Long Lake Aquatic Plant Survey 2005

by Tip of the Mitt Watershed Council

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Table of Contents

Page

List of Tables

Page

List of Figures

Page

INTRODUCTION

Problem statement:

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 tends to create a recreational nuisance, making it difficult or undesirable to boat, fish and swim. In lakes plagued by nuisance plant species, it may be necessary to develop and implement programs to control excessive growth and non-native species. The first step in such a program is to document all plant communities present in the lake to determine if growth is excessive and if there are non-native and other nuisance species that are disrupting natural aquatic plant communities.

Due to concerns from residents of Long Lake in Cheboygan County about a perceived proliferation of non-native species (specifically Eurasian watermilfoil) as well as declining fisheries, the Cheboygan Long Lake Area Association decided to take the first step and contracted the Tip of the Mitt Watershed Council to conduct a comprehensive aquatic plant survey on Long Lake. This survey was performed by

Watershed Council staff during the week of July 11-15, 2005, the results of which are contained in this report. Survey methods, results and a discussion are included as well as recommendations for aquatic plant and general lake management approaches.

Study area:

Long Lake is located in Aloha Township (T36N.-R1W-S1,2,3,11,12) in northeast Cheboygan County, which is located in the northeast tip of the lower peninsula of Michigan. The lake is composed of three distinct basins that are hereafter referred to as the northwest, central and southeast basins. Based upon GIS (Geographical Information System) files generated through on-screen digitization of 1998 aerial photos, the shoreline measures 5.8 miles and the lake surface area totals 388 acres. Maps acquired from the Michigan Department of Natural Resources (DNR) Institute for Fisheries Research indicate that the deepest point in Long Lake is 61 feet. A stream referenced as Long Lake Creek on a USGS 1:100,000 topographic map is the only outlet from Long Lake, exiting the southeast side of the lake and draining into the Black River and there are no major inlets.

The Long Lake watershed, according to GIS files developed by the Watershed Council using watershed delineation and elevation data acquired from the State of Michigan, encompasses approximately 1500 acres, which includes the lake area (Figure 1). The watershed size without the lake area totals 1116 acres, giving a watershed area to lake area ratio of 2.88. The ratio provides a statistic to make comparisons with other lakes; Long Lake has only ~3 acres of land for each acre of water and is therefore more susceptible to landscape changes in the watershed than other lakes with larger watershed:lake area ratios.

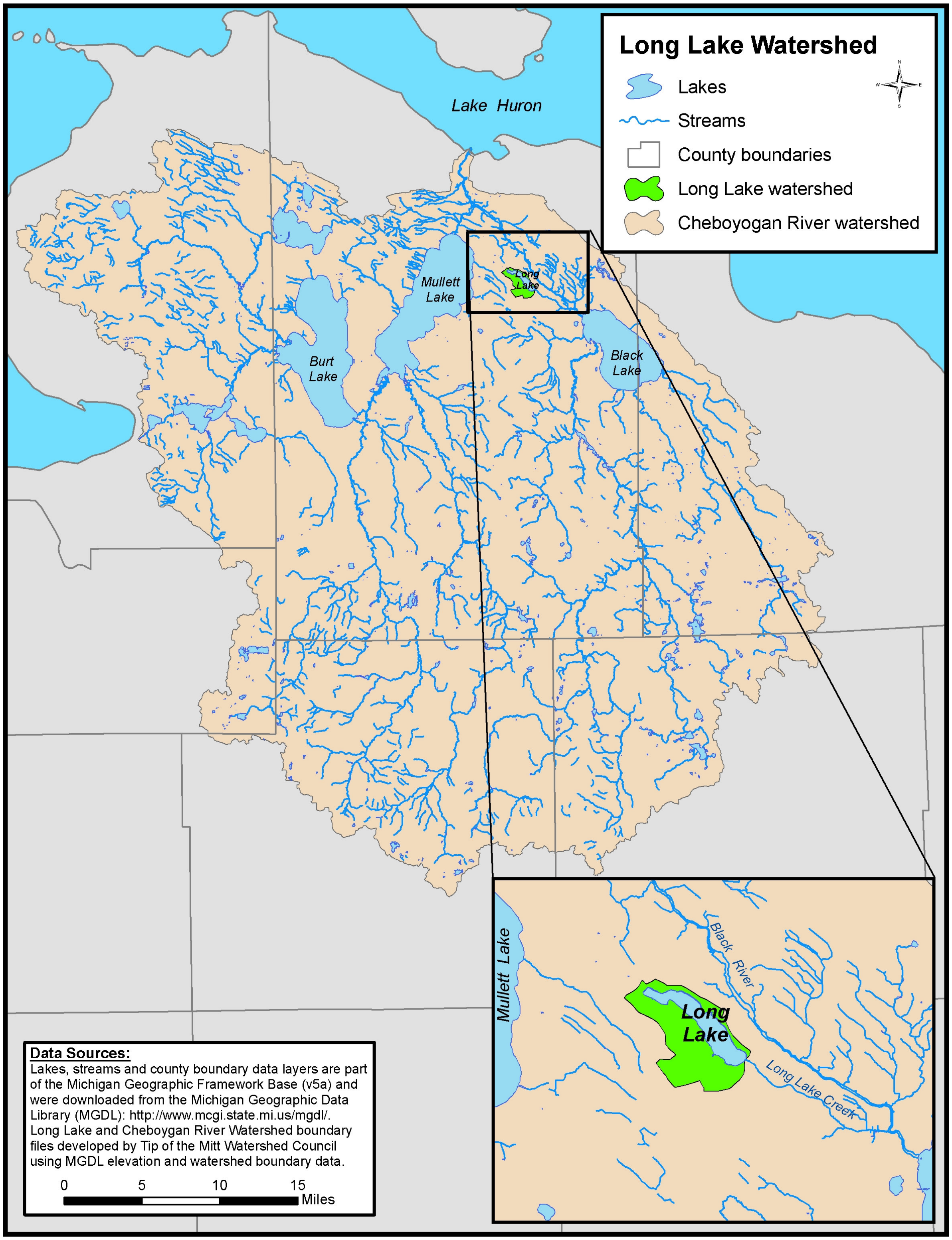
Land cover statistics were generated for the watershed using remotely sensed data from the year 2000 gathered as part of the Coastal Great Lakes Land Cover project (Table 1). Based upon these statistics, it appears that the watershed is still in good shape with a very small percentage of land cover classified as urban or agriculture (~3.5%).

Table 1. Long Lake Watershed Land Cover.

Land Cover Type	Acreage	Percent
Agriculture	7.99	0.53
Forested	648.48	43.08
Grassland	206.29	13.70
Scrub/shrub	40.58	2.70
Urban	46.41	3.08
Water	389.15	25.85
Wetlands	166.33	11.05
TOTAL	1505.23	100.00

Results from data collected on Long Lake through Tip of the Mitt Watershed Council water quality monitoring programs indicate that it is an oligotrophic lake. It has been classified as an oligotrophic lake due to water quality records showing high water transparency, low algae abundance and low nutrient (particularly phosphorus) concentrations. Oligotrophic lakes are characteristically deep, clear lakes with low biological productivity. This characterization is supported by DNR fisheries surveys conducted on Long Lake, which report that many species are present, but that growth is slow. Dissolved oxygen (DO) levels measured by Tip of the Mitt Watershed Council in early spring show high levels throughout the water column, but DNR data from late summer show low DO levels below 35 feet of depth (<5 milligrams/liter, which causes stress or mortality in many aquatic organisms).

