# Mullett Lake Aquatic Plant Survey 2007-2008

*by Tip of the Mitt Watershed Council*

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# SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but can become a recreational nuisance when growth is excessive. Excessive aquatic plant growth also has the potential to disrupt lake ecosystems, particularly when non-native species are introduced. To aid lake management efforts, the Mullett Lake Area Preservation Society contracted the Tip of the Mitt Watershed Council to conduct an aquatic plant survey on Mullett Lake in north-central Cheboygan County, Michigan. The aquatic plant survey was conducted during the late summer and early fall of 2007 and 2008. Aquatic plant specimens were collected and documented at 712 sites throughout the lake and major plant communities were also mapped. A total of 42 aquatic plant taxa were documented, including three non-native species. The majority of Mullett Lake contains little or no aquatic vegetation (~81%). Muskgrass (*Chara spp.*) and variable-leaf watermilfoil (*Myriophyllum heterophyllum*) were the most commonly collected species while muskgrass, watermilfoils, and pondweeds (*Potamogetonaceae*) most commonly dominated submerged plant communities. Sample site and community mapping data showed that aquatic plant densities typically ranged from light to moderate. Large vegetated areas occurred in the northern and southern ends of the lake, probably a result of extensive shallow areas. Shallow areas and nutrient inputs from inlet streams likely contribute to the heavy aquatic plant growth found in the Indian River Spreads and Pigeon River Bay. Decomposing and algae-encrusted plants were noted in a sizable area along the southwest shore of Pigeon River Bay, indicating herbicide use or nutrient pollution. A review of DEQ records revealed permits for treatment in this area in 2007 and 2008. Property owners in the area should be notified of the potential dangers of chemical application, particularly of opening the door for invasives to come in, and encouraged to discontinue. Invasive aquatic plant species found include purple loosestrife (*Lythrum salicaria*), curly-leafed pondweed (*Potamogeton crispus*), and Eurasian watermilfoil (*Myriophyllum spicatum*). Purple loosestrife occurred primarily in the Indian River Spreads where biological control has been applied and appears to be successful. Curly-leaved pondweed was found in two locations, Pigeon River Bay and near the Aloha State Park boat launch, and therefore, removal by hand could be an environmentally safe and feasible control option. Eurasian watermilfoil was found at 15 sample sites, but heavy density growth was only found in the north end of the lake in the boating channel at Aloha State Park and at the Mullett Lake Marina. To prevent the spread of Eurasian watermilfoil, these dense infestations should be addressed; biological control using weevils (*Euhrychiopsis lecontei)* native to the region is recommended as it is an environmentally safe and potentially long-term solution. The Mullett Lake Area Preservation Association can use results from this comprehensive survey to guide aquatic plant management decisions and track changes over time. Optimally, aquatic plant surveys should be conducted on the lake every 5-10 years.

# INTRODUCTION

## Background:

Aquatic plant communities provide numerous benefits to lake ecosystems. Aquatic plants provide habitat, refuge and act as a food source for a large variety of waterfowl, fish, aquatic insects, and other aquatic organisms. Like their terrestrial counterparts, aquatic plants produce oxygen as a by-product of photosynthesis. Aquatic plants utilize nutrients in the water that would otherwise be used by algae and potentially result in nuisance algae blooms. A number of aquatic plants, including bulrush, water lily, cattails, and pickerel weed help prevent shoreline erosion by absorbing wave energy and moderating currents. Soft sediments along the lake bottom are held in place by rooted aquatic plants.

Lake systems with unhealthy or reduced aquatic plant communities will likely experience declining fisheries due to habitat and food source losses. Aquatic plant loss may also cause a drop in daytime dissolved oxygen levels and increased shoreline erosion. If native aquatic plants are removed through harvesting or herbicide application, resistance of the naturally occurring plant community is weakened and can open the door for invasive species such as curly-leaf pondweed or Eurasian watermilfoil.

In spite of all the benefits associated with aquatic plants, some aquatic ecosystems suffer from overabundance, particularly where non-native nuisance species have been introduced. Excessive plant growth can create a recreational nuisance by making it difficult or undesirable to boat, fish and swim, but it also has the potential to cause aquatic ecosystem disruptions. In lakes plagued by nuisance plant species, it sometimes becomes necessary to develop and implement programs to control excessive growth and non-native species.

Aquatic plant management is a critical component of lake management. Thus, an important first step in developing a sound lake management program is to survey the aquatic plant communities to document species, abundance, density, and the presence or absence of non-native species. In 2007 the Mullett Lake Area Preservation Association contracted with Tip of the Mitt Watershed

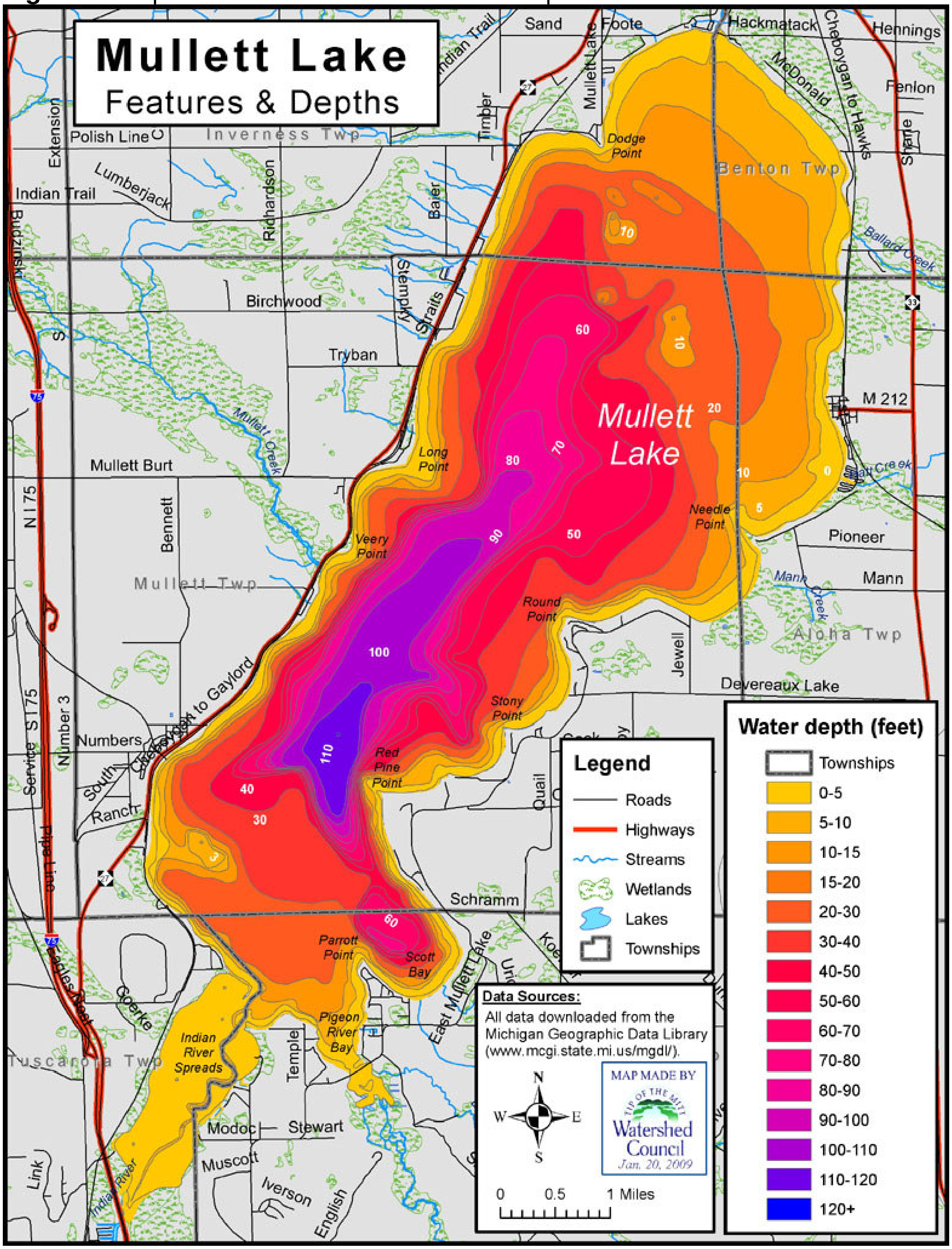
Council to perform a comprehensive aquatic plant survey of Mullett Lake. Additional funding for the survey was provided by a grant from the National Fish and Wildlife Foundation. The results of this survey will provide the lake association with an informational tool to assist in lake management. Watershed Council staff collected field data during the summers of 2007 and 2008. Survey field methods, data management procedures, project results, and discussion of results are contained in this report.

**Study area:**

Mullett Lake is located in the northeast tip of the Lower Peninsula of Michigan; in Aloha, Benton, Inverness, Koehler, Mullett, and Tuscarora Townships of north-central Cheboygan County. Based upon digitization of aerial orthophotographs acquired from the Cheboygan County GIS Department (2004), the shoreline of Mullett Lake proper measures 30.48 miles and lake surface area totals 16,512 acres, while the Indian River Spreads connecting at the south of Mullett Lake includes an additional 692 acres. Mullett Lake is approximately 9 miles long, gradually widening from the southwest to northeast. Pigeon River and Scott Bays are located in the southern part of the lake and prominent points are interspersed along the shoreline including Dodge, Long, Needle, Parrott, Round, Stony, and Veery Points (Figure 1).

Bathymetry maps from the State of Michigan as well as the Sportsman's Connection Fishing Map Guide show the deepest area located directly out from Red Pine Point with a maximum depth of 120 feet. However, a deeper hole not appearing on these maps is known to exist in front of Long Point where sampling by Tip of the Mitt Watershed Council staff has documented a depth in excess of 140 feet. According to digitized bathymetry maps acquired from the Michigan Geographic Data Library, approximately 62% of the lake (including Indian River Spreads) exceeds 20 feet of depth. Relatively shallow areas are found in the southwest in the Indian River Spreads and Pigeon River Bay and in the northeast where there is a broad shallow plateau.

**Figure 1.** Map of Mullett Lake: Features and Depths



Mullett Lake is a drainage lake with water flowing into and out of the lake. The primary inlets include the Indian and Pigeon Rivers in the southwest end of the lake and the only outlet is the Cheboygan River in the northeast end. A number of smaller tributaries enter into the lake throughout its length, including Ballard, Hatt, Mullett, Mullett Lake, and Scott Creeks (USGS, 1990).

