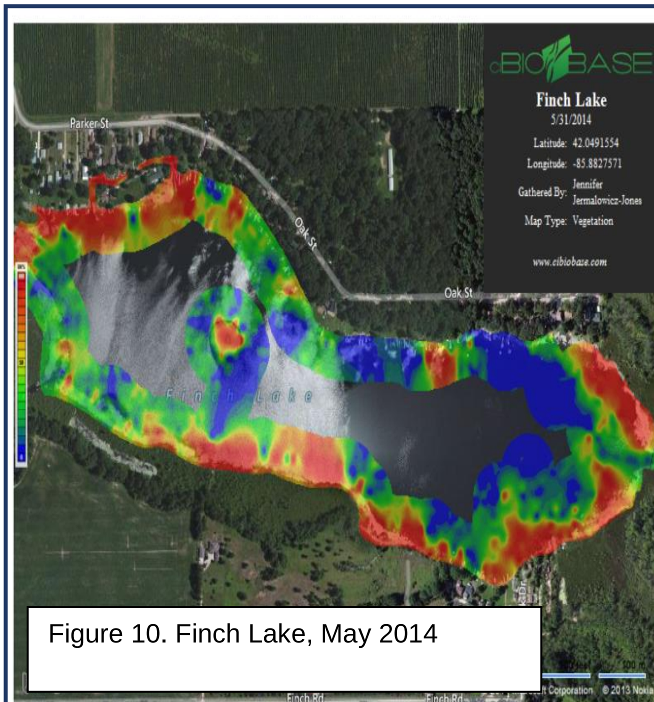

Figure 10. Finch Lake, May 2014

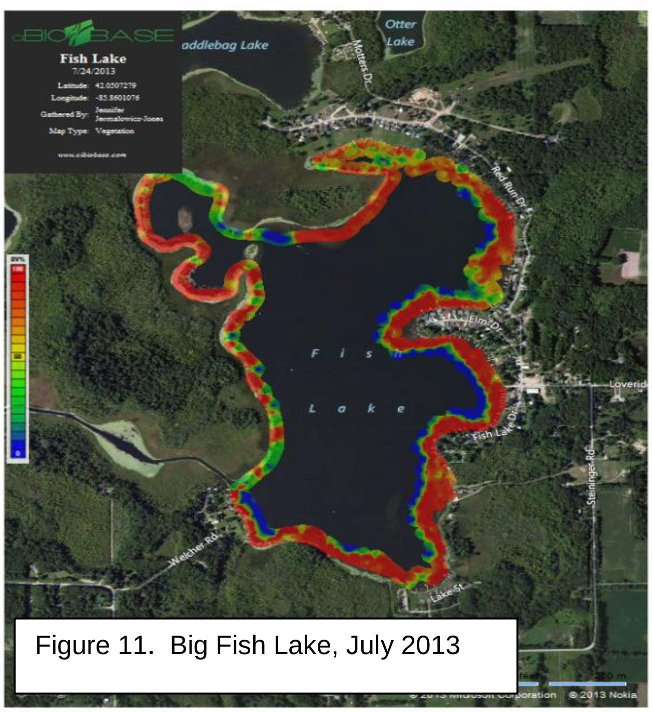

Figure 11. Big Fish Lake, July 2013

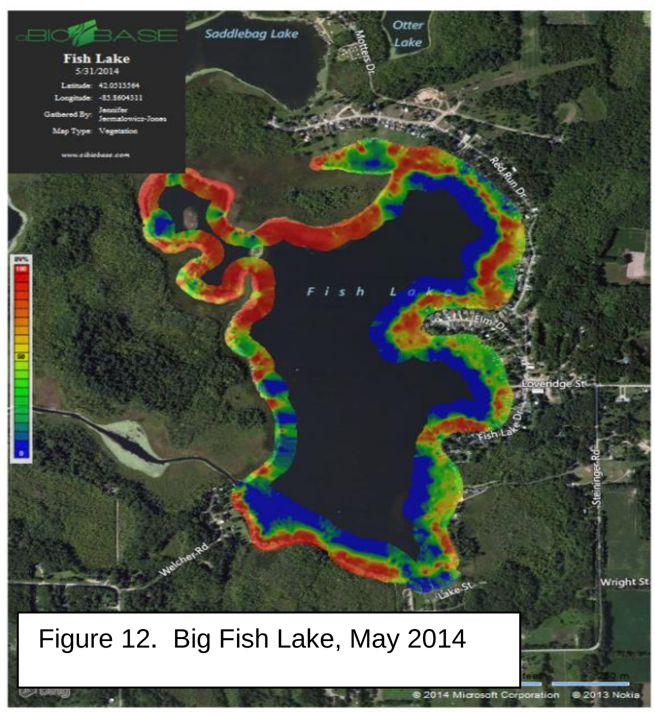

Figure 12. Big Fish Lake, May 2014

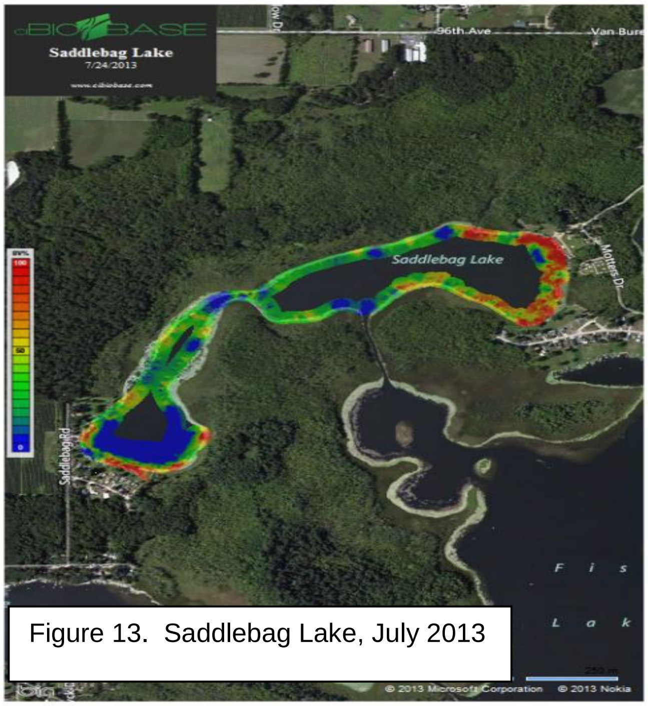