Figure 1. Long Lake Watershed



METHODS

An aquatic vegetation survey was conducted on Long Lake during the week of July 11-15, 2005. The aquatic plant communities of Long Lake were documented using two primary methods: 1) aquatic plant sampling at specific locations, and 2) generalized aquatic plant community mapping. Both methods were employed from a motorized boat using a mapping grade GPS (global positioning system). After performing surveys, data collected in the field was processed, cleaned and extrapolated to produce a map of the lake's aquatic plant communities.

Aquatic plant sampling at specific locations:

To gather specific information about aquatic plant community composition, specimens were collected, identified, photographed and recorded in a notebook at 104 sampling stations throughout the lake. Sample site locations (Figure 2) were not random, but rather selected with the intent of collecting representative information on all aquatic plant communities that currently exist in the lake. Transects from shallow to deep vegetated areas were sampled at somewhat regular intervals, but varied depending upon plant community changes that were observable from the surface. Sampling was also conducted in areas of the lake with no visible plants to confirm the areal extent of plant communities. In addition, the precise location of each sampling station was determined using a Trimble GeoExplorer3 GPS unit with a reported accuracy of 1-3 meters.

At each sample site, the boat was anchored, water depth measured and GPS data recorded. 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. A minimum of three throws (using the sampling device) were made at each site, collecting from both sides of the boat. Sampling continued until collector was satisfied that all plant species present at the site were represented in the sample.

Specimens were identified to the species level and representative samples of each species were laid out and photographed with a paper indicating the number assigned to that site. Species density was subjectively determined (in relation to all plants 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) (Appendix A). 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, other aquatic plant experts. All species names, relative species density, overall site density and comments were recorded in a waterproof field notebook. If no plants were encountered during sampling, 'no vegetation' was recorded in the field notebook.

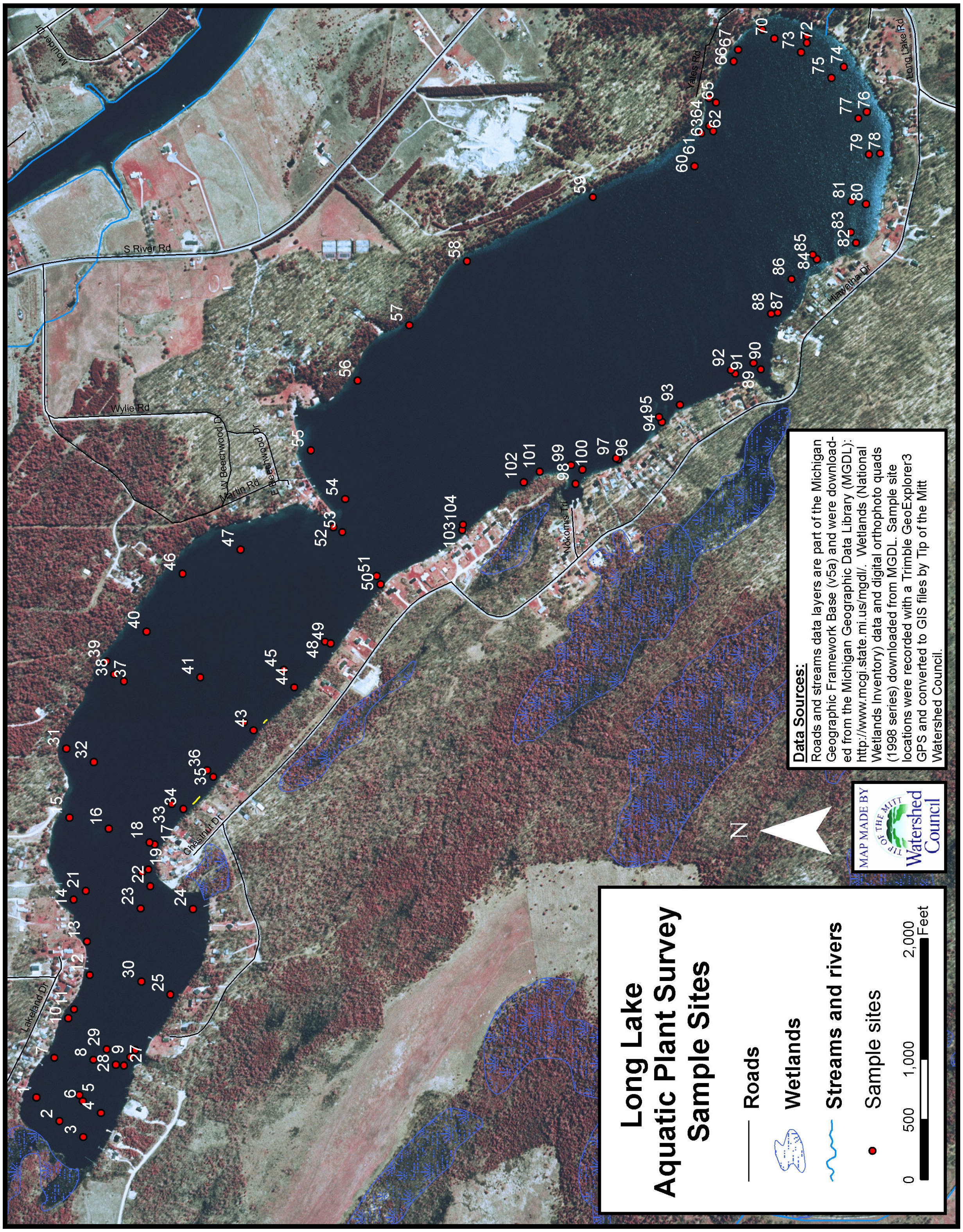
Generalized aquatic plant community mapping:

To supplement aquatic plant species data collected at sample sites and improve the accuracy of delineations between plant communities, notes and GPS data were taken regarding general aquatic plant communities. Neither plant specimens nor photographs were collected for this portion of the field work. Although some of this information was recorded at sample site locations, the majority was collected by surveying emergent vegetation and distinct plant beds in other areas.

At sample sites, comments were often written in the field notebook describing plant communities; e.g. composition, extent, and density. Plant communities described included those extending toward shore, extending along the shore in either direction, and extending from the boat outward. The absence of vegetation in any direction was also noted.

Emergent vegetation and distinct plant beds were mapped directly by navigating around the feature being surveyed or indirectly at an offset distance. Where depth allowed, the perimeter of the plant bed was followed as closely as possible in the boat, collecting GPS data at major vertices to develop polygons representing plant beds. In shallow, shoreline areas, GPS data were collected along the length of shoreline containing the plant bed and an offset distance from the shoreline was estimated (and recorded). On a few occasions, emergent plants and distinct submergent plant communities were mapped in shallow areas by wading.