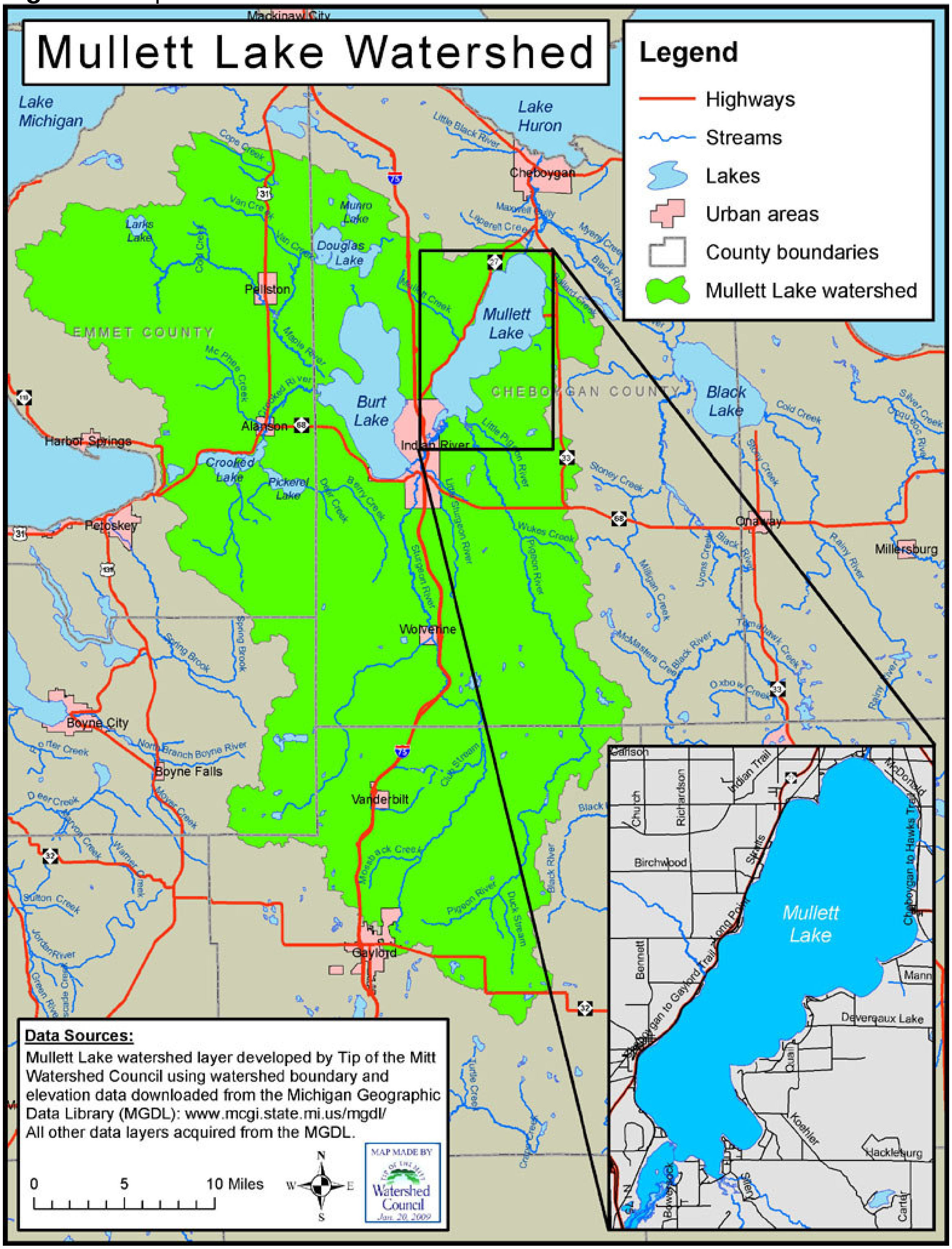
According to GIS (Geographical Information System) files developed by the Watershed Council using watershed boundary and elevation data acquired from the State of Michigan, the Mullett Lake watershed encompasses approximately 560,000 acres of land and water. The watershed stretches from the City of Gaylord in the south to the Cheboygan River to the north and contains a number of other regionally important water bodies including Burt Lake, Douglas Lake, Crooked Lake, the Maple River, the Sturgeon River and the Pigeon River (Figure 2). A watershed ratio of 32.55 was calculated by dividing the lake surface area into the watershed area (not including the lake), indicating that there are over 32 acres of watershed area for each acre of Mullett Lake water surface. The ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover.

Land cover statistics were generated for the watershed using remotely sensed data from the year 2000, which was produced as part of the Coastal Great Lakes Land Cover project (Table 1). Based on these data, there is little agricultural landcover within the watershed (~8%) and even less urban (~2.5%). The majority of the watershed's landcover is natural; consisting of forest, wetlands, and grassland.

**Table 1.** Mullett Lake watershed 2000 land cover statistics.

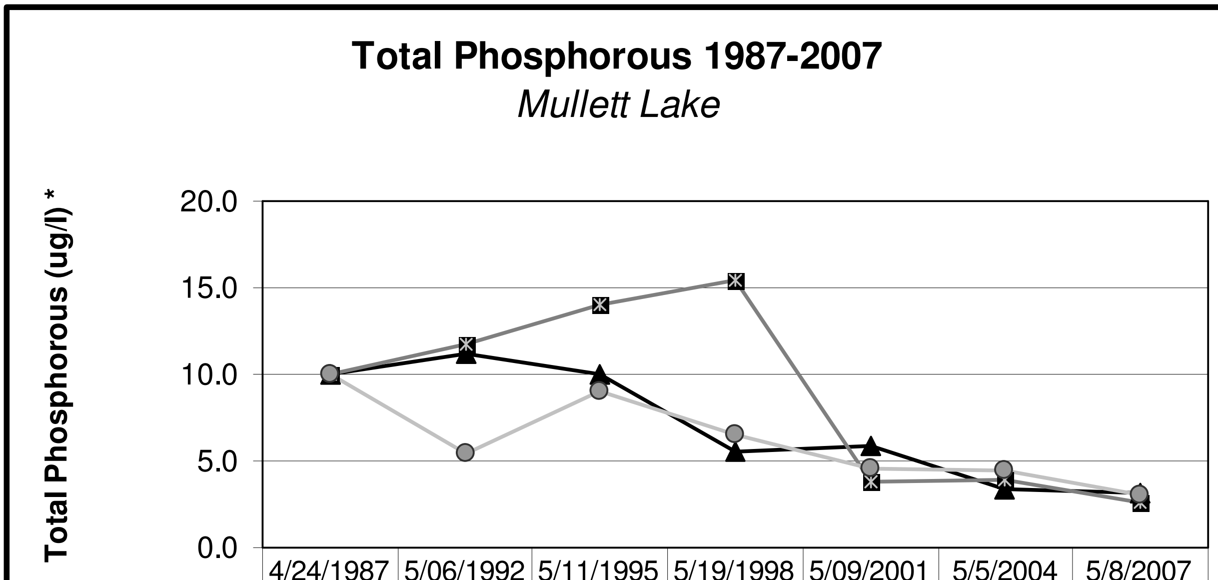
| Land Cover Type | Acreage | Percentage |
|---|---:|---:|
| Urban | 13,153 | 2.35 |
| Agricultural | 45,102 | 8.06 |
| Grassland | 82,856 | 14.82 |
| Forested | 276,088 | 49.37 |
| Scrub/Shrub | 18,273 | 3.27 |
| Wetland | 76,005 | 13.59 |
| Barren/Shore | 1,223 | 0.22 |
| Water | 46,544 | 8.32 |
| Total | 559,245 | 100.00 |

**Figure 2.** Map of the Mullett Lake Watershed.



The water quality of Mullett Lake has been monitored consistently for many years. The Mullett Lake Area Preservation Society (MAPS) has actively supported water quality monitoring programs on Mullett Lake, providing volunteers for the volunteer water quality monitoring programs coordinated by the Watershed Council and the Michigan Lakes and Streams Association. In addition, Watershed Council staff monitor Mullett Lake water quality as part of the Comprehensive Water Quality Monitoring program (CWQM). Watershed Council databases contain Volunteer Lake Monitoring and CWQM data that date back to 1986 and 1987 respectively. Data collected through these programs indicate that water quality remains high. Total phosphorus data collected as part of the CWQM program show that levels have dropped throughout the last 20 years and are now consistently below 10 parts per billion (PPB), which is typical for high quality lakes of northern Michigan (Figure 3). Based on trophic status index values generated from volunteer lake monitoring data, Mullett Lake falls in the oligotrophic category, which is typical for pristine, large, deep lakes (Figure 4).

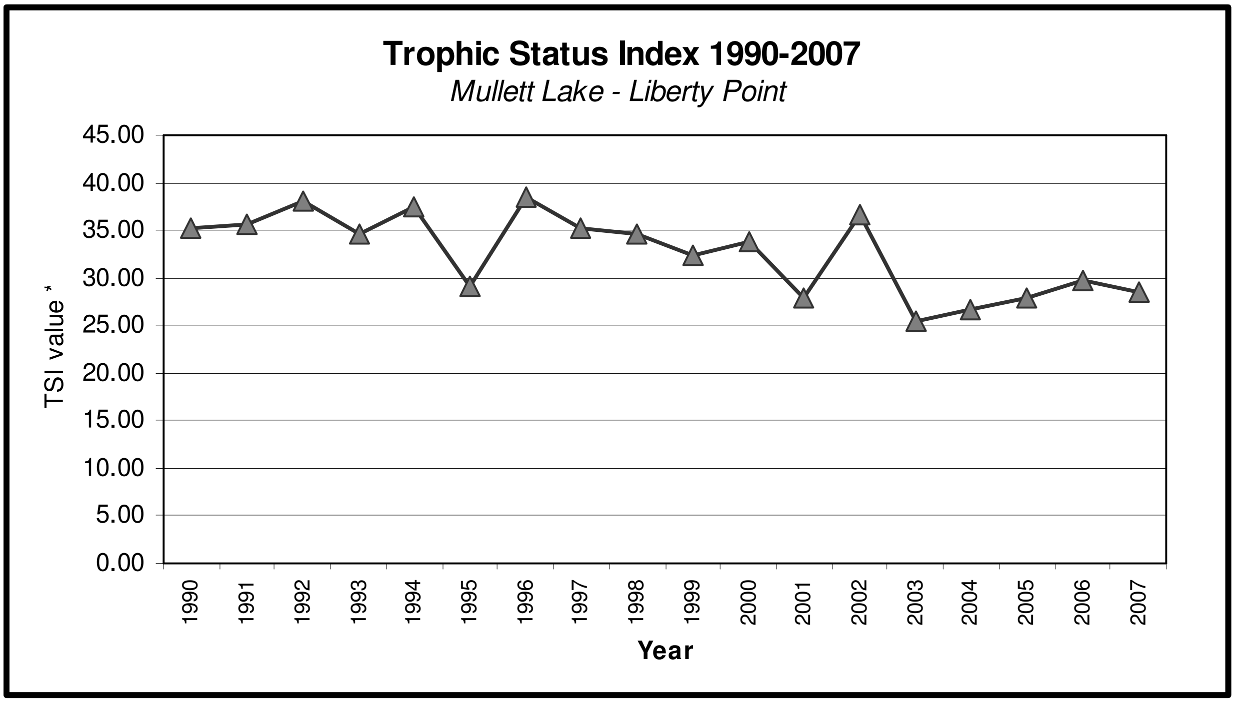
**Figure 3**. Chart of phosphorus data from Mullett Lake




| | 4/24/1987 | 5/06/1992 | 5/11/1995 | 5/19/1998 | 5/09/2001 | 5/5/2004 | 5/8/2007 |
|---|---|---|---|---|---|---|---|
| Surface | 10.0 | 11.2 | 10.0 | 5.5 | 5.9 | 3.4 | 3.1 |
| Middle | 10.0 | 11.7 | 14.0 | 15.4 | 3.8 | 3.9 | 2.6 |
| Bottom | 10.0 | 5.4 | 9.0 | 6.5 | 4.6 | 4.5 | 3 |

**Total phosphorus measured in ug/l, which is milligrams per liter or parts per billion.*

**Figure 4.** Chart of trophic status index data from Mullett Lake




**TSI determines trophic status of lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive system), and 50+ = eutrophic (highly productive system).*

# METHODS

Field data for the Mullett Lake aquatic plant survey were collected over the course of two field seasons, beginning on July 21, 2007 and finishing on October 7, 2008. Aquatic vegetation was documented in all lake areas except where dense emergent growth limited access in portions of the Indian River Spreads. The aquatic plant communities of Mullett Lake were documented using two primary methods: 1) documenting aquatic plants at sample sites, and 2) mapping aquatic plant community lines. Both methods were carried out using the Watershed Council's Boston Whaler 150 Sport. After performing surveys, data collected in the field was processed and used to produce a map of the lake's aquatic plant communities.