Figure 13. Saddlebag Lake, July 2013

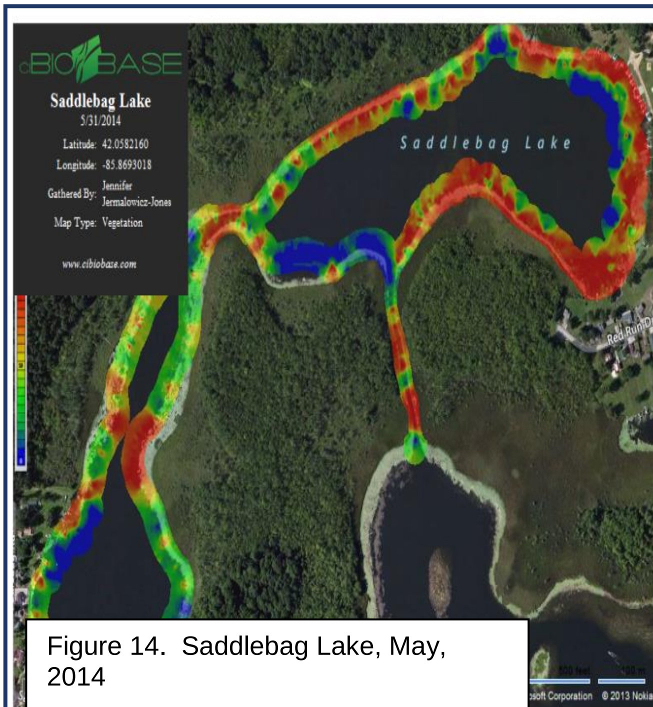

Figure 14. Saddlebag Lake, May, 2014

Note: The red areas on Saddlebag Lake correspond to nuisance pondweed growth with some milfoil which was treated with heavy systemic herbicide in 2014.