Figure 2. Long Lake Aquatic Plant Survey Sample Sites



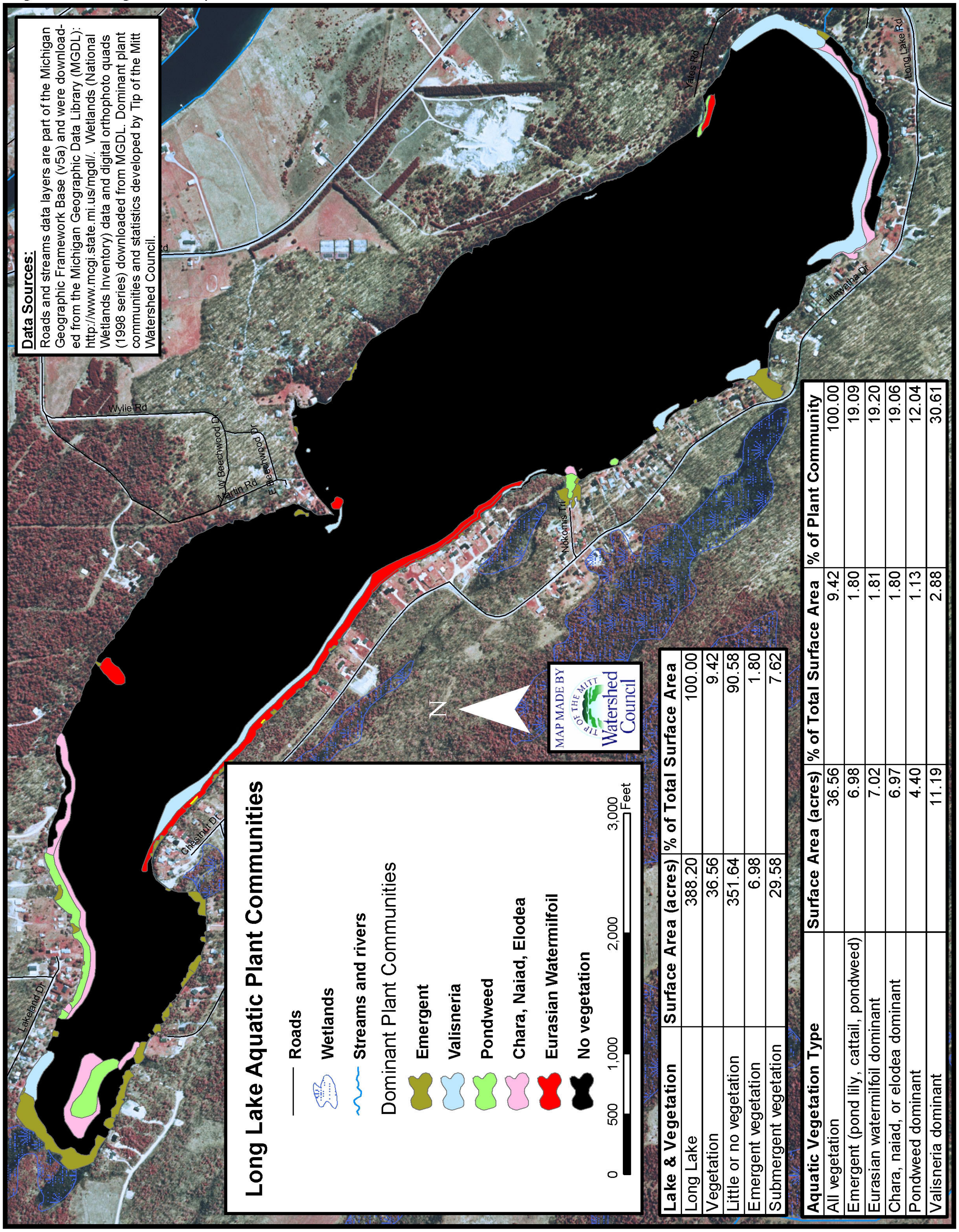
Data processing and map development:

GPS data collected in the field were post-processed and exported into a GIS (Geographical Information System) file format using GPS Pathfinder Office 2.90 software. Polygons depicting distinct plant communities were created using the ESRI GIS software package: ArcView 9.0. Where possible, polygons were developed directly from line or area features mapped with GPS in the field. Otherwise, polygons were created indirectly by extrapolating from or interpolating between sample sites.

Data collected at sample sites and recorded in the field notebook (species names, species density, overall community density, water depth and comments) were entered into a spreadsheet organized by site number. Columns were added to the spreadsheet to include number of species, dominant taxon, and aquatic plant community at each site (Appendix A). Data recorded in the spreadsheet were saved to a *.dbf format, joined to the 'point' GIS data layer, and then exported to a new GIS data layer containing all attribute information collected in the field. Digital photographs were renamed to match sample site numbers and linked to corresponding GPS points in ArcView.

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 interactive and hard-copy maps. The hard-copy map depicts major plant communities in the lake (Figure 3) and the interactive map allows GIS users to view photographs of specimens collected in the field as well as all tabular data associated with the site (by clicking on the point representing the sample site). Upon completing GIS work to develop polygons representing plant communities and vegetation types, area statistics for specific plant communities and vegetation types were calculated.

Figure 3. Long Lake Aquatic Plant Communities.



Lake & Vegetation	Surface Area (acres)	% of Total Surface Area
Long Lake	388.20	100.00
Vegetation	36.56	9.42
Little or no vegetation	351.64	90.58
Emergent vegetation	6.98	1.80
Submergent vegetation	29.58	7.62

Aquatic Vegetation Type	Surface Area (acres)	% of Total Surface Area	% of Plant Community
All vegetation	36.56	9.42	100.00
Emergent (pond lily, cattail, pondweed)	6.98	1.80	19.09
Eurasian watermilfoil dominant	7.02	1.81	19.20
Chara, naiad, or elodea dominant	6.97	1.80	19.06
Pondweed dominant	4.40	1.13	12.04
Valisneria dominant	11.19	2.88	30.61

RESULTS

Specific results from sample sites:

Of the 104 locations sampled on Long Lake, aquatic plant specimens were collected, identified and photographed at 60 sites. The remaining 44 sites had no or little vegetation. A total of 18 different aquatic plant species were collected. The number of species encountered at a site ranged from zero to eight, with an average of 3.8 for sites where vegetation was found.

Table 2. Number of sample sites where specific species were collected.

Aquatic plant species	Number of sites where collected
Vale (eel-grass)	50
Slender naiad	37
Eurasian watermilfoil	28
Muskgrass	28
Broad-leaved pondweed	26
Fries' pondweed	18
Illinois pondweed	18
Common watermilfoil	11
Elodea	11
Floating-leaf pondweed	8
Sago-pondweed	7
Water marigold	4
Whitestem pondweed	4
Common bladderwort	2
Haynes' pondweed	2
Richardson's pondweed	2
Slender pondweed	2
Straight-leaf pondweed	1

Vale and slender naiad were the most common species; collected at 50 and 37 sites respectively (Table 2). Also quite common were Eurasian watermilfoil, muskgrass, and broad-leaved pondweed, found at 26-28 sites. The least common plant species were common bladderwort and Haynes', Richardson's, slender and straight-leaf pondweeds. Aquatic plant communities at the sample sites were dominated by vale and Eurasian watermilfoil (Table 3).