Watershed Council staff took great care to collect the most accurate field data possible. A considerable amount of time was devoted to quality control during data collection, data processing, and data analyses. The Watershed Council is confident that the final results in this report represent a high-quality product.

**Documenting aquatic plants at sample sites:**

Specimens were collected, identified, photographed and recorded in a notebook at 712 sample sites throughout the lake to document aquatic plant taxa. Sample site locations (Figures 5 and 6) were not random, but rather selected with the intent of collecting representative information on all aquatic plant communities currently inhabiting the lake. Transects across the lake were sampled at intervals that varied depending upon plant community changes that were observable from the surface. In areas where plant communities were not visible, sample sites were selected at regular intervals across the transect. Sampling was also conducted in areas of the lake with no visible plants to confirm the areal extent of plant communities.

At each sample site, the boat was anchored, water depth noted, and GPS (global positioning system) data recorded. Water depth was measured using a Hummingbird depth finder installed on the boat. It should be noted that water

**Figure 5.** Map of sample sites on northern Mullett Lake.

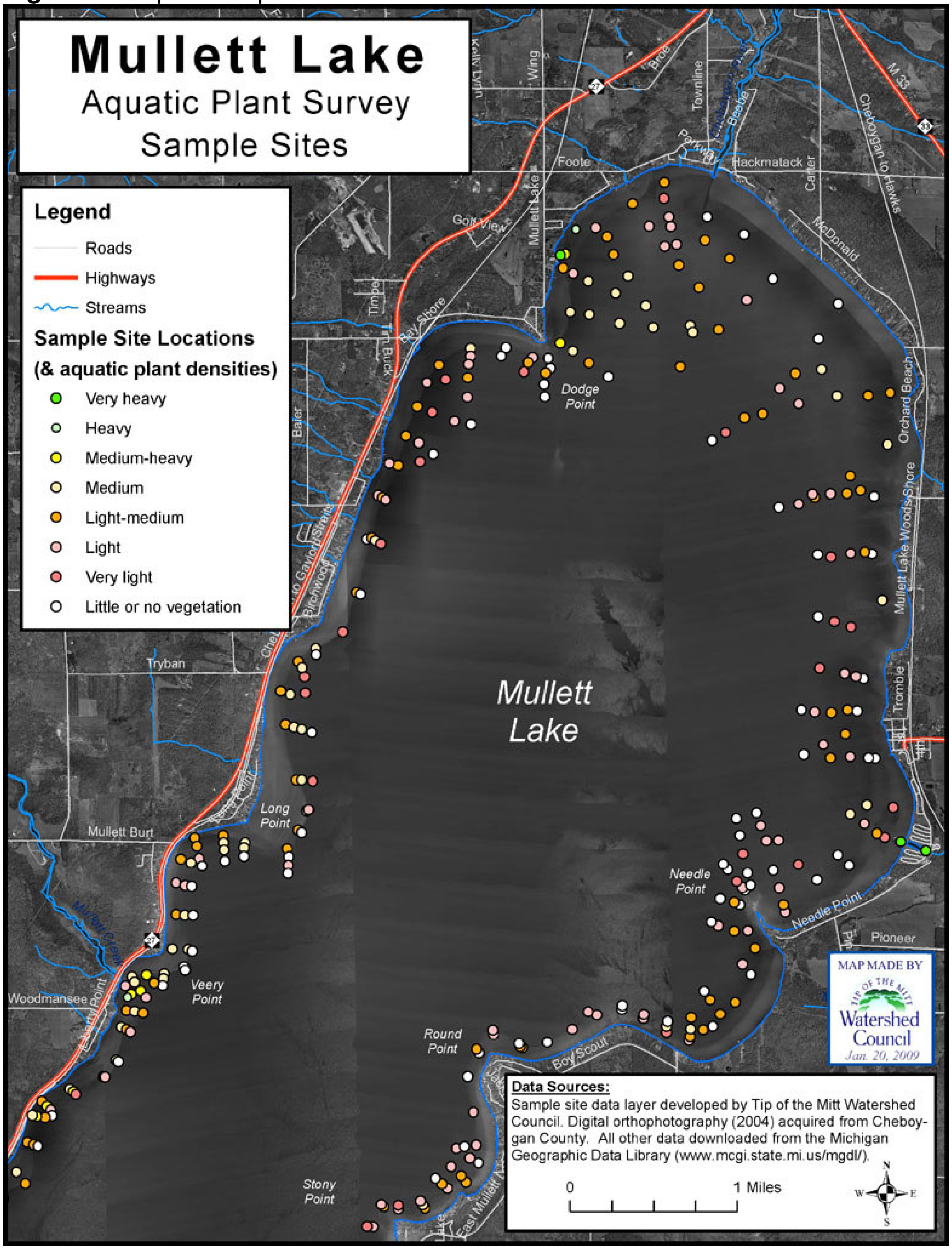
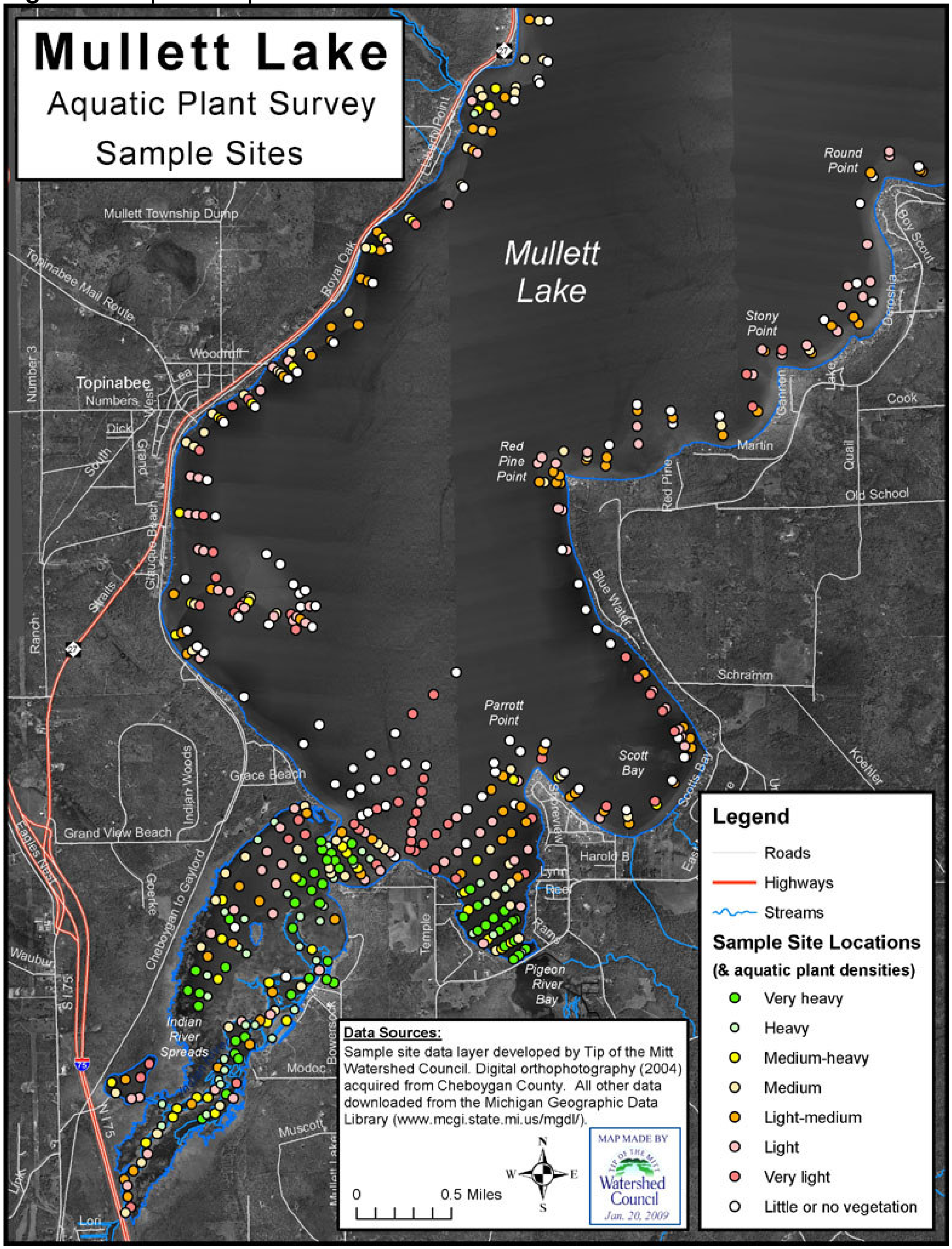


**Figure 6.** Map of sample sites on southern Mullett Lake.



depths recorded in the field may not be comparable as there were certainly lake water level fluctuations in the two-year time period of the survey. The location of each sampling station was recorded using a Trimble GeoExplorer3 GPS unit with a reported accuracy of 1-3 meters.

Plant specimens were collected using a sampling device consisting of two garden rake heads fastened together back to back with a length of rope attached. Using the sampling device, multiple throws were made at each site, collecting from all sides of the boat. Sampling continued until the collector was satisfied that all plant taxa present at the site were represented in the sample. Fairly rigorous sampling techniques and effort were employed, but there is a possibility that not all species were collected at each site.

Specimens were identified to the lowest taxonomic level possible and representative samples of each species were laid out and photographed with a slip of paper indicating the number assigned to that site. Taxon density was subjectively determined (in relation to all plant taxa collected in the sample) and recorded as light (L), medium (M), or heavy (H), but also including the sub-categories of very light (VL), medium-light (ML), medium-heavy (MH) and very heavy (VH). Furthermore, overall plant density for the site was subjectively determined and noted using the same categorization system. If a specimen could not be identified immediately, it was stored in a sealed bag and identified later with the aid of taxonomic keys, mounted herbarium specimens, and, if necessary, assistance from other aquatic plant experts. All taxa names, relative taxa densities, overall site density and comments were recorded in a field notebook. If no plants were encountered during sampling, 'no vegetation' was recorded in the field notebook.

To assist in mapping the aquatic vegetation in Mullett Lake, additional photographs were taken to document emergent vegetation. At each sample site located within or adjacent to emergent vegetation, pictures were taken of surrounding areas. Most pictures were taken with a Ricoh Pro G3 GPS camera (accuracy = 3-10 meters). At times when the GPS camera was not available, pictures of emergent vegetation were taken with a 5-megapixel Sony digitital camera.