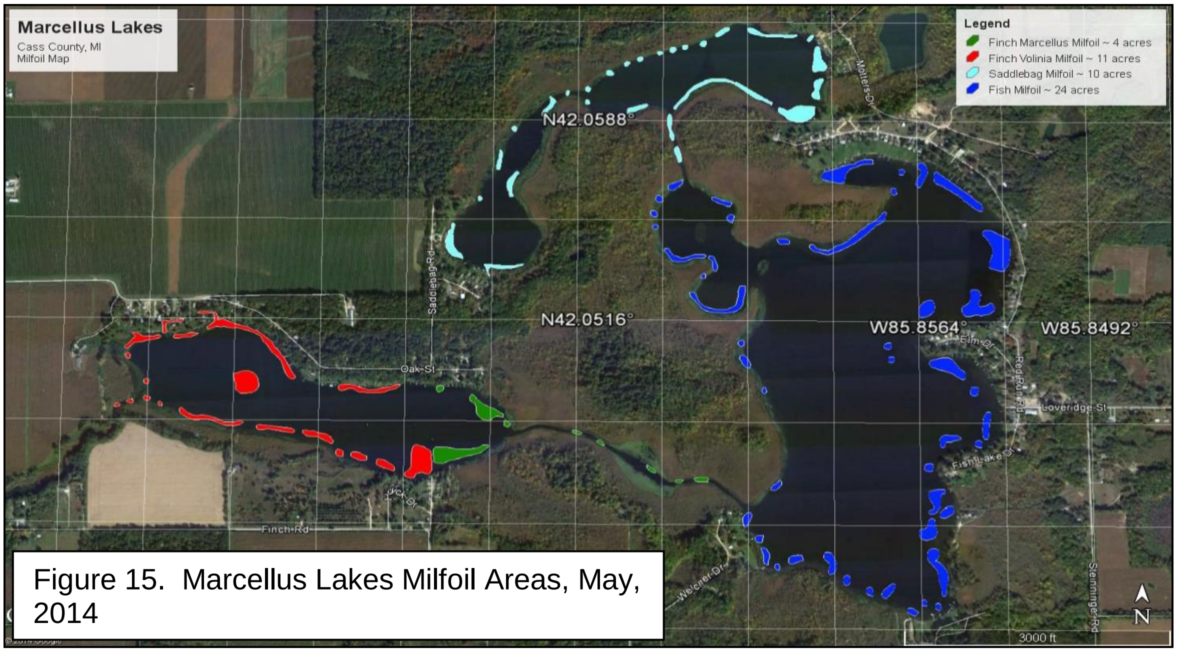

Figure 15. Marcellus Lakes Milfoil Areas, May, 2014

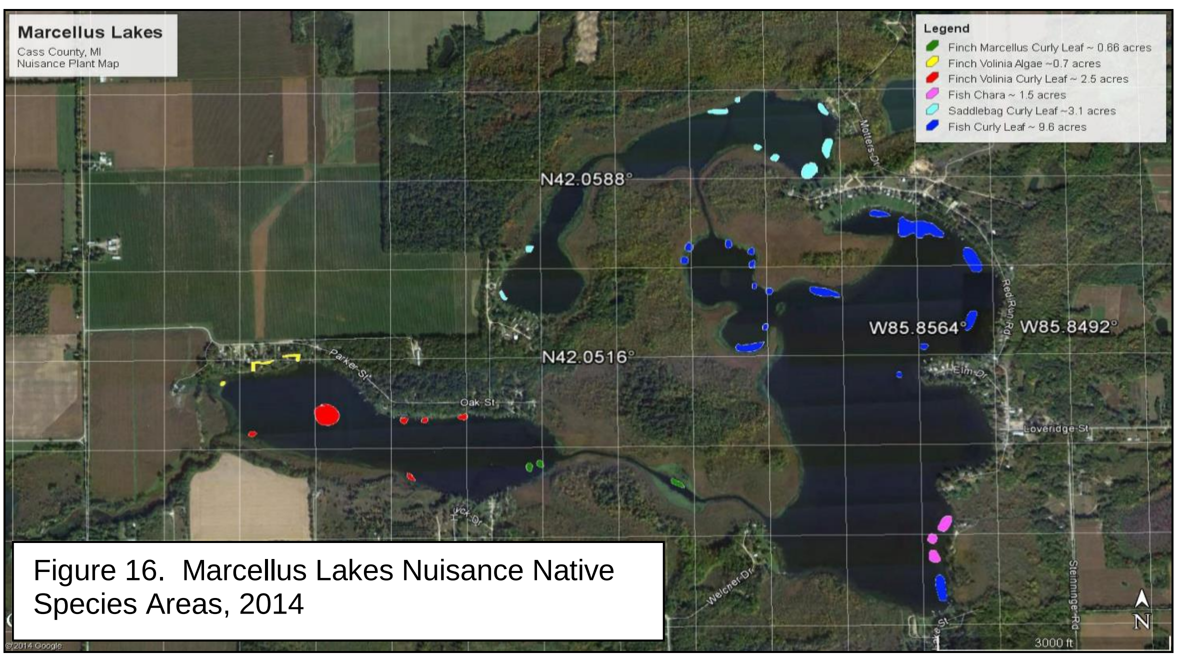

Figure 16. Marcellus Lakes Nuisance Native Species Areas, 2014

4.0 MARCELLUS LAKES WATER QUALITY

Water quality is highly variable among Michigan's inland waters, although some characteristics are common among particular waterway classification types. The water quality of each waterway 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 and waterways have a fairly long hydraulic residence time, the water may remain in the waterway for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, water quality helps to determine the classification of particular waterways (Table 4). Waterways 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**. Waterways that fall in between these two categories are classified as **mesotrophic**. **All of the Marcellus Lakes are classified as eutrophic due to the high nutrient concentrations and excessive weed and algae growth.**

Lake Trophic Status	*Total Phosphorus ($\mu g\ L^{-1}$)*	*Chlorophyll-a ($\mu g\ L^{-1}$)*	*Secchi Transparency (feet)*
Oligotrophic	< 10.0	< 2.2	> 15.0
Mesotrophic	10.0 – 20.0	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 20.0	> 6.0	< 7.5

Table 4. Lake Trophic Status Classification Table (MDNR)

4.1 Marcellus Lakes Water Quality Parameters

Parameters such as, but not limited to, dissolved oxygen, water temperature, oxidative reduction potential, conductivity, turbidity and total dissolved solids, pH, total alkalinity, total phosphorus, total Kjeldahl nitrogen, sediment % organic matter, chlorophyll-*a*, algal species, and Secchi transparency, respond to changes in water quality and consequently serve as indicators of change. During the study, RLS collected water samples from the deep basin of the each lake and analyzed them in the laboratory for analysis. **The deep basin results are discussed below and are presented in Tables 5-7. All water samples and readings were collected on July 25, 2014 with the use of a Van Dorn horizontal water sampler and Hanna® multi-meter probe with parameter electrodes, respectively.**