Table 3. Aquatic plant communities at sample sites.

Plant community	Number of sites
Vale mix	26
Eurasian watermilfoil mix	20
Muskgrass mix	8
Pondweed mix	6
Elodea mix	3
Naiad mix	2

<u>Generalized results from interpreted data:</u>

Statistics generated from GIS files reveal that only ~10% of Long Lake's 388 acres contain aquatic plants (Table 4). Approximately 20% of vegetated areas are covered with emergent vegetation (cattails, bulrush, etc.), while the other 80% contains submergent vegetation only. In the areas with submergent vegetation only, Vale-dominated communities are the most common, accounting for over 30% of all plant communities (Table 5). Eurasian watermilfoil dominated communities also cover a large percentage of the total plant community at 20%.

Table 4. Lake and vegetated area statistics.

Lake & Vegetation	Surface Area (acres)	% of Total Surface Area
Long Lake	388.20	100.00
Vegetation	36.56	9.42
Little or no vegetation	351.64	90.58
Emergent vegetation	6.98	1.80
Submergent vegetation	29.58	7.62

Table 5. Submergent vegetation statistics.

Dominant submerged vegetation type	Surface area (acres)	% of lake surface area	% of all plant communities*
Vale dominant	11.19	2.88	30.61
Eurasian watermilfoil dominant	7.02	1.81	19.20
Muskgrass, naiad, or elodea dominant	6.97	1.80	19.06
Pondweed dominant	4.40	1.13	12.04

**emergent plants account for remaining 19.09%*

DISCUSSION

General:

The vast majority of Long Lake contains no or little aquatic plant life (>90%). Although unable to state with certainty the cause for this lack of aquatic plant life, it likely originates from a combination of factors. Lake depth, climatic variables and human activity are probably all factors that contribute to the conspicuous absence of plants.

Based upon data collected during other aquatic plant surveys conducted by the Watershed Council, the majority of aquatic plant life is found in areas of 20 feet of depth or less. Long Lake is deep for its size, possessing extensive areas greater than 20 feet deep. Although the percentage of the lake where depth exceeds 20 feet was not calculated, an approximation based upon bathymetrical (lake bottom contour) maps indicates that roughly 60-80% of the lake surface area is too deep to sustain aquatic plant life. Thus, depth accounts for the majority of the lake area devoid of plants.

Results from field data collection show a pronounced absence of plants from the east side of the lake, particularly in the central and southeast basins (Figure 3). Prevailing winds in this region originate from the northwest and wave action generated from these winds would create adverse environmental conditions not suitable to plant growth. This effect would be most pronounced in the wide lake areas that allow the generation of larger, more powerful, and erosive waves, which is supported by the data. This phenomenon, the absence of plant life on the east-southeast side of the lake, has also been noted in other aquatic plant surveys conducted in the area. The area of the lake affected in this way has not been calculated, but is believed to be substantial and may account for a large percentage of the lake area that is shallower than 20 feet.

Ecosystem disruptions probably also contribute to the limited surface area containing plants. Human activity impacts all aspects of the lake ecosystem, from fisheries to phytoplanktonic algae blooms to aquatic plant growth. Recreational activities, such as boating and swimming damage aquatic plants and plants are often removed or smothered intentionally for these activities. However, human activity can also augment plant growth by adding excess nutrients to the water as a result of lawn fertilization and improper septic system maintenance.

Perhaps even more substantial in terms of ecosystem disruption, though more subtle, is the impact of non-native (also referred to as invasive or exotic) species introduced by humans. Non-native species impact aquatic ecosystems through predation on or displacement of native species, but also cause ecosystem wide changes by disrupting the natural food-web cycle. Three invasive species of concern, noted in this or other surveys on Long Lake, are rusty crayfish (*Orconectes rusticus*), zebra mussels (*Dreissena polymorpha)* and Eurasian watermilfoil (*Myriophyllum spicatum).*

Rusty crayfish, an invasive decapod native to streams of Ohio, Kentucky and Tennessee have been noted by Michigan DNR staff conducting fisheries surveys on Long Lake. Rusty crayfish displace native crayfish and feed heavily on aquatic macroinvertebrates and aquatic vegetation. Native crayfish have similar feeding habits, but the higher metabolic rates of rusty crayfish result in greater consumption. Aquatic plant communities suffer directly due to increased predation. Fisheries suffer indirectly due to competition for available food supply and habitat loss (reduction of aquatic plant beds). Although not scientifically proven, it is speculated that rusty crayfish also impact fisheries through predation on eggs. Unfortunately, there are still no methods for controlling rusty crayfish beyond preventing their introduction.

Zebra mussels, which have European origins, abound in Long Lake. They were frequently observed during this survey and often found in plant samples gathered throughout the lake. Zebra mussels are prolific filter feeders, filtering up to 1 liter of water per day per mussel, feeding upon plankton (minute plant and animal organisms) in the water column. The impacts of zebra mussels are far-reaching as they remove a substantial portion of the food-chain base from the ecosystem, the same base upon which other aquatic organisms depend. In effect, zebra mussels disrupt the natural cycle, removing energy (and nutrients) from the water column and depositing it along the lake bottom.

Although all aspects of zebra mussel impacts on the aquatic plant community are not completely understood, there are processes that are generally agreed upon by aquatic ecologists. On one hand, phytoplanktonic algae populations suffer heavily as they are predated upon by the mussels. On the other hand, zebra mussels deposit nutrients along the lake bottom that provide nourishment for more complex rooted aquatic plants. Thus, the introduction of zebra mussels may actually stimulate growth of rooted plants and increase the overall biomass of this portion of the aquatic plant community. As with rusty crayfish, a safe, reliable, comprehensive method for controlling zebra mussels has not been found.

The invasive species that may be having the greatest impact on the aquatic plant community is Eurasian watermilfoil. Eurasian watermilfoil, like the other non-natives, was probably introduced to the lake by being transported in or on a boat or boat trailer. First documented in the United States in the 1940's, Eurasian watermilfoil has spread throughout the Great Lakes region, now occurring in many of Michigan's inland lakes.

Eurasian watermilfoil is a nuisance species, proliferating and dominating aquatic plant communities where it is introduced. It also hinders recreation, making it difficult to swim, boat and fish. It is particularly problematic for lakes with extensive shallow areas and has recently received considerable media attention in Houghton Lake, which has a surface area of ~20,000 acres and a maximum depth of 25 feet, ideal conditions for this nuisance species. Fortunately, the morphological characteristics of Long Lake, with its ample deep areas, will prevent Eurasian watermilfoil from becoming the nuisance that it has in shallow lakes. However, if left unchecked it could have considerable impacts on the lake ecosystem.

Aquatic ecosystems, like terrestrial, are extremely complex systems, wherein a great variety of organisms interact for survival. Many species have symbiotic (or parasitic) relationships with other species and depend upon them for survival. This being the case, the elimination or severe reduction of an aquatic plant species as the result of the introduction of and domination by a non-native species like Eurasian watermilfoil could have significant and long-lasting, if not permanent, effects on the ecosystem. Once introduced, a non-native species will probably never be completely eliminated from the system. However, there are a variety of methods available for controlling Eurasian watermilfoil, which are presented in the next section.