**Mapping aquatic plant community lines:**

Information about aquatic plant communities that were visible from the water surface was recorded to improve the accuracy of delineations between plant communities. During the survey, aquatic plant community details observed at sample sites were noted in the field notebook. Plant communities were described in terms of areal extent, shape, and density. Changes in plant communities between sample sites and the absence of vegetation in any direction were also noted. Plant specimens were not collected when mapping community lines.

Emergent vegetation and distinct plant beds were mapped directly with GPS by navigating around the feature being surveyed. Where feasible, the perimeter of the plant bed was followed as closely as possible in the boat and GPS data collected at major vertices to develop polygons representing plant beds. On occasion, emergent plants and distinct submergent plant communities were mapped in shallow areas by wading. Areas of densely vegetated emergent growth not surveyed in the Indian River Spreads were categorized as "mixed emergents" and given a density rating of "VH".

In spite of sampling at 712 sites and subsequent community line mapping, some small or isolated plant communities were probably missed. Sampling was not carried out in areas between survey transects and plant community mapping may have not occurred in those areas either if conditions did not allow. Upon many occasions, plant community mapping was impeded by poor visibility, whether from wave turbulence, turbidity, or simply water depth and attenuation of sunlight.

**Data processing and map development:**

GPS data collected with the Trimble GeoExplorer3 were post-processed and exported into a GIS (Geographical Information System) file format using

GPS Pathfinder Office 3.10 software. Two GIS data layers were developed using the field GPS data collected with the Trimble; a point layer using the GPS data collected at sample sites and a polygon layer using a combination of information collected at sample site points and plant community mapping line data. Where possible, polygons were developed directly from line features mapped with GPS in the field. Otherwise, polygons were created based on data collected at sample sites. All GIS work was performed using the ESRI GIS software package ArcView 9.2.

Digital photographs taken with the Ricoh Pro G3 GPS camera were processed and developed into a GIS data layer using GPS-Photo Link, Version 3.1.0 Ricoh Edition. Photographs were rotated and light levels adjusted as necessary. The date, time, and location (latitude and longitude in the WGS84 datum) were included when processing the photographs and appear on the "tagged" digital photographic files. Pictures taken with the Sony digital camera (without GPS capabilities) were linked in a GIS to sample site points recorded with the Trimble GPS unit. All photographs taken at sample sites were renamed using the lake name, survey and year, and the sample site number (e.g., the first photograph taken at the first sample site = "Mullett_APsurvey2007_001-0.jpg"). An ESRI shapefile was created to display photographs taken at sample sites, hyperlinking photographs to sample points in a GIS.

Data collected at sample sites and written in the field notebook were entered into a database. A record was entered into the database for each sample site, using the sample site number as the unique identifier. Field data were entered as separate attributes in the database table, including water depth, taxa names, taxa densities, areas of little/no vegetation, overall community density, and comments. Additional columns were added to the database for the number of taxa, the dominant taxa, and the dominant community at each site. Data recorded in the spreadsheet were saved to a *.dbf format and imported into a GIS. The *.dbf file was joined to the sample site GIS point data layer, and then exported to a new GIS point data layer containing all attribute information collected in the field for each sample site. After developing polygons representing plant communities and vegetation types, area statistics for specific plant communities and vegetation types were calculated.

The final products include both maps and statistics generated from digital map layers. All GPS, tabular and photographic data were combined in an ArcView project to develop digital and hard-copy maps. The maps depict sample site locations, plant community density at sample sites, and dominant plant communities in the lake. In addition, the ArcView project file allows GIS users to view photographs taken at sample sites (by clicking on point features at the sample site) as well as all tabular data associated with the site.

# RESULTS

**Sample site results:**

A total of 42 aquatic plant taxa were collected or documented during the survey conducted on Mullett Lake (includes five emergent taxa noted in comments, but not collected: cattail, phragmites, purple loosestrife, sedge, and sweet gale). Of the 712 locations sampled on the lake, aquatic plants were found at 574 sites (81%) while 138 sites (19%) had little or no vegetation. The number of aquatic plant taxa encountered at a site ranged from zero to 14 with an average of 3.1 taxa per sample site. Three invasive species were encountered during this survey: Eurasian watermilfoil, curly-leaved pondweed, and purple loosestrife.

Muskgrass and variable-leaf watermilfoil were the most commonly encountered species; collected at approximately 69% and 33% of sites respectively (Table 2). Seven other species were collected at 50 sites or more and considered common; including bladderwort, eelgrass, elodea, naiad, and pondweeds. A total of 22 plant species occurred uncommonly, which was defined as occurring at 10 to 50 sites. The remaining six species were rarely collected (occurring at fewer than 10 sites).

Muskgrass occurred as a dominant or co-dominant plant at the greatest number of sample sites (~57%, Table 3). Next in line were pondweeds and watermilfoils, which occurred as dominant or codominant taxa at ~16% and ~14% of sample sites respectively. All other taxa were dominant or co-dominant at less than 10% of sample sites.

Typical for lakes in this region, the pondweed family (*Potamogetonaceae)* was the most speciose. A total of 13 pondweed species were documented in Mullett Lake during this survey. At least one pondweed hybrid was encountered and confirmed as such by aquatic plant expert, PhD. Barre Helquist.

**Table 2.** Aquatic plant species occurrence at sample sites.

| Genus and species | Common Name | # of sites | Occurrence* |
|---|---|---|---|
| *Chara spp.* | Muskgrass | 490 | Common |
| *Myriophyllum heterophyllum* | Variable-leaf watermilfoil | 238 | Common |
| *Najas flexilis* | Slender naiad | 185 | Common |
| *Vallisneria americana* | Eel-grass | 180 | Common |
| *Potamogeton zosteriformis* | Flat-stem pondweed | 124 | Common |
| *Stuckenia pectinata* | Sago-pondweed | 100 | Common |
| *Utricularia vulgaris* | Common bladderwort | 94 | Common |
| *Potamogeton gramineus* | Variable-leaf pondweed | 80 | Common |
| *Elodea Canadensis* | Elodea | 56 | Common |
| *Potamogeton friesii* | Fries' pondweed | 49 | Uncommon |
| *Sagittaria spp.* | Arrowhead | 47 | Uncommon |
| *Potamogeton richardonii* | Richardsons' pondweed | 45 | Uncommon |
| *Potamogeton illinoensis* | Illinois pondweed | 41 | Uncommon |
| *Potamogeton strictifolius* | Narrow-leaf pondweed | 37 | Uncommon |
| *Potamogeton amplifolius* | Broad-leaved pondweed | 36 | Uncommon |
| *Potamogeton praelongus* | Whitestem pondweed | 35 | Uncommon |
| *Megalondonta beckii* | Water marigold | 32 | Uncommon |
| *Schoenoplectus subterminalis* | Swaying bulrush | 32 | Uncommon |
| *Utricularia minor* | Lesser bladderwort | 28 | Uncommon |
| *Myriophyllum sibiricum* | Common watermilfoil | 26 | Uncommon |
| *Potamogeton robbinsii* | Robbins' pondweed | 26 | Uncommon |
| *Potamogeton natans* | Floating-leaf pondweed | 24 | Uncommon |
| *Potamogeton xhybrid* | Pondweed hybrid | 20 | Uncommon |
| *Heteranthera dubia* | Water stargrass | 19 | Uncommon |
| *Nuphar variegata* | Yellow pond lily | 19 | Uncommon |
| *Schoenoplectus acutus* | Hardstem bulrush | 16 | Uncommon |
| *Myriophyllum spicatum* | Eurasian watermilfoil | 15 | Uncommon |
| *Utricularia gibba* | Humped bladderwort | 13 | Uncommon |
| *Ceratophylum demersum* | Coontail | 12 | Uncommon |
| *Hippuris vulgaris* | Mare's Tail | 11 | Uncommon |
| *Nymphaea odorata* | White pond lily | 11 | Uncommon |
| *Sparganium angustifolium* | Narrow leaf Bur-reed | 3 | Rare |
| *Potamogeton crispus* | Curly-leaved pondweed | 2 | Rare |
| *Schoenoplectus tabernaemontani* | Softstem bulrush | 2 | Rare |
| *Potamogeton pusilus* | Fine-leaved pondweed | 1 | Rare |
| *Sparganium eurycarpum* | Giant Bur-reed | 1 | Rare |
| *Stuckenia filiformis* | Slender pondweed | 1 | Rare |

**Occurrence categories determined by Watershed Council staff based on natural breaks: 1-10 = rare, 11-50 = uncommon, and 51+ = common.*

**Table 3.** Aquatic plant dominance at sample sites

| Dominant Aquatic Plant | Number of sites | Percent of sites |
|---|---|---|
| Muskgrass | 409 | 57.44 |
| Pondweed | 116 | 16.29 |
| Watermilfoil | 103 | 14.47 |
| Eelgrass | 53 | 7.44 |
| Naiad | 40 | 5.62 |
| Bladderwort | 26 | 3.65 |
| Arrowhead | 15 | 2.11 |
| Bulrush | 14 | 1.97 |
| Elodea | 10 | 1.40 |
| Mare's Tail | 2 | 0.28 |
| Water marigold | 2 | 0.28 |
| Water stargrass | 2 | 0.28 |
| Coontail | 1 | 0.14 |

Aquatic plant densities were light to moderate at a majority of the sample sites. Very light to moderate plant densities were found at approximately 62% of sample sites whereas moderate-heavy to very heavy densities were found at less than 20% of sites (Table 4). Most sample sites with heavy or very heavy plant densities were located in the Indian River Spreads or in the Pigeon River Bay (Figure 6).

**Table 4.** Aquatic plant densities at sample sites.

| Density Category | Number of sites | Percent of sites |
|---|---|---|
| No Vegetation | 138 | 19.38 |
| Very Light (VL) | 73 | 10.25 |
| Light (L) | 136 | 19.10 |
| Light-moderate (LM) | 135 | 18.96 |
| Moderate (M) | 97 | 13.62 |
| Moderate-heavy (MH) | 42 | 5.90 |
| Heavy (H) | 40 | 5.62 |
| Very Heavy (VH) | 51 | 7.16 |
| TOTAL | 712 | 100 |

**Community mapping results:**

The aquatic plant community map layer developed in a GIS revealed that 13,897 of the 17,205 acres (~81%) of Mullett Lake contained little or no aquatic vegetation (Table 5 & Figure 7). Vegetated areas were divided into broad categories of emergent vegetation (bulrush, cattails, pond-lilies, etc.), submergent vegetation (muskgrass, pondweed, naiad, etc.), and a mix of the two. Of the 3,307 acres of Mullett Lake containing aquatic vegetation, approximately 86% was dominated by submergent vegetation, 12% by emergent vegetation, and the remaining 2% consisted of a mix of emergent and submergent.

**Table 5.** Lake and vegetated area statistics.

| Lake & Vegetation | Surface Area (acres) | Percent of Total Surface Area |
|---|---|---|
| Mullett Lake | 17204.84 | 100.00 |
| Little or no vegetation | 13894.31 | 80.76 |
| Aquatic vegetation: | 3310.53 | 19.24 |
| a. Emergent vegetation | 382.53 | 2.21 |
| b. Submergent vegetation | 2859.89 | 16.61 |
| c. Mixed emergent & submergent | 68.11 | 0.40 |

Mirroring results from sample sites, muskgrass was the dominant species in the majority of aquatic plant communities mapped on Mullett Lake, covering over 2,400 acres of lake bottom (Table 6 and Figure 8). Mixed emergent plant communities, primarily within the Indian River Spreads, were the next most prevalent in terms of areal extent, covering a total of 323 acres. Mixed submergent plant communities covered 192 acres of lake area and all other dominant community types covered less than 100 acres each.