4.1.1 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 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. **Dissolved oxygen concentrations ranged between 9.1–0.9 mg L^{-1}, with concentrations of dissolved oxygen higher at the surface. The lowest concentrations were measured at the bottom of Fish Lake, which is common for a eutrophic and deep lake.**

4.1.2 Water Temperature

A waterway's water temperature varies within and among seasons, and is nearly uniform with depth under the winter ice cover because water mixing is reduced when waters are not exposed to the 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, shallow waterways will not stratify and deeper ones may experience single or multiple turnover cycles. Water temperature is measured in degrees Celsius (ºC) or degrees Fahrenheit (ºF) with the use of a submersible thermometer. **The July 25, 2014 water temperatures in the Marcellus Lakes ranged from 72.5°F measured at the surface to 48.9°F measured at the deep basin of Fish Lake.**

4.1.3 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 with water temperature and the amount of dissolved minerals and salts. Conductivity is measured in micro ohms per centimeter (µmho cm^{-1}) with the use of a conductivity probe and meter.

Conductivity values in the Marcellus Lakes ranged from 368-416 mS cm^{-1}. These values are moderate and mean that the water does contain some excessive dissolved metals and ions such as calcium, potassium, magnesium, sodium, chlorides, sulfate, and carbonate. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on the water quality of the Marcellus Lakes over a long period of time, or to trace the origin of a substance to the water in an effort to reduce pollutant loading.