Aquatic Plant Control Options:

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. An aquatic plant control option matrix was developed for quick reference regarding advantages and disadvantages of each option (Appendix B).

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: reports/surveys from regulatory agencies such as DNR, research reports from universities, and reports/surveys from other organizations/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

Chemical control, the application of herbicides, is the easiest, fastest and often cheapest (in the short-term) method for controlling an aquatic nuisance plant species. 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.

If it seems too good to be true, then it probably is: there are a number of downsides to chemical application. A variety of human and animal health problems, ranging from cancer to infertility, are associated with chemicals in the environment and herbicide application is doing just that, introducing chemicals into your environment. Even though companies producing herbicides to treat aquatic plant growth consistently guarantee the safety of their products and even if the Michigan Department of Environmental Quality gives its stamp of approval (approved herbicides and target species - Appendix C), you may want to think twice about adding chemicals to the water that you swim and fish in. Beyond surface water contamination, groundwater contamination should also be considered as chemicals in surface water have been shown to migrate into groundwater (Lovato et al. 1996).

Chemical application, in the case of rapid-acting herbicides, also has the potential to cause problems in the aquatic ecosystem that lead to fish kills. A large amount of dead and decaying plant material as the result of herbicide treatment may lead to dissolved oxygen depletion as these materials are consumed by aerobic decomposers. Depleted or low dissolved oxygen levels will kill or stress fish and many other organisms as almost all life needs oxygen to survive.

Another consideration regarding chemical control is 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 the other methods. More alarming still 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. There are many drawbacks to this approach, which are discussed by Wisconsin DNR staff in a 2005 issue of Lake Tides (Hauxwell 2005). If the Lake Association opts for any type of chemical control, a permit through the Michigan Department of Environmental Quality will be required.

Physical control

Physical aquatic plant control can be accomplished through various means including: manual cutting/removal, mechanical cutting/removal, dredging, lake drawdown, and barrier installation. Manual removal is performed by getting into the water and 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 eliminates sunlight and prevents plant growth. The following paragraphs discuss each physical method in greater detail, including advantages and disadvantages.

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.

Advantages of both cutters and harvesters are that large areas of open water are immediately opened and, because the entire plant is not removed, habitat for fish and other aquatic organisms are preserved. One of the biggest disadvantages of both is the costs for purchasing/renting equipment or contracting the work to be performed. Cutters are less expensive than harvesters, but do not remove the plant material and thus, require extra work to gather cut plant material (to prevent dissolved oxygen loss due to decomposing plant matter). Whether collecting plants immediately with a harvester or after the fact when using a cutter, some plant cuttings are missed and will accumulate on shore or decompose in the water. By removing plant material harvesters have the added benefit of removing nutrients, such as phosphorus and nitrogen, from the ecosystem (providing that materials are disposed of in such a manner that the nutrients are not re-introduced to the lake). The downside of removing plant material is that fish, aquatic insects and other invertebrates are inevitably removed along with the plants.

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. Eurasian watermilfoil fragments 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.

Aquatic plant control using cutters and harvesters in lakes containing many obstructions in the cutting zone, such as logs, may be difficult. Besides the possibility of hitting obstacles and damaging equipment, the poor maneuverability of harvesters for moving around obstructions (including docks) and operating in shallow water should be considered. Specific to harvesters, plant material disposal needs to be considered and planned for. On large lakes, multiple sites may be needed for off-loading spoils in order to reduce harvester travel time. Collected plants will need to be properly disposed of, such that decaying plant material and nutrients are not re-introduced to the lake. Any cutting or harvesting equipment brought in from another lake must be carefully inspected to ensure that no invasive species are on it. A final consideration is maintenance; cutters and harvesters will eventually require maintenance and therefore, these costs will need to be accounted for.

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 large 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. Any type of dredging requires a permit by the Michigan Department of Environmental Quality (DEQ).

Lake drawdown is a cost-effective method used for aquatic plant control where lake-level control structures are in place. For species that do not have overwintering structures (seeds, winter buds, etc.) such as milfoil or elodea, exposure to freezing temperatures during lake drawdown is fatal. Lake drawdown during hot, dry summer months will kill some aquatic plants due to desiccation and high temperatures. To be effective, lake water levels need to be lowered to the extent that sediments containing nuisance plant areas are exposed for a long period of time (one month or more is recommended).

Lowering lake levels also impacts other denizens of the aquatic community, such as turtles, frogs and macroinvertebrates that reside or overwinter in shallow areas. If drawdowns are not performed on a regular basis, aquatic plants will simply recolonize affected areas. Some aquatic plants thrive under drawdown conditions and there may be long-lasting or even permanent changes in the aquatic plant community. Other considerations for shoreline residents include: boats may not be able to be launched, docks and water intakes may be left high and dry, and lakeside well water-levels may lower. Performing lake drawdowns requires a permit by DEQ.

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 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 (DEQ). The introduction of untested, non-native bio-control organisms can severely alter the native ecosystem.

Bio-control is often expensive or may not even be available for the nuisance aquatic plant species in question. The native weevil that feeds upon Eurasian watermilfoil is available through EnviroScience, Inc. in Ohio, but costs over one dollar each and thousands or often, tens of thousands, need to be stocked to control Eurasian watermilfoil. Surveys conducted before, during and after stocking efforts to gauge project progress result in additional costs. The purple loosestrife beetle is not even commercially available, but rather has to be gathered by hand from locations where it has become established. 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: availability of suitable habitat for weevil over-wintering, sufficient stocking numbers, and recreational impacts on stocked weevils (such as boating and swimming). 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. The most notable is the resounding and enduring success of the first Eurasian watermilfoil weevil stocking control project in Michigan. While conducting an aquatic plant survey in 1996, Tip of the Mitt Watershed Council documented problematic Eurasian watermilfoil growth in Paradise Lake in Cheboygan County. The Paradise Lake Association contracted EnviroScience to stock weevils for a period of several years, but surveys conducted after the first two years of stocking indicated that further treatment was unnecessary and no stocking has been required since.

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 there aren't even any concerns of introducing an exotic species as the weevil is native.

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 Eurasian 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 first good 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. Certain variables, such as lake morphology and prevailing winds cannot be controlled by watershed residents and lake users. The important thing is to concentrate efforts on factors that can be controlled. 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 other non-native species (such as the nuisance plant hydrilla that looms on the horizon) by posting signs and educating members and other lake users.

Non-native species in the aquatic plant community, specifically Eurasian watermilfoil, was an issue of great concern expressed by Long Lake residents. Eurasian watermilfoil was encountered in all three of the major basins of Long Lake and was particularly abundant along the southwest shore of the central basin. Left unchecked, this invasive species could further impact the native aquatic plant community and cause ecosystem-wide changes.

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.