Aquatic plant densities from community mapping data (Table 7) and densities recorded at sample sites (Table 4) were similar in most respects. Plant community mapping showed the greatest area, over 2,500 acres, falling in the light to moderate categories. The areal extent of communities with very heavy plant densities, at nearly 500 acres, was higher than would have been expected based upon the sample site data, but this number was probably influenced by the heavy density vegetation not sampled in the Indian River Spreads.

**Table 6.** Dominant aquatic plant community types and acreage.

| Dominant Community | Acreage | Percentage |
|---|---|---|
| Muskgrass Mix | 2452.25 | 14.25 |
| Mixed Emergents | 322.94 | 1.88 |
| Mixed Submergents | 191.88 | 1.12 |
| Watermilfoil Mix | 95.30 | 0.55 |
| Pondweed Mix | 82.88 | 0.48 |
| Bulrush Mix | 67.60 | 0.39 |
| Submergent-Emergent Mix | 21.62 | 0.13 |
| Swaying Bulrush Mix | 20.25 | 0.12 |
| Eelgrass Mix | 19.02 | 0.11 |
| Bladderwort Mix | 13.22 | 0.08 |
| Lily Mix | 5.73 | 0.03 |
| Arrowhead Mix | 3.99 | 0.02 |
| Naiad Mix | 3.40 | 0.02 |
| Cattail Mix | 1.92 | 0.01 |
| Elodea Mix | 1.90 | 0.01 |
| Eelgrass mix | 1.84 | 0.01 |
| Bur-reed Mix | 0.74 | 0.00 |
| Wild Rice Mix | 0.60 | 0.00 |
| Water Marigold Mix | 0.15 | 0.00 |
| Little/no veg | 13897.59 | 80.78 |
| TOTAL | 17204.84 | 100.00 |

**Table 7.** Aquatic plant community densities.

| Density Category | Acres | Percent |
|---|---|---|
| No vegetation | 13897.59 | 80.78 |
| Very Light | 125.53 | 0.73 |
| Light | 875.55 | 5.09 |
| Light to Moderate | 1094.14 | 6.36 |
| Moderate | 579.86 | 3.37 |
| Moderate to Heavy | 74.30 | 0.43 |
| Heavy | 94.94 | 0.55 |
| Very Heavy | 462.92 | 2.69 |
| TOTAL | 17204.84 | 100.00 |

**Figure 7.** Map of aquatic plant community types in Mullett Lake.

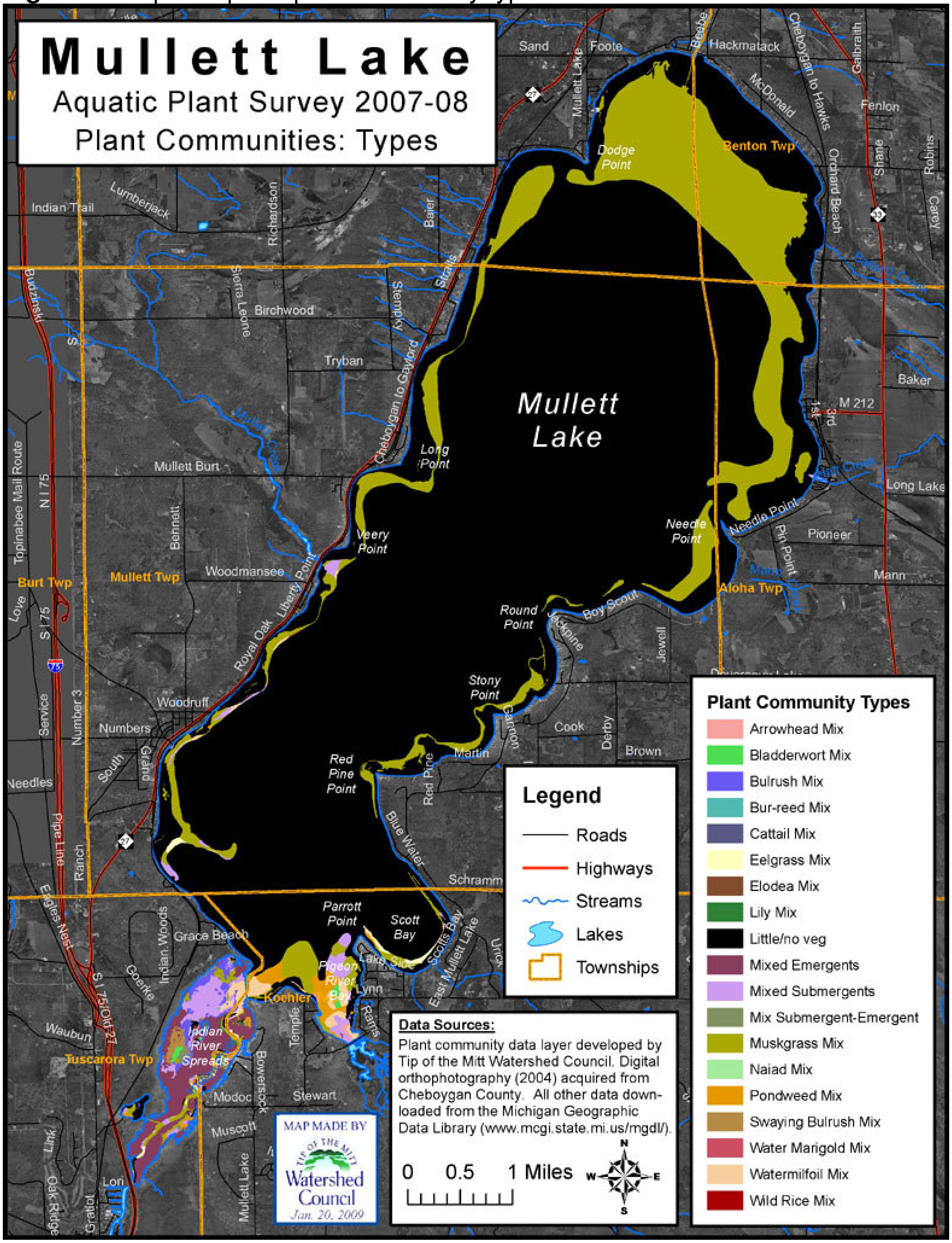
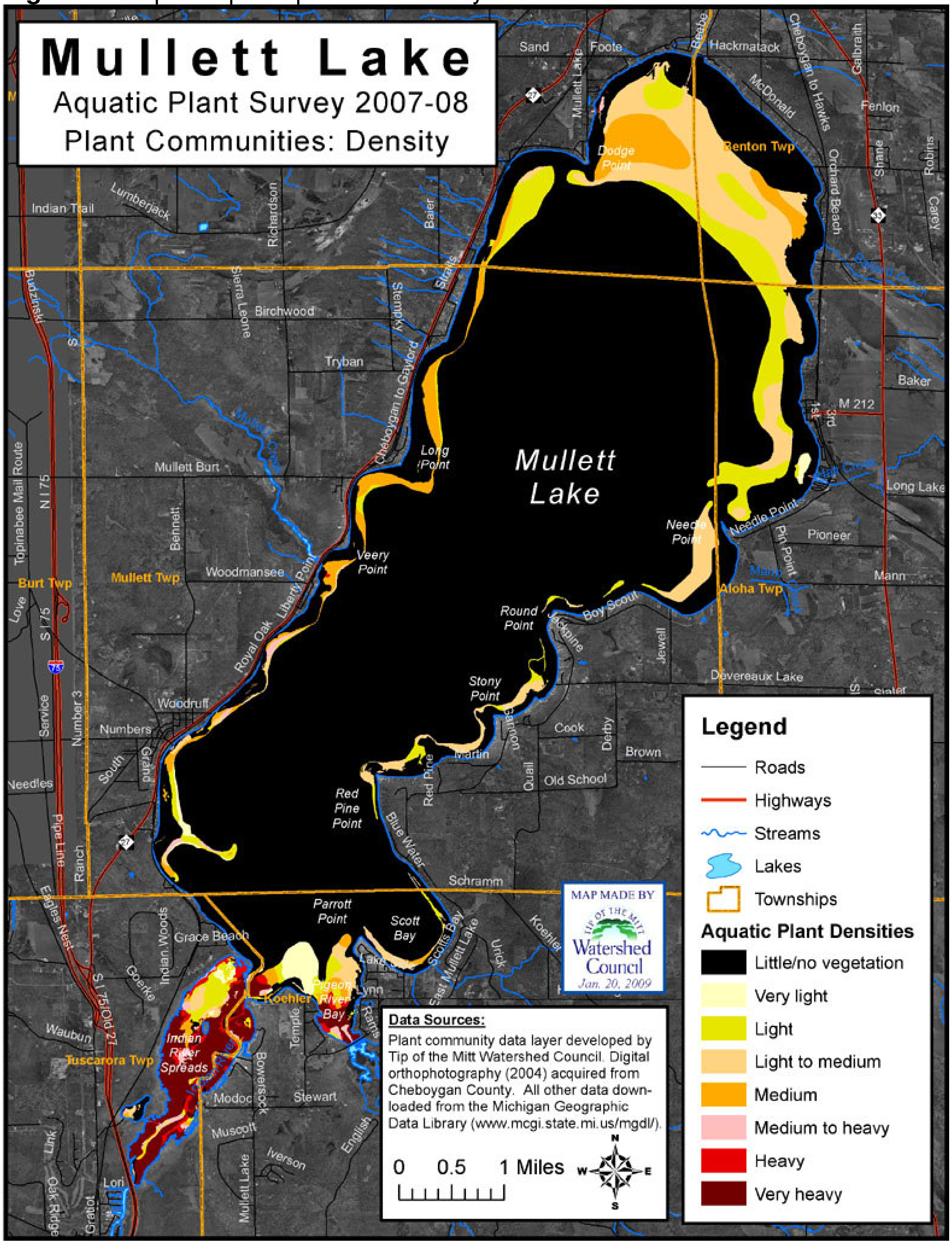


**Figure 8.** Map of aquatic plant community densities in Mullett Lake.



# DISCUSSION

## General

Despite vast areas of Mullett Lake being devoid of vegetation, a diverse aquatic flora exists in the lake. In terms of surface area, over 80% of the lake contains little or no vegetation. In vegetated areas a total of 42 aquatic plant taxa were documented during the survey, which ranks Mullett Lake at the top for aquatic plant diversity in lakes surveyed by the Watershed Council (Table 8), However, the averaged diversity across sampling sites in Mullett Lake (3.1 taxa/site) was lower than other lakes surveyed. The majority of the lake proper contained muskgrass and little else, resulting in the low average diversity score, There were areas of high diversity, such as the Indian River Spreads and Pigeon River Bay, where the number of aquatic plant taxa per site was 6.7.

As would be expected due to the inability of aquatic plants to survive in deep waters (generally greater than 20 feet of depth), the percent of lake with aquatic vegetation appears to be related to maximum water depth. Shallow lakes, such as Millecoquin and Wycamp, have very high percentages of lake surface area with vegetation (Table 8). The deeper lakes have a much smaller percent with vegetation, but the percent for Mullett was greater than that of Black or Long Lakes even though Mullett Lake's maximum depth is twice that of the others. This inconsistency points out that other factors beyond maximum depth contribute to the percent of a lake's surface area with vegetation including: average depth, substrate types, nutrient availability, water clarity, water currents, fetch, wind and wave action and more.