4.1.4 Turbidity & Total Dissolved Solids

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 by erosion inputs, phytoplankton blooms, storm water 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 water temperatures. 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 in Marcellus Lakes is quite low in Fish Lake, moderate in Finch Lake, and elevated in Saddlebag Lake. Turbidity values ranged from a low of 0.8 NTU's to a maximum of 4.5 NTU's. The lake bottom is predominately marl, muck, and silt which is variable in bulk density and will may be suspended in the water column as readily on windy days as mucky sediment would be.** On the day of sampling, the winds were calm and turbidity measurements should only be collected on calm days.

Total Dissolved Solids

Total dissolved solids (TDS) are 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 are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. **The TDS ranged from 120-128 mg L^{-1} for the deep basins which is moderate and correlates with the measured moderate conductivity.**

4.1.5 pH

pH is the measure of acidity or basicity of water. pH is measured with a pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan waters have pH values that range from 6.5 to 9.5. Acidic waters (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). **The pH in the Marcellus Lakes water ranged from 8.5 – 7.8 S.U. during the sampling event. This range of pH is slightly basic on the pH scale.**

4.1.6 Total Alkalinity

Total alkalinity is the measure of the pH-buffering capacity of water. Waters 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 in the Marcellus Lakes is considered “moderate” (> 120 mg L^{-1} of $CaCO_3$), and indicates that the water is slightly alkaline**. Total alkalinity in the deep basins ranged from 123-131 mg L^{-1} of $CaCO_3$ during the sampling event.** 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 water.

4.1.7 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. Waters which contain greater than 0.20 mg L^{-1} of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from 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 auto analyzer. **TP concentrations in the Marcellus Lakes ranged from 0.029-0.195 mg L^{-1}, which is high and is associated with abundant weed and algae growth.**

4.1.8 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 water bodies through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In waters with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic plant growth. Alternatively, in waters 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. Water bodies 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. **The TKN concentrations measured in the Marcellus Lakes ranged from 0.50-3.5 mg L^{-1} which is high.**

4.1.9 Chlorophyll-a

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 waters. 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 Marcellus Lakes water column at the deep basin sites from just above the lake bottom to the lake surface. **The chlorophyll-*a* concentration in the deep basins ranged from 5.6-13.3 µg L^{-1}, which indicates a high amount of planktonic algae throughout the water column.** It is likely that these values are slightly higher in the spring after spring runoff or in late summer when water temperatures increase and lead to the growth of algae in the water column (planktonic form) or on the surface (filamentous form).

4.1.10 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 in the Marcellus Lakes deep basins ranged from a low of 6.0 feet in Saddlebag Lake to a high of 22 feet in Fish Lake. Measurements were collected during calm wind conditions.**

4.1.11 Oxidative Reduction Potential

The oxidation-reduction potential (ORP or E_h) of 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 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 values in the Marcellus Lakes ranged from 132.8-35.9 mV from the surface to the bottom.** The high variability could be due to numerous factors such as degree of microbial activity near the sediment-water interface, quantity of phytoplankton in the water, or mixing of the lake water. These values indicate oxidized rather than reduced conditions which is more favorable for water quality.

Depth ft.	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	72.5	9.0	8.5	416	0.8	0.50	123	0.029
20	65.8	6.8	8.1	379	1.0	0.80	127	0.068
40	48.9	0.9	7.8	368	2.1	3.50	131	0.195

Table 5. Fish Lake water quality parameter data collected in the deep basin (July 25, 2014).

Depth ft.	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	73.2	9.0	8.5	377	0.9	0.50	125	0.030
15	67.1	7.0	8.3	389	2.1	0.60	128	0.055
30	53.7	4.8	8.1	369	3.1	1.50	128	0.950

Table 6. Finch Lake water quality parameter data collected in the deep basin (July 25, 2014).

Depth ft.	***Water Temp ºF***	***DO mg L^{-1}***	***pH S.U.***	***Cond. µS cm^{-1}***	***Turb. NTU***	***Total Kjeldahl Nitrogen mg L^{-1}***	***Total Alk. mgL^{-1} $CaCO_3$***	***Total Phos. mg L^{-1}***
0	73.9	8.6	8.4	382	0.9	0.50	128	0.035
15	68.2	6.1	8.4	388	1.8	1.00	130	0.075
30	55.1	1.2	8.2	381	4.5	2.80	130	0.115

Table 7. Saddlebag Lake water quality parameter data collected in the deep basin (July 25, 2014).