In general, the Watershed Council does not support the use of chemicals for controlling aquatic plants due to the many known negative impacts to the aquatic ecosystem, but perhaps more importantly, because of the unknown effects of releasing chemicals into the water. Plant cutting and/or removal, whether by hand or machine, is also not recommended as it could exacerbate the problem due to the ability of Eurasian watermilfoil to spread through fragmentation. Dredging on the level required to control the extensive Eurasian watermilfoil would be very expensive, severely impact the ecosystem and probably not be permitted by DEQ. Lake drawdown could also severely disturb the lake ecosystem and thus, not recommended by the Watershed Council.

As only one aquatic plant is creating a nuisance and an environmentally safe bio-control agent exists for that plant, the Watershed Council recommends stocking the aquatic weevil (*Euhrychiopsis lecontei)* to control the Eurasian watermilfoil infestation. The high initial costs of surveying and stocking the weevil 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.

EnviroScience, Inc developed the MiddFoil® process for biological control of Eurasian watermilfoil using weevils and can be contacted at: 3781 Darrow Road, Stow, OH 44224 (800) 940-4025. Dialogue should begin between the Lake Association and EnviroScience as soon as possible as developing a weevil stocking program requires a great deal of advance planning. The Watershed Council has worked with EnviroScience on other projects and may be available to assist with certain aspects of the MiddFoil® process.

The results of this study should be widely dispersed to get maximum returns 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 Long Lake, there will be less resistance to proposed solutions. Furthermore, an informed public may lead to behavioral changes that benefit aquatic plant management, such as reducing lake nutrient loads and preventing the introduction of more non-native species.

To properly manage the aquatic plant community of Long 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 presence of additional non-native aquatic plant species. Although dependent upon many different circumstances, surveying the aquatic plant community on a 5-10 year basis should be sufficient.

Sources of error:

There were certain limitations in resources and methodology that could have produced errors in the data generated from this survey. Sampling 104 sites provided enough data to map major plant communities, but some small or isolated plant communities might not be represented in the final product. Fairly rigorous sampling techniques and effort were employed, but there is a possibility that not all species were collected at each site.

Sample site selection was not completely random, which has consequences for statistical analysis and study repeatability. Sample sites were spread throughout the lake, but shallow areas with visible plant growth were given heavier bias. Only the largest and therefore, most obvious aquatic plant communities were mapped, though extra attention was given to accurately mapping Eurasian watermilfoil beds due to concerns expressed by the Lake Association.

All GPS units have accuracy limits. The mapping-grade GPS unit used for this survey has a reported accuracy of 1 to 3 meters. Field checks on known benchmarks by Watershed Council staff have shown the spatial error to usually be less than 1 meter, which is more than adequate for the needs of this study. Some plant communities, particularly emergents and near-shore submergents, were often mapped at an offset due to inaccessibility. Much of the aquatic plant community mapping was performed in a GIS by interpolation between sampling points or extrapolation from sampling points.

Watershed Council staff collected the most accurate field data possible considering time and resource constraints. A considerable amount of time was devoted to quality control while collecting data in the field and processing and analyzing data in the office. The Watershed Council is confident that the final results represent the best product possible under the circumstances.

CONCLUSION

The areal extent of habitat suitable for aquatic plants on Long Lake appears to be limited due to lake morphology and climatic variables. Human activity and the introduction of exotic species threaten existing native plant communities. Despite all these problems, the aquatic plant community of Long Lake has maintained a healthy diversity (18 species total) of largely native species.

Eurasian watermilfoil was found to dominate substantial areas of the plant community throughout the lake. If left unchecked, it could have long-lasting or permanent impacts on the lake ecosystem. Fortunately, an environmentally safe bio-control agent exists for this invasive aquatic plant. By stocking aquatic weevils the aquatic plant community should be brought back into balance, ultimately benefiting the entire ecosystem.

Data collected during this survey should provide a strong basis for making informed and therefore, good lake-wide aquatic plant management decisions. Survey information also provides a reliable base for making comparisons and examining trends. Unfortunately, historical aquatic plant data was not found and may, in fact, not exist, so it is impossible to quantitatively discuss changes in aquatic plant abundance. Despite the lack of historical data, the Lake Association now has the ability to track changes in the aquatic plant community and adjust lake management practices accordingly.

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Appendix A: Sample Site Data.

Site ID	Depth (ft)	Muskgrass	Elodea	Water marigold	Common watermilfoil	Eurasian watermilfoil	Slender naiad	Broadleaved pondweed	Fries's pondweed
1	3' 6"	L	No	L	No	No	L	No	L
2	5' 6"	No	No	No	No	No	No	No	No
3	5' 1"	M	VL	No	M	No	L	No	No
4	7' 8"	M	No	No	L	No	L-M	No	No
5	9' 10"	M	No	No	VL	No	L	No	No
6	9' 7"	No	No	L-M	No	VL	VL	No	No
7	13' 1"	VL	No	No	No	No	L-M	No	No
8	20' 8"	VL	No	No	No	No	No	No	No
9	7' 5"	No	No	No	No	No	VL	No	No
10	8' 5"	VL	No	No	No	No	L-M	No	No
11	9' 11"	VL	H	No	No	L	VL-L	M	No
12	9'	VL	L	No	VL	M	L	M	No
13	8'	No	M	No	No	H	L	L	H
14	7' 10"	L	No	M-H	No	No	No	No	H
15	5' 5"	M	No	No	No	No	M	No	No
16	5' 11"	No	No	No	No	No	No	No	No
17	5' 7"	L	H	L	No	H	No	H	M
18	19' 5"	No	No	No	No	No	No	No	No
19	6' 3"	M	No	No	No	H	M	M-H	No
20	20' 10"	No	No	No	No	No	No	No	No
21	11' 8"	No	No	No	No	No	No	No	No
22	5' 2"	No	No	No	No	No	No	No	No
23	18' 3"	No	No	No	No	No	No	No	No
24	4'	No	No	No	No	No	No	No	No
25	8' 3"	No	No	No	No	No	No	No	No
26	7' 11"	No	No	No	VL	VL	L	L	No
27	8' 2"	No	No	No	No	No	L	No	No
28	10' 6"	No	No	No	No	No	No	No	L
29	20' 2"	No	No	No	No	No	No	No	No
30	28' 8"	No	No	No	No	No	No	No	No
31	8' 4"	L-M	No	No	No	No	M	No	VL
32	16' 2"	No	No	No	No	No	No	No	No
33	8' 9"	No	No	No	No	No	No	L	No
34	4' 9"	H	VL	No	No	M-H	VL	L	No
35	6' 3"	VL	VL	No	No	VH	No	No	No
36	9' 1"	No	No	No	No	No	No	No	No
37	13' 8"	No	No	No	L-M	L-M	L	No	M
38	11'	No	No	No	No	VH	L	L	No
39	7'2"	L	No	No	No	H	M	M-H	No
40	13' 9"	No	No	No	No	No	No	No	No
41	26'	No	No	No	No	No	No	No	No
42	11' 3"	No	No	No	No	No	No	No	No
43	8' 3"	VL	No	No	No	VH	VL	No	No
44	8' 9"	No	No	No	No	VH	VL	No	No
45	14'	No	No	No	No	No	No	No	No
46	12' 2"	No	No	No	No	No	No	No	No
47	11' 3"	No	No	No	No	No	No	No	No
48	10' 10"	No	No	No	No	No	No	No	No
49	7' 10"	No	No	No	No	VH	VL	No	No
50	2' 11"	No	No	No	No	VL-L	M	M	No
51	11' 4"	No	No	No	No	VH	No	No	No