**Table 8.** Aquatic plant survey statistics from area lakes.

| Lake name | Acreage | Maximum depth (ft) | Percent with vegetation | Number of total taxa | Number of taxa/site |
|---|---|---|---|---|---|
| Black | 10,133 | 50 | 13% | 32 | 3.7 |
| Long | 388 | 61 | 9% | 18 | 3.8 |
| Millecoquin | 1,116 | 12 | 95% | 20 | 6.0 |
| Mullett | 17,205 | 144 | 19% | 42 | 3.1 |
| Wycamp | 689 | 7 | 83% | 35 | 4.9 |

Not surprisingly, the most extensive areas with aquatic plant cover in Mullett Lake were in the north and south ends (Figure 7). The northern end of the lake had large areas of muskgrass-dominated, low-density plant growth while a diverse and dense assemblage of aquatic plants was found in the southern end in the Indian River Spreads and Pigeon River Bay. There are similar conditions at both ends of the lake that contribute to the plant growth. The north end, Indian River Spreads, and Pigeon River Bay all possess extensive shallow areas and have major stream inlets or outlets nearby. Shallow areas are more conducive to plant growth than deep areas because sunlight can penetrate to the lake bottom. Nutrient concentrations are typically higher in streams than in oligotrophic lakes like Mullett, which helps explain the dense aquatic plant growth in the south end as a result of inflows from the Indian and Pigeon Rivers. The Cheboygan River outlet in the northern tip probably has little effect on the aquatic plant populations in that area, but there are several small feeder streams that flow and carry nutrients into the north end of the lake.

A relatively large contiguous area of the lake had little or no vegetation. In general, the areas lacking vegetation occurred in deeper waters. Other aquatic plant surveys conducted in the region have evidenced a pattern of the eastern side of the lake being devoid of plants as a result of wave action generated by prevailing winds from the west and northwest. This phenomenon was not seen in the Mullett Lake survey as the areal extent of vegetation on the northwest side of the lake mirrored that of the southeast side.

Ecosystem disruptions may also affect aquatic plant coverage, distribution and density. Human activity impacts all aspects of the lake ecosystem, from fisheries to phytoplanktonic algae blooms to aquatic plant growth. Recreational activities such as boating damage aquatic plants and can lead to the introduction of invasive species. Human activity can also augment plant growth by adding excess nutrients to the water from sources such as fertilizers, stormwater, and septic systems.

Mullett Lake is part of the Inland Waterway and therefore, a popular thoroughfare for boat traffic, which has impacts upon the aquatic vegetation.

Dredging and herbicide application to maintain the boating channel impacts the aquatic plant community. Barren areas and areas of reduced aquatic plant growth were observed during this survey while sampling in the boat channel in the Indian River Spreads. Also evident during this survey was damage or destruction of aquatic plants in shallow areas as a result of propeller gouging from the large number of boats traversing the lake. Interestingly, boat traffic also has some potential to increase plant growth as evidenced by the narrow swath of plant growth that follows the boating path extending from the north end of the lake into the Cheboygan River channel.

Boat traffic has almost certainly led to the introduction of invasive species in the lake, particularly the submerged invasive plant species: Eurasian watermilfoil and curly-leaved pondweed. The impact of invasive (i.e., non-native or exotic) species introduced by humans is possibly the most serious in terms of ecosystem disruption, though often more subtle. Non-native species have the potential to cause fundamental changes in an aquatic ecosystem, whether through predation on native species, displacement of native species, or disruption of the natural food chain.

Nutrient availability is a determining factor in aquatic plant growth and likely influenced by human activity along the Mullett Lake shoreline and in its watershed. A shoreline survey sponsored by the Mullett Lake Area Preservation Society and conducted by Tip of the Mitt Watershed Council during the summer of 2008 documented shoreline conditions that had the potential to adversely impact water quality, with a particular focus on nutrient pollution. Extensive and excessive *Cladophora* growth, a filamentous green alga that serves as a bio-indicator of nutrient pollution, was observed along much of the Mullett Lake shoreline during the survey. Based on results of this survey, it appears that nutrient inputs from human activity, whether from fertilizers, malfunctioning septic systems, erosion, stormwater or other sources, are contributing to aquatic plant growth in the lake. In addition, the Lake Association and Watershed Council have collaborated to monitor water quality of the streams flowing into Mullett Lake and found high levels of nutrients in Mullett Creek, which flows in to the northwest side of the lake. Nutrient pollution in Mullett Creek is believed to originate from agricultural activity in its watershed.

**<u>Aquatic plant control options:</u>**

In general, there are four major approaches to aquatic plant management as well as combinations of these. The first option is to do nothing and let nature take its course. Otherwise, options for controlling problematic aquatic plant growth consist of chemical, physical or biological treatment. Chemical control would entail the application of herbicide to kill or suppress growth of nuisance plants. Physical control involves plant removal, dredging, lake drawdown or barrier installation. Biological control is accomplished by introducing another living organism that feeds upon or by some other means, disrupts the life cycle of the target species.

Aquatic plant control options should be carefully evaluated, weighing the positive against the negative aspects of each one. Following the wrong road could lead to even greater problems. Aquatic plants that seem like a nuisance to a swimmer or boater may be a sanctuary for small fish, macroinvertebrates and other aquatic life. Drastic alteration of the aquatic plant community could have far-reaching and devastating impacts on fisheries and the entire ecosystem. The information provided in the following section is summarized in an aquatic plant control options matrix (Appendix A).

**Natural control**

Aquatic plant communities and growth or density within these communities fluctuates naturally over time. There may be periods of heavy nuisance growth in a given area that are followed by periods of little to no growth. Sometimes, simply being patient and letting nature take its course is the best option.

There are a variety of resources for determining natural fluctuations in the aquatic plant community on a given lake. One of the best is people; particularly individuals who have lived on or near the lake for a long period of time and can provide the “big picture”. Other resources include: surveys and reports from regulatory agencies such as the DNR, research reports from universities, and surveys and reports from other organizations or companies working in water resource management. Even archive newspapers and other forms of media may provide clues to historical trends in aquatic plant growth in the lake. Unfortunately, conducting background research takes a lot of time and effort and may not provide reliable results.

Natural control may not be appropriate for lakes that are or have become 'unnatural.' Human-made lakes, lakes being polluted from excessive urban or agricultural runoff, and lakes suffering from the introduction of invasive species are all examples of unnatural lakes. In instances like these, not taking action to control aquatic plant growth could result in further problems. However, solutions may consist of indirect methods, such as changing human behavior and practices (e.g., reducing fertilizer application or properly maintaining septic systems), as opposed to direct control of plant growth.

**Chemical control**

There are many chemicals on the market that are used to control aquatic plants. Some of the most commonly used include endothall, glyphosate, copper-sulfate and diquat. Some herbicides, such as fluridone and 2-4.D, selectively control Eurasian watermilfoil and a limited number of other species when applied at proper rates. Michigan Department of Environmental Quality (MDEQ) maintains a list of approved herbicides and target species (Appendix D). Research by MDEQ staff has shown that herbicides applied to surface water can migrate into shallow lakeshore groundwater (Lovato et al. 1996).

Herbicide application has the potential to indirectly stress or kill aquatic organisms. Following herbicide treatment, dead plant material settles to the lake bottom and is consumed by aerobic decomposers. Depending on the amount of dead plant material, decomposers can substantially reduce or even deplete the dissolved oxygen stores in a localized area, which can be particularly problematic in deep areas of stratified lakes. Depleted or low dissolved oxygen levels will stress or kill fish and most other organisms living in the aquatic environment.

Fish have the ability to rapidly move to other areas of the lake with higher dissolved oxygen concentrations, but smaller less mobile organisms, such as midges, mayflies, and snails cannot move as quickly and are more likely to succumb to localized dissolved oxygen deficits.

Chemical control creates the distinct possibility of long-term application; year after year, perhaps indefinitely into the future. Although often less expensive than physical or biological control in the short-term, long-term chemical control costs may reach or surpass that of other methods. Of greatest concern is that some chemicals, particularly copper from copper-sulfate, build up in the environment with continual application and can reach levels that are toxic for aquatic organisms (Oleskiewicz 2002).

Whole-lake herbicide treatment has been used on some lakes that are heavily infested with Eurasian watermilfoil. However the same drawbacks, which are discussed by Wisconsin DNR staff in a 2005 issue of Lake Tides (Hauxwell 2005), should apply. If the Lake Association opts for any type of chemical control, a permit through the Michigan Department of Environmental Quality (MDEQ) will be required.

**Physical control**

Physical aquatic plant control can be accomplished through various means including: manual cutting/removal, mechanical cutting/removal, dredging, and barrier installation. Manual removal is performed by pulling or cutting aquatic plants by hand or with hand tools. Mechanical cutting/removal uses machines to cut and remove aquatic plants. Dredging deepens an area by removing soft bottom sediments, essentially reducing habitat for aquatic plants by reducing the lake bottom area that receives sunlight. Lake drawdown consists of lowering the water level of the lake and eliminating plants from the shallow (dry) areas. The remaining option is to install fabric barriers along the lake bottom, which blocks sunlight and prevents plant growth. Most of these methods require a permit from DEQ.

Manual aquatic plant removal is an age-old technique that is commonly applied in small areas. You simply get into the water and pull plants (and roots) out by hand or use a tool, such as a scythe to cut plants or a rake to remove plants. Advantages of this method include low costs, the ability to remove specific species, and long duration of control if the entire plant is removed. The disadvantages for manual removal are that it is labor intensive, time consuming, creates some localized turbidity, and requires diving equipment in deep areas. In general, this method is only feasible for a small area.

Mechanical cutting and removal is a method commonly applied in large areas, using equipment that functions like a lawn mower. Like lawn mowers, some systems simply cut the plants while others cut and collect. Aquatic plant cutters range from simple systems that can be attached to a small boats (14'+ of length) to specialized cutting boats. The cutters typically cut to a depth of 4-7 feet. Aquatic plant harvesters are large machines that cut and collect aquatic plants. Harvesters typically cut a swath 6 to 20' wide and 5 to 10 feet deep, removing the plants from the water and storing them for later disposal.

There are a number of other considerations pertaining to cutters and harvesters. As with mowing a lawn, aquatic plants may need to be cut several times per season. Some species are difficult to cut, while others fragment when cut and spread to (and colonize) other parts of the lake. Watermilfoils fragment when cut and therefore, should not be controlled using cutters or harvesters. Sediments may be loosened when using cutters and harvesters in shallow areas of lakes with soft sediments. Loosened sediments that become suspended in the water column will clog fish and invertebrate gills as well as smother and reduce habitat of small aquatic organisms when resettling.