5.0 BIG FISH, SADDLE BAG, AND FINCH LAKE MILFOIL AND WILD CELERY CONTROL RECOMMENDATIONS

5.1 Treatment Recommendations for 2015 and Beyond

The use of aquatic chemical herbicides is regulated by the MDEQ under Part 33 (Aquatic Nuisance) of the Natural Resources and Environmental Protection Act, P.A. 451 of 1994, and requires a permit from the Michigan Department of Environmental Quality (MDEQ). 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. Furthermore, residents that reside within 100 feet of the proposed treatment area must be notified at least seven days, but not more than forty-five days prior to the initial treatment date. A licensed herbicide applicator notices the residents in advance of the proposed treatment date, and during the day of treatment.

Contact and systemic aquatic herbicides are the two primary herbicide types used in aquatic systems. **Contact herbicides cause damage to leaf and stem structures**; whereas systemic herbicides are assimilated by the plant roots and are lethal to the entire plant. Some contact herbicides such as Diquat (Trade Name: Reward®), Endothol (Trade Name: Aquathol K®), and even chelated copper algaecides such as (Trade Name: Cutrine®), have shown substantial control over a broad spectrum of nuisance aquatic vegetation such as Coontail, Thin-leaf pondweed, Elodea, Chara, milfoil, Curly-leaf Pondweed, and nuisance algae growth.

The MDEQ restricts treatment of native species to prior to June 15 which can become problematic since many of the nuisance native species in the lakes grow after that date (i.e. Wild Celery and some species of pondweeds). Thus, mechanical harvesting may be used in these areas. Unfortunately, there are not systemic herbicides for nuisance native species and thus control is temporary.

Wherever possible, it is preferred to use a systemic herbicide for long-term milfoil control. There are often restrictions with usage of some systemic herbicides around shoreline areas that contain shallow drinking wells. Systemic herbicides such as 2,4-D (Trade Name: Navigate®) and Triclopyr (Trade Name: Renovate®) could be used to successfully treat localized or widely dispersed beds of milfoil. A new product called Renovate® Max G was recently developed by SePRO® Corporation and is a combination of both 2,4-D and Triclopyr. The current infestation of Big Fish, Saddlebag, and Finch Lakes could be spot-treated with granular systemic herbicides in the late spring or early summer with 2,4-D in offshore areas and Triclopyr in areas with wells greater than 30 feet deep. **The use of a whole-lake fluridone (Sonar®) treatment is not recommended due to outflow, hybridity of the milfoil species, and possible stimulation of nuisance species such as Wild Celery and Starry Stonewort.** In addition, all herbicides should be applied during calm weather conditions to minimize drift of the chemical from the treatment site.

5.2 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 17). The mechanical harvester collects numerous loads of aquatic plants as they are cut near the lake bottom. The plants are off-loaded onto a conveyor and then into a dump truck. Harvested plants are then taken to an offsite landfill or farm where they can be used as fertilizer. Mechanical harvesting is preferred over chemical herbicides when primarily native aquatic plants exist, or when excessive amounts of plant biomass need to be removed. Mechanical harvesting is usually not recommended for the removal of Eurasian Watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. **Due to the threat of milfoil fragmentation, the use of mechanical harvesting for the removal of the milfoil in the Marcellus Lakes is not recommended. However, removal of nuisance native aquatic vegetation via mechanical harvesting after mid-June (due to MDEQ restrictions on treatment of nuisance natives and shoreline vegetation after June 15) is recommended for riparian use of the lakes given the high density of nuisance aquatic vegetation in the shoreline areas.**

Mechanical harvesting does not require a permit from the Michigan Department of Environmental Quality (MDEQ); however, some counties require a launch site use permit from the Michigan Department of Natural Resources (MDNR) if a public access site is present.

A recommended budget for 2015 is shown in Table 8 below.

Figure 17. A mechanical harvester.

Lake Improvement Item for all lakes	**Estimated 2014-2016 Cost**
Systemic & Contact Herbicides for EWM & nuisance native plants; MDEQ permit fees	$60,000
Professional Services (limnologist surveys, oversight, processing, education, newsletter)[2]	$9,000
Contingency[3]	$6,900
Total Annual Estimated Cost	$75,900

Table 8. Proposed budget for Big Fish, Saddlebag, and Finch Lakes (2014-2016).

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