Site ID	Illinois pondweed	Floatingleaf pondweed	Whitestem pondweed	Slender pondweed	Richardsons pondweed	Straightleaf pondweed	Haynes' pondweed	Sago pondweed	Common bladderwort
1	No	L	L-M	No	No	No	No	No	L
2	No	No	No	No	No	No	No	No	No
3	No	No	M	No	No	No	No	No	No
4	M	No	No	No	No	No	No	No	No
5	No	No	No	No	No	No	No	No	No
6	No	No	H	No	No	No	No	L	No
7	No	No	No	No	No	No	No	No	No
8	No	No	No	No	No	No	No	No	No
9	No	No	No	No	No	No	No	No	No
10	L-M	No	No	No	No	No	No	No	No
11	L-M	No	No	No	No	No	No	No	No
12	No	No	No	No	No	No	No	No	No
13	No	No	No	No	No	No	No	H	No
14	No	No	No	No	L	No	No	No	No
15	L	No	No	No	No	No	No	No	No
16	No	No	No	No	No	No	No	No	No
17	No	No	No	No	No	No	No	No	No
18	No	No	No	No	No	No	No	No	No
19	L	No	No	No	L	No	No	No	No
20	No	No	No	No	No	No	No	No	No
21	No	No	No	No	No	No	No	No	No
22	No	No	No	No	No	No	No	No	No
23	No	No	No	No	No	No	No	No	No
24	No	No	No	No	No	No	No	No	No
25	No	No	No	No	No	No	No	No	No
26	No	No	No	No	No	No	No	No	No
27	No	No	No	No	No	No	No	No	No
28	No	No	M	No	No	No	No	L	No
29	No	No	No	No	No	No	No	No	No
30	No	No	No	No	No	No	No	No	No
31	No	No	No	No	No	No	No	No	No
32	No	No	No	No	No	No	No	No	No
33	No	No	No	No	No	No	No	No	No
34	No	No	No	No	No	No	No	No	No
35	L	No	No	No	No	No	No	No	No
36	No	No	No	No	No	No	No	No	No
37	No	No	No	No	No	No	No	VL	No
38	No	No	No	No	No	No	M	VL	No
39	No	L	No	No	No	No	No	No	No
40	No	No	No	No	No	No	No	No	No
41	No	No	No	No	No	No	No	No	No
42	No	No	No	No	No	No	No	No	No
43	No	No	No	No	No	No	No	No	No
44	No	No	No	No	No	No	No	No	No
45	No	No	No	No	No	No	No	No	No
46	No	No	No	No	No	No	No	No	No
47	No	No	No	No	No	No	No	No	No
48	No	No	No	No	No	No	No	No	No
49	No	No	No	No	No	No	No	No	No
50	No	No	No	M-H	No	No	No	No	No
51	No	No	No	No	No	No	No	No	No

Site ID	Eel-grass	# of taxa	Dominant taxon	Community
1	H	8	Vale and pondweed	Vale mix
2	No	0	None	
3	No	5	Chara, pondweed, and native milfoil	Chara mix
4	L	5	Chara and pondweed	Chara mix
5	M	4	Chara and vale	Chara mix
6	L-M	6	Pondweed	Pondweed mix
7	L	3	Najas and vale	Vale mix
8	No	1	Chara	Chara mix
9	No	1	Najas	Najas mix
10	L	4	Najas and pondweed	Pondweed mix
11	L-M	8	Elodea, pondweed, and vale	Elodea mix
12	No	6	Eurasian watermilfoil and broad-leaf pondweed	EWM mix
13	L	8	Eurasian watermilfoil and pondweed	EWM mix
14	M-H	5	Fries pondweed, vale and marigold	Vale mix
15	L	4	Chara and najas	Chara mix
16	No	0	None	None
17	M	7	Elodea, pondweed, and EWM	Elodea mix
18	No	0	None	None
19	M-H	7	Eurasian watermilfoil, broad-leaf pondweed & vale	EWM mix
20	No	0	None	None
21	No	0	None	None
22	No	0	None	None
23	No	0	None	None
24	No	0	None	None
25	No	0	None	None
26	No	4	EWM, pondweed, najas	Najas mix
27	L	2	Najas and bladderwort	Najas mix
28	No	3	Pondweeds	Pondweed mix
29	No	0	None	None
30	No	0	None	None
31	L	4	Najas and chara	Chara mix
32	No	0	None	None
33	M	2	Vale and pondweed	Vale mix
34	M	6	Chara, EWM and vale	Chara mix
35	L-M	5	EWM and vale	EWM mix
36	No	0	None	None
37	L	6	EWM, pondweed, vale	EWM mix
38	VL	5	EWM, pondweed, vale	EWM mix
39	M	6	EWM, pondweed, vale, najas	EWM mix
40	No	0	None	None
41	No	0	None	None
42	No	0	None	None
43	L	4	EWM, vale, najas	EWM mix
44	M	3	EWM, vale, najas	EWM mix
45	No	0	None	None
46	No	0	None	None
47	No	0	None	None
48	No	0	None	None
49	No	2	EWM, vale	EWM mix
50	H	5	Vale, pondweed, najas	Vale mix
51	VL	2	EWM, vale	EWM mix