Dredging is sometimes used as a method for aquatic plant control, but has many drawbacks. Although aquatic plants are removed during dredging operations, long-term plant control is achieved by deepening an area sufficiently to reduce lake bottom area suitable for plant growth. Aquatic plant surveys conducted by Watershed Council staff indicate that aquatic plants usually exist in lake areas up to approximately 20 feet in depth, though dense aquatic plant growth generally disappears in depths that exceed 15 feet. Even dredging small areas to a depth of greater than 15 feet would be a costly and time-consuming operation. Plant removal as a result of dredging has the potential to destabilize lake bottoms and even cause shoreline erosion as roots hold sediments in place and plant stems/leaves absorb wave energy and currents. Furthermore, dredging stirs up sediments and may cause nutrients and other contaminants to be released into the water column. Loosening sediments has the same biological consequences as described above for harvesters.

Diver dredging is an aquatic plant control technique that utilizes SCUBA divers to remove plants using hoses and suction. This method is particularly useful for removing aquatic plants from around docks and other areas that are difficult to access. Diver dredging also allows for selective removal of target species. However, the procedure is not 100% effective as root masses are not always removed. As with other forms of dredging, diver dredging is expensive and has the same negative impacts on lake ecosystems, though to a lesser degree as mostly plant material and little sediment is removed.

Benthic barriers are installed in limited areas to control patches of aquatic nuisance plant growth or to eliminate plants from swimming areas. Benthic barriers reduce or eliminate aquatic plant growth due to compression and lack of sunlight. Materials ranging from burlap to synthetics have been used as benthic barriers. Barrier installation is accomplished more easily in late fall, winter, or early spring, when plant growth is minimal. It is extremely important to securely fasten barriers to the lake bottom as gases building up underneath will cause the barrier to bulge and rise. Aquatic plant control will only last as long as the barrier remains intact or until enough sediments have been deposited on top of the barrier to allow for plant growth.

Free-floating aquatic plant species, such as coontail, are not controlled by barriers. Other plants growing near the barriers, such as watermilfoils, are able to send out lateral shoots and inhabit areas where barriers have been installed. Spawning fish and other aquatic organism inhabiting lake bottom areas covered by barriers may be affected. Benthic barriers are susceptible to damage by anchors, fishing gear, harvesters, weather and other factors and must be inspected regularly as they can create safety hazards for navigation and swimming.

**Biological control**

Biological control of aquatic plants has primarily been used in Michigan to control the growth of two non-native species: Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria*). In both cases, a specific aquatic beetle known to feed upon the invasive plant is stocked in infested areas. The beetle (*Galerucella spp.*) used to control purple loosestrife originates from Europe, but underwent extensive testing before being released in the United States. The beetle (*Euhrychiopsis lecontei*) used to control Eurasian watermilfoil is native to Michigan due to the presence of native watermilfoils, but feeds preferentially on the exotic watermilfoil. Both of these bio-control agents have been quite successful in controlling growth of the target nuisance aquatic plant species.

The biggest drawback to using biological control is the potential for non-native bio-control agents, such as the purple loosestrife beetle, to proliferate, become a nuisance and cause ecosystem disruptions. Non-native species should never be introduced as bio-control agents unless approved by regulatory agencies (i.e., DEQ). The introduction of untested, non-native bio-control organisms can severely alter the native ecosystem.

Bio-control can be expensive. Surveys conducted before, during and after stocking efforts to gauge project progress result in additional costs. The purple loosestrife beetle is commercially available through a few vendors, but is also commonly gathered by hand from locations where it has become established and spread to other infested areas. Safe bio-control agents have not yet been found for other invasive aquatic plant species such as curly-leaved pondweed.

Biological control can potentially take many years and there is no guarantee that it will be effective. The success of controlling Eurasian watermilfoil using weevils hinges on many factors including: a sufficient quantity during stocking, an adequate food supply to maintain the population, and recreational impacts (primarily from boats moving through the treatment areas). Furthermore, there is always the potential need for additional stocking in the future if ecosystem equilibrium is disrupted and the invasive aquatic plants gain the upper hand.

There are many success stories throughout Michigan and the nation using beetles to control purple loosestrife and Eurasian watermilfoil. Locally, weevils have been used successfully to control Eurasian watermilfoil in Burt Lakes in Cheboygan County and in Manistee Lake in Kalkaska County. The *Galerucella* beetle has also been used in this region to control purple loosestrife; successfully reducing growth of this invasive plant in several water bodies in the Inland Waterway in Emmet and Cheboygan Counties.

In spite of the fact that biological control is not guaranteed and takes time, patience, and money, there are many benefits that may outweigh these drawbacks. If successful, biological control provides a fairly long-term solution for target nuisance species without introducing chemicals into the environment, disturbing sediments, or killing other aquatic organisms. Maintenance is minimal, restocking only if the system again becomes imbalanced. In the case of the watermilfoil weevil, the introduction of an exotic species is not an issue as the weevil is native to Michigan's aquatic ecosystems.

**Integrated control**

Integrated control consists of a mix of any of the previously described methods of aquatic plant control. Some situations may require an integrated approach as one method may not be suitable for controlling differing types of nuisance aquatic plant growth within a lake. For example, a lake association may opt for stocking weevils to control an area of the lake infested with watermilfoil while at the same time installing benthic barriers in a public swimming area that is experiencing nuisance native aquatic plant growth.

By taking an integrated approach you get the combined benefits of all methods used, but also the combined problems of all methods. In addition, one method may affect the success of another. For example, cutting aquatic plants may spread plant fragments that recolonize other parts of the lake where other methods like manual removal were employed. Another situation where mixing control methods causes problems is when widespread chemical treatment destroys the food source which sustains a biological control organism that is being used.

**Recommendations:**

The aquatic plant community is a vital component of the aquatic ecosystem, such that good aquatic plant management translates to good lake ecosystem management. To properly manage aquatic plants in your lake, an aquatic plant management plan should be developed. There are a number of guides available to help your organization develop such a plan, including *Management of Aquatic Plants* by Michigan DEQ, *Aquatic Plant Management in Wisconsin* by University of Wisconsin Extension, and *A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans* by the Washington State Department of Ecology. Your organization's decision to have this survey conducted was a good first step in creating a management plan.

Human activity in a multitude of forms typically has the greatest impact on a lake's aquatic plant community. Therefore, effectively managing the lake's aquatic plants requires information and education outreach projects that target shoreline property owners, watershed residents and all other lake users. Residents can improve land management practices to reduce nutrient loading (to control excessive plant growth) by establishing naturally vegetated buffers along the shoreline, reducing or eliminating yard fertilizers, and properly maintaining septic systems. Lake associations can help prevent the introduction of non-native species (such as the nuisance plant *Hydrilla* that looms on the horizon) by posting signs and educating members and other lake users. Outreach activities should not be limited to dos and don'ts, but also include general information about aquatic plants and their importance to the lake ecosystem.

Nuisance aquatic plant growth, both native and non-native, is an issue of great concern for some Mullett Lake shoreline residents and recreationalists. In the Pigeon River Bay and Indian River Spreads, aquatic plant growth is quite heavy due to, at least in part, extensive shallow areas and nutrients transported by the streams emptying into or passing through those areas. Although invasive species were documented in these areas, occurrences were rare and densities were low. Both the Pigeon River Bay and Indian River Spreads have incredibly vibrant, healthy, and diverse native aquatic plant communities, which almost certainly help resist the invasion by non-native species.

During the survey, decomposing and algae-encrusted plants were noted in a sizable area along the southwest shore of Pigeon River Bay. It appeared that either herbicides had been applied to control aquatic plant growth or excessive nutrient pollution from sources such as fertilizers and erosion were the source of the problem. Upon reviewing DEQ permit records, it was found that a group of individual property owners applied for permits in 2007 and 2008 to chemically treat the south side of Pigeon River Bay for navigation and to control Eurasian watermilfoil. Eurasian watermilfoil was not found in Pigeon River Bay during this survey and curly-leafed pondweed was found only on the northeast side. Stressors on the native aquatic plant community caused by such chemical application could open the door for invasive species to come in and take over. The property owners applying herbicides in the Bay should be informed of the potential dangers of herbicide application and encouraged to discontinue; thereby allowing the native plant community to return to a healthy state.

Invasive plant species were encountered in several locations throughout Mullett Lake and may require action in some areas. Purple loosestrife, curly-leaved pondweed, and Eurasian watermilfoil were documented in Mullett Lake during this survey. Purple loosestrife was common in the Indian River Spreads, curly-leafed pondweed was found in a few locations in the lake proper, and Eurasian watermilfoil was found at several sites in the Indian River Spreads and the lake proper.

*Galerucella* beetles were stocked by Tip of the Mitt Watershed Council staff in the Indian River Spreads in the summer of 2008 to control purple loosestrife. During stocking, it was noted that purple loosestrife plants throughout the area were already heavily populated by *Galerucella* beetles. Thus, it would appear that biological control of purple loosestrife is already well underway and presently not in need of further treatment. However, it is recommended that follow-up surveys be carried out in the future to assess the purple loosestrife and *Galerucella* beetle populations.

Curly-leafed pondweed was found in the Pigeon River Bay and near the boat launch at Aloha State Park. There was a very limited amount in the Bay, but heavy growth near the boat launch. Biological control is not currently an option for controlling curly-leafed pondweed, so a physical or chemical method would have to be applied to control this invasive plant. During a concurrent aquatic plant survey on Pickerel and Crooked Lakes (2008), a patch of curly-leaved pondweed was discovered in Crooked Lake and the Pickerel-Crooked Lake Association took immediate action to remove as much of the invasive plant in the infested area as possible by hand or with hand tools. This approach is preferable to chemical treatment and feasible for Mullett Lake considering that only two sites need to be addressed.

Eurasian watermilfoil was documented at 15 sample sites, but heavy growth was limited to just three sites. There were several occurrences in the Indian River Spreads, but in all cases plant density was light to very light. The dense Eurasian watermilfoil growth was found in the north end of the lake in the channel leading to the boat launch at Aloha State Park and at the Mullett Lake Marina. These dense infestations are quite limited in scope, but are located in areas with heavy boat traffic and therefore, have greater potential for spreading the plant throughout Mullett Lake and even to other lakes in the region. In light of this potential danger, actions should be taken to control these dense Eurasian watermilfoil beds. We recommend biological control using the watermilfoil weevil as it is an environmentally safe and potentially long-term solution.

If successful, the high initial costs of using biological control and the length of time required to achieve results (at least 2 full years) are easily offset by the positive aspects of using an environmentally safe method. Chemicals will not be introduced into the lake, sediments will not be stirred up, and there will be no unnecessary loss of aquatic life. Furthermore, biological control offers a possible long-term solution.

Providing that the Lake Association is interested in pursuing biological control, EnviroScience, Inc. should be contacted early on as a typical weevil stocking program requires a great deal of advance planning. EnviroScience can be contacted for further information and estimates at: 3781 Darrow Road, Stow, OH 44224 (800) 940-4025. The Watershed Council has worked with EnviroScience on other projects and may be available to assist with certain aspects of their MiddFoil® process.

The results of this study should be widely dispersed to get a maximum return on the Lake Association's investment. Sharing the results with members, non-member lake users, government officials, and others will alert the public to problems occurring in the lake and provide information regarding strategies for resolving the problems. If the public fully understands aquatic plant management issues on Mullett Lake, there will be less resistance to proposed solutions. Furthermore, an informed public may result in behavioral changes that benefit aquatic plant management, such as reducing lake nutrient loads and preventing the introduction of additional non-native species.

To properly manage the aquatic plant community of Mullett Lake, additional aquatic plant surveys should be conducted in the future. Future surveys will provide the Lake Association with valuable data for determining trends over time, evaluating successes or failures of aquatic plant management projects, and documenting the locations and spread of non-native aquatic plant species. Although dependent upon many different variables, surveying the aquatic plant community on a 5-10 year basis should be sufficient.

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**Appendix A:** Aquatic plant control options matrix.

| **AQUATIC PLANT CONTROL OPTIONS MATRIX** | | |
|---|---|---|
| **primary source: http://www.ecy.wa.gov/programs/wq/plants/management/* | | |
| **Control Method** | **Advantages** | **Disadvantages** |
| Herbicide Application | Recreational activities such as swimming and boating improve. | Habitat and refuge loss for aquatic species that depend upon aquatic plants. |
| | Often get quick results, though some treatments take weeks or months. | Food source reduced or eliminated for aquatic organisms that feed on plants or on other organisms that live on/in plants. |
| | Short-term costs are generally low compared to other forms of treatment. | Native species may also be killed by the herbicide, weakening the native plant community and opening door to invasives. |
| | Herbicides and application services are readily available through a variety of companies. | Herbicides kill plants, but leaves decaying plant material in the water, which can lead to oxygen depletion and fish kills. |
| | | Spot treatment using herbicide is prone to dispersal by winds, waves, and currents, potentially impacting non-target areas. |
| | | Herbicides have been shown to migrate from surface waters into and contaminate groundwater. |
| | | Some chemicals accumulate in sediments and may reach toxic levels for aquatic life occupying that niche. |
| | | Full extent of chemical impacts on other organisms within the ecosystem are usually unknown. |
| | | Resource expenditure (money and effort) is usually continual and long-term. |
| | | Restricts use of some lake areas that must be closed for a time after herbicide application. |
| Manual plant removal | Able to remove plants from dock and swimming areas. | Treatment may need to be repeated several times each summer. |
| | Inexpensive. | Not practical for large areas or thick weed beds. |
| | Selective aquatic plant removal. | It is difficult to collect all plant fragments (most aquatic plants can re-grow from fragments). |
| | Environmentally sound. | Plants with large rhizomes, like water lilies, are difficult to remove. |
| | | Loosened sediments have biological impacts in immediate area and makes it difficult to see remaining plants. |
| | | Bottom-dwelling animals in affected area disturbed or killed. |

| Control Method | Advantages | Disadvantages |
|---|---|---|
| Cutters | Water area immediately opened, improving recreational opportunities. | Plants may need to be cut several times per season. |
| | May work in shallow waters not accessible to larger harvesters. | Some species are difficult to cut. |
| | Habitat for fish and other organisms is retained if the plants are not cut too short. | Plant fragments from cutting may enhance the spread of invasive plants such as Eurasian watermilfoil. |
| | Can target specific locations and protect designated conservancy areas. | Decomposing plant fragments potentially reduce dissolved oxygen in water (and create a nuisance when drifting to shore). |
| | Prices are much lower than harvesters. | Little or no reduction in plant density. |
| | | Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling. |
| Harvesting | Water area immediately opened, improving recreational opportunities. | Initial costs for equipment are high and maintenance is required. |
| | Removes plant nutrients, such as nitrogen and phosphorus, from the lake. | Plants may need to be cut several times per season. |
| | Harvesting as aquatic plants are dying back for the winter can remove organic material and help slow the sedimentation rate in a waterbody. | Little or no reduction in plant density (# of plants per area). |
| | Habitat for fish and other organisms is retained if the plants are not cut too short. | Must have off-loading sites and disposal areas for cut plants. |
| | Can target specific locations and protect designated conservancy areas. | Not easily maneuverable in shallow water or around docks or other obstructions. |
| | | Small fish and other aquatic organisms are often collected and killed. |
| | | Plant fragments from cutting may enhance the spread of invasive plants such as Eurasian watermilfoil. |
| | | Decomposing plant fragments potentially reduce dissolved oxygen in water (and create a nuisance when drifting to shore). |
| | | Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling. |
| | | May not be suitable for lakes with many bottom obstructions (stumps, logs). |
| | | May not be suitable for very shallow lakes (3-5 feet of water) with loose organic sediments |
| | | Harvesters from other waterbodies must be thoroughly cleaned and inspected to avoid introduction of exotic species. |

| Control Method | Advantages | Disadvantages |
|---|---|---|
| Dredging | Long-term control in areas that are sufficiently deepened. | Expensive. |
| | Water area immediately opened, improving recreational opportunities. | Sediments are stirred up, which could release nutrients or long-buried toxic materials into the water column. |
| | Plant material and nutrients or contaminants permanently removed from the lake. | Stirred sediments clog gills of fish and macroinvertebrates, smother small organisms and potentially reduce habitat when resettling. |
| | Diver dredging can selectively remove target species. | Bottom-dwelling animals in affected area disturbed or killed. |
| | Diver dredging can remove plants around docks and in other difficult to reach areas. | Aquatic plant root removal may destabilize lake bottom. |
| | | Aquatic plant removal could lead to shoreline erosion as wave energy and currents are no longer absorbed. |
| | | Root crowns may be missed and lead to future growth. |
| | | Spoils must be properly disposed of. |
| Lake Drawdown | Cost effective, if water control structure is in place. | Costly if a water level control structure is not in place (requires high capacity pumps). |
| | Re-colonization by native aquatic plants in areas formerly occupied by exotic species can be enhanced. | Does not kill all plants and enhances growth of some aquatic plants. |
| | Game fish populations are reported to improve after drawdown. | Success in killing the target species dependent on weather (e.g. warm winters or wet summers). |
| | Provides an opportunity to repair and improve docks and other structures. | Docks and water intakes left high and dry, boat launching complicated, and well water levels may lower. |
| | Loose, flocculent sediments can become consolidated. | Exposing lake bottom areas impacts fish and other aquatic wildlife. |
| | | Algal blooms have been reported to occur after drawdowns. |

| Control Method | Advantages | Disadvantages |
|---|---|---|
| Benthic Barriers | Water area immediately opened, improving recreational opportunities. | Only suitable for localized control, as barriers cover sediment and reduce habitat. |
| | Easy installation around docks and in swimming areas. | Require regular inspection and maintenance for safety and performance. |
| | Can control 100 percent of aquatic plants, if properly installed. | May be damaged or dislodged by anchors, harvesters, rotovators, fishing gear, propeller backwash, weather, etc. |
| | Materials for constructing barriers are often readily available. | Dislodged or improperly anchored barriers may create safety hazards for boaters and swimmers. |
| | Can be installed by homeowners or divers. | Swimmers may be injured by anchors used to fasten barriers. |
| | | Some bottom screens are difficult to anchor on deep muck sediments. |
| | | Barriers interfere with fish spawning and bottom-dwelling animals. |
| | | Aquatic plants may quickly recolonize if barrier is not maintained. |
| | | Not effective against free-floating plants. |
| Biological control | Long-term solution, if successful. | Usually only effective against one target species. |
| | Long-term maintenance is minimal. | May introduce a non-native species. |
| | No chemicals introduced, sediments are not disturbed, other aquatic organisms not sacrificed. | Bio-control agents may not be available for plant in question or not commercially available. |
| | | Slow process, taking years. |
| | | Success is not guaranteed. |
| | | Initial stocking and survey costs are usually high. |

**Appendix B:** Herbicides approved by Michigan DEQ and target species.

DEQ

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER BUREAU

This table contains information concerning the herbicides permitted for aquatic plant and algae control in Michigan and the plant species for which they may serve as potential control agents. Refer to product labels for additional details.

Permits may be required prior to use of any pesticide, including "unclassified" pesticides. Contact the DEQ, Aquatic Nuisance Control & Remedial Action Unit at 517-241-7734, by e-mail at DEQ-LWM-ANC@michigan.gov, or visit our website at www.michigan.gov/deq.

| Common Plant Species | Copper Sulfate | Chelated Copper | Amine Salts of Endothall* (Hydrothol 191) | Dipotassium Salts of Endothall* (Aquathol K) | Diquat dibromide** (Reward) | 2,4-D* (Navigate, Aquakleen, Aquacide) |
|---|---|---|---|---|---|---|
| **Algae** | | | | | | |
| Filamentous | x | x | x | | x | |
| Macroalgae (e.g., Chara) | x | x | x | | | |
| Planktonic | x | x | x | | | |
| | | | | | | |
| **Macrophytes** | | | | | | |
| **Submergents** | | | | | | |
| Coontail | | | x | x | x | x |
| Curly leaf pondweed | | | x | x | x | |
| Elodea | | | x | | x | |
| Large leaf pondweed | | | x | x | x | |
| Milfoil | | | x | x | x | x |
| Naiad | | | x | x | x | |
| Sago pondweed | | | x | x | x | |
| Wild Celery | | | x | | x | |
| **Emergents** | | | | | | |
| Arrowhead | | | | | | x |
| Bulrush | | | | | | x |
| Cattails | | | | | | x |
| Phragmites | | | | | | |
| Purple Loosestrife | | | | | | |
| Water lily | | | | | | x |
| **Free Floating** | | | | | | |
| Duckweed | | | | | x | |

* Granular endothall and/or granular 2,4-D products may not be applied within 75 feet of ANY drinking water well or within 250 feet of drinking water wells that are less than 30 feet deep. Isolation distances are measured from the well location, not the shoreline.

** Diquat products are restricted for all aquatic uses, except in small ponds, such as farm ponds that have no outflow and are under the control of the user. This means that you must be licensed by the Michigan Department of Agriculture as a certified pest control applicator to use this material in all waterbodies except small ponds. Diquat is the only "Restricted Use" pesticide on the chart. All others are "Unclassified."

**MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY**
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| Common Plant Species | Fluridone (Sonar, AVAST!) | Glyphosate (Rodeo, Eagre, AquaNeat) | Imazapyr**** (Habitat) | Komeen | Nautique | Sodium Carbonate Peroxyhydrate (GreenClean Pro, Pak 27*****) | Triclopyr (Renovate 3) |
|---|---|---|---|---|---|---|---|
| **Algae** | | | | | | | |
| Filamentous | | | | | | X | |
| Macroalgae (e.g., Chara) | | | | | | | |
| Planktonic | | | | | | X | |
| **Macrophytes** | | | | | | | |
| **Submergents** | | | | | | | |
| Coontail | | | | X | | | |
| Curly leaf pondweed | | | | | | | |
| Elodea | | | | X | | | |
| Large leaf pondweed | | | | | | | |
| Milfoil | X*** | | | X | | | X |
| Naiad | | | | X | X | | |
| Sago pondweed | | | | X | | | |
| Wild Celery | | | | | X | | |
| **Emergents** | | | | | | | |
| Arrowhead | | | | | | | |
| Bulrush | | | X | | | | |
| Cattails | | X | X | | | | |
| Phragmites | | | | | | | |
| Purple Loosestrife | | X | X | | | | X |
| Water lily | X | X | | | | | X |
| **Free Floating** | | | | | | | |
| Duckweed | | | X | | | | |

*** Fluridone use may require a Lake Management Plan. Rates requested above 6 ppb must follow evaluation protocol.

**** As indicated on the label, application of Habitat can only be made by applicators who are licensed or certified as aquatic pest control applicators and are authorized by the state or local government.

***** The label indicates use for treatment of blue-green algae.