Site ID	Depth (ft)	Muskgrass	Elodea	Water marigold	Common watermilfoil	Eurasian watermilfoil	Slender naiad	Broadleaved pondweed	Fries's pondweed
52	5' 9"	No	No	No	No	L	M	M	No
53	17' 7"	No	No	No	No	No	No	No	No
54	12' 4"	No	No	No	No	VH	No	No	No
55	7' 1"	No	No	No	No	No	No	No	No
56	8' 1"	No	No	No	No	No	No	No	No
57	8' 5"	No	No	No	No	No	No	No	No
58	6' 9"	No	No	No	No	No	No	No	No
59	9' 1"	No	No	No	No	No	No	No	No
60	9' 3"	No	No	No	No	No	No	No	No
61	4' 10"	VL	No	No	No	No	No	M	No
62	?	No	No	No	No	No	No	No	No
63	12' 2"	VL	No	No	No	VH	No	L	No
64	5' 11"	No	M-H	No	No	VL	No	M	M
65	11'	L-M	VL	No	M	M	No	L	L
66	6' 11"	No	No	No	No	No	No	No	No
67	6' 5"	L	No	No	No	No	L	No	No
68	4' 3"	No	No	No	No	No	L	L	No
69	7' 9"	No	No	No	No	No	No	M	H
70	12' 8"	No	No	No	No	No	No	No	No
71	5' 3"	No	No	No	No	No	No	No	M
72	7' 11"	No	No	No	No	No	No	No	M
73	21' 12"	No	No	No	No	No	No	No	No
74	5' 5"	L	No	No	No	VL	L-M	No	L
75	17' 7"	No	No	No	No	No	No	No	No
76	8' 4"	No	No	No	No	No	No	L	No
77	14'	No	No	No	No	No	No	No	No
78	7' 8"	L	No	No	No	No	L-M	No	No
79	12' 4"	No	No	No	No	No	VL	No	No
80	6'	L	No	No	No	VL	L	No	No
81	12' 9"	No	No	No	No	No	No	No	No
82	6' 5"	L	No	No	No	No	L	L	M
83	10' 9"	No	No	No	No	No	No	No	No
84	8' 3"	No	L	No	VL	No	No	M-H	L
85	11' 7"	No	No	No	No	No	No	No	No
86	10' 1"	No	No	No	No	No	VL	No	No
87	10' 1"	No	No	No	L-M	No	VL	VL	No
88	11' 11"	No	No	No	No	No	No	No	No
89	6'	No	No	No	No	No	L	No	H
90	9' 1"	No	No	No	No	No	VL	No	No
91	10'	L	No	No	L-M	No	No	L	No
92	11' 7"	No	No	No	No	No	No	No	No
93	6' 4"	No	No	No	No	No	No	No	VL
94	5' 4"	No	No	No	No	No	No	No	No
95	12' 5"	No	L	No	No	No	No	No	No
96	4' 6"	No	No	No	No	No	No	No	No
97	8' 7"	No	No	No	No	No	No	No	No
98	3' 10"	L	No	No	No	No	M	H	No
99	6' 7"	No	No	No	No	No	No	No	No
100	6' 2"	No	No	No	No	M	No	No	No
101	6' 3"	No	No	No	No	No	No	M	No
102	8' 10"	No	No	No	VL-L	VH	No	L-M	No
103	3' 6"	No	No	No	No	VH	No	No	No
104	9' 11"	No	No	No	No	VH	No	No	No

Site ID	Illinois pondweed	Floatingleaf pondweed	Whitestem pondweed	Slender pondweed	Richardsons pondweed	Straightleaf pondweed	Haynes' pondweed	Sago pondweed	Common bladderwort
52	L-M	L-M	No	No	No	No	No	L	No
53	No	No	No	No	No	No	No	No	No
54	No	No	No	No	No	No	No	No	No
55	VL	No	No	No	No	No	No	No	No
56	No	No	No	No	No	No	No	No	No
57	No	No	No	No	No	No	No	No	No
58	No	No	No	No	No	No	No	No	No
59	No	No	No	No	No	No	No	No	No
60	No	No	No	No	No	No	No	No	No
61	M-H	M	No	No	No	No	No	No	No
62	No	No	No	No	No	No	No	No	No
63	No	No	No	No	No	No	No	No	No
64	L	No	No	No	No	No	No	No	No
65	No	No	No	No	No	No	No	No	No
66	No	No	No	No	No	No	No	No	No
67	No	No	No	No	No	No	No	No	No
68	L	No	No	No	No	No	No	No	No
69	No	M	No	No	No	No	No	No	No
70	No	No	No	No	No	No	No	No	No
71	L	No	No	No	No	No	No	No	No
72	No	No	No	No	No	No	No	No	No
73	No	No	No	No	No	No	No	No	No
74	L	No	No	No	No	No	No	VL	No
75	No	No	No	No	No	No	No	No	No
76	No	No	No	No	No	No	No	No	No
77	No	No	No	No	No	No	No	No	No
78	L-M	No	No	No	No	No	No	No	No
79	No	No	No	No	No	No	No	No	No
80	No	No	No	No	No	No	No	No	No
81	No	No	No	No	No	No	No	No	No
82	VL	No	No	No	No	No	No	No	No
83	No	No	No	No	No	No	No	No	No
84	No	L	No	No	No	No	No	No	No
85	No	No	No	No	No	No	No	No	No
86	No	No	No	No	No	No	No	No	No
87	No	No	No	No	No	VL	No	No	No
88	No	No	No	No	No	No	No	No	No
89	No	No	No	No	No	No	No	No	No
90	No	No	No	No	No	No	No	No	No
91	No	No	No	No	No	No	No	No	No
92	No	No	No	No	No	No	No	No	No
93	No	No	No	No	No	No	No	No	No
94	M-H	L	No	No	No	No	No	No	No
95	No	No	No	No	No	No	No	No	No
96	H	No	No	No	No	No	L	No	No
97	No	No	No	No	No	No	No	No	No
98	L-M	No	No	H	No	No	No	No	L
99	No	No	No	No	No	No	No	No	No
100	No	No	No	No	No	No	No	No	No
101	No	No	No	No	No	No	No	No	No
102	No	No	No	No	No	No	No	No	No
103	No	L-M	No	No	No	No	No	No	No
104	No	No	No	No	No	No	No	No	No

Site ID	Eelgrass	# of taxa	Dominant taxon	Community
52	VL	2	EWM, vale	EWM mix
53	M-H	7	Vale, pondweed, najas	Vale mix
54	No	0	None	None
55	M	2	EWM, vale	EWM mix
56	M	2	Vale and pondweed	Vale mix
57	No	0	None	None
58	No	0	None	None
59	No	0	None	None
60	L	1	Vale	Vale mix
61	No	0	None	None
62	M-H	5	Vale and pondweed	Vale mix
63	No	0	None	None
64	No	3	EWM and pondweed	EWM mix
65	No	5	Elodea and pondweed	Elodea mix
66	VL	7	EWM, native mifoil, chara	EWM mix
67	No	0	None	None
68	M	3	Vale, najas, chara	Vale mix
69	M	4	Vale, pondweed, najas	Vale mix
70	H	4	Vale and pondweed	Vale mix
71	No	0	None	None
72	L-M	3	Vale and pondweed	Vale mix
73	No	1	Fries pondweed	Pondweed mix
74	No	0	None	None
75	M	7	Vale, pondweed, najas	Vale mix
76	No	0	None	None
77	No	1	Pondweed	Pondweed mix
78	No	0	None	None
79	No	3	Pondweed and najas	Pondweed mix
80	L	2	Vale and najas	Vale mix
81	No	3	Najas and chara	Chara mix
82	VL	1	Vale	Vale mix
83	M-H	6	Vale, pondweed, najas	Vale mix
84	No	0	None	None
85	H	6	Vale, pondweed, elodea	Vale mix
86	No	0	None	None
87	No	1	None	None
88	M-H	5	Vale and native milfoil	Vale mix
89	No	0	None	None
90	H	3	Vale and pondweed	Vale mix
91	No	1	None	None
92	M-H	4	Vale and native milfoil	Vale mix
93	No	0	None	None
94	L	2	Vale and pondweed	Vale mix
95	H	3	Vale and pondweed	Vale mix
96	L-M	2	Vale and elodea	Vale mix
97	H	3	Vale and pondweed	Vale mix
98	No	0	None	None
99	H	7	Vale, pondweed, najas	Vale mix
100	No	0	None	None
101	No	1	EWM	EWM mix
102	H	2	Vale and pondweed	EWM mix
103	L-M	4	EWM, vale, pondweed	EWM mix
104	VL	3	EWM, vale, pondweed	EWM mix

Appendix B: 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 C: 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."

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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.