Black Lake Aquatic Plant Survey 2005

by Tip of the Mitt Watershed Council

Completed by Kevin L. Cronk

March 25, 2006

Table of Contents

List of Tables

Page

List of Figures

Page

SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but become a recreational nuisance when growth is excessive. Non-native or invasive aquatic plants potentially impact lake ecosystems by dominating and reducing native plant communities. Responding to concerns expressed by shoreline residents regarding problematic aquatic plant growth and the possibility of non-native species impacting the lake ecosystem, the Black Lake Association contracted the Tip of the Mitt Watershed Council to conduct an aquatic plant survey on Black Lake in Cheboygan and Presque Isle Counties, Michigan. The aquatic plant survey was conducted during the months of July and August in 2005. Aquatic plant specimens were collected and documented at 145 sites around the lake and major plant communities were also mapped. A total of 32 aquatic plant species were documented, all native to Michigan. The majority of Black Lake contains little or no vegetation (>85%). Muskgrass (*Chara spp.*) and variable-leaf watermilfoil (*Myriophyllum heterophyllum*) were the dominate species in over 90% of vegetated areas. Variable-leaf watermilfoil growth is excessive in some areas, causing a recreational nuisance and potentially impacting the lake ecosystem. There are many options for controlling plant growth, though most are not recommended due to feasibility or water quality issues. Biological control may be possible using a native aquatic weevil (*Euhrychiopsis lecontei),* which has been used to control growth of a related, yet non-native species, Eurasian watermilfoil (*Myriophyllum spicatum*). The weevil has not been tested on native watermilfoils, but this may be an opportunity to do so. The Black Lake Association now has a good data set to help guide aquatic plant management decisions and to track changes over time. Optimally, aquatic plant surveys should be conducted on the lake every 5-10 years. Future surveys can be improved by tweaking methodologies and reserving additional time and resources for more comprehensive field data collection.

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 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 establishing an aquatic plant management 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 expressed by Black Lake shoreline residents regarding nuisance aquatic plant growth, the Black Lake Association members took this first step and contracted the Tip of the Mitt Watershed Council to conduct a comprehensive aquatic plant survey on the lake. Watershed Council staff collected field data during the summer of 2005. Survey field methods, data management procedures, project results, discussion of results, aquatic plant control options and recommendations are contained in this report.

Study area:

Black Lake is located in the northeast tip of the Lower Peninsula of Michigan; in Grant and Waverly Townships of Cheboygan County and Bearinger and North Allis Townships of Presque Isle County. Although not pronounced, there are two distinguishable basins in Black Lake. The northwest end of the lake (northwest of a line drawn from Taylor Road on the west side to the Black Lake State Forest Campground boat ramp on the east side) is characterized by broad shallow areas that deepen gradually. The southeast end of the lake is much deeper, wider and has a more pronounced drop-off, particularly on the western side. Based upon GIS (Geographical Information System) files generated through on-screen digitization of 1998 aerial photos, the shoreline measures 19.2 miles and lake surface area totals 10,133 acres. Maps acquired from the Michigan Department of Natural Resources (DNR) Institute for Fisheries Research indicate that the deepest point is located in the southwest section of Black Lake and measures approximately 50 feet.

The largest inlet is the Black River, which flows into Black Lake on the west side, just north of Five-mile Point. The next largest tributary is the Rainy River, which enters in the southeast corner of the lake. Several smaller streams, including Stony, Stewart, and Fisher Creeks in the south, Mud Creek in the west and Cains Creek to the north, also flow into Black Lake. The Lower Black River is the only outlet, which exits from the northwestern corner of the lake.

According to GIS files developed by the Watershed Council using watershed boundary and elevation data acquired from the State of Michigan, the Black Lake watershed encompasses approximately 357,307 acres, which includes the lake area (Figure 1). By dividing the lake surface area into the watershed area (not including the lake), a watershed area to lake area ratio of 34.26 was calculated. The ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover. There are over 34 acres of land in the watershed for each acre of Black Lake water surface, which, compared to other lakes in Michigan, is quite high. Essentially, the statistic indicates that the large size of the Black Lake watershed provides a protective buffer for lake water quality; i.e., it would require considerable landscape development (in terms of area) to negatively impact water quality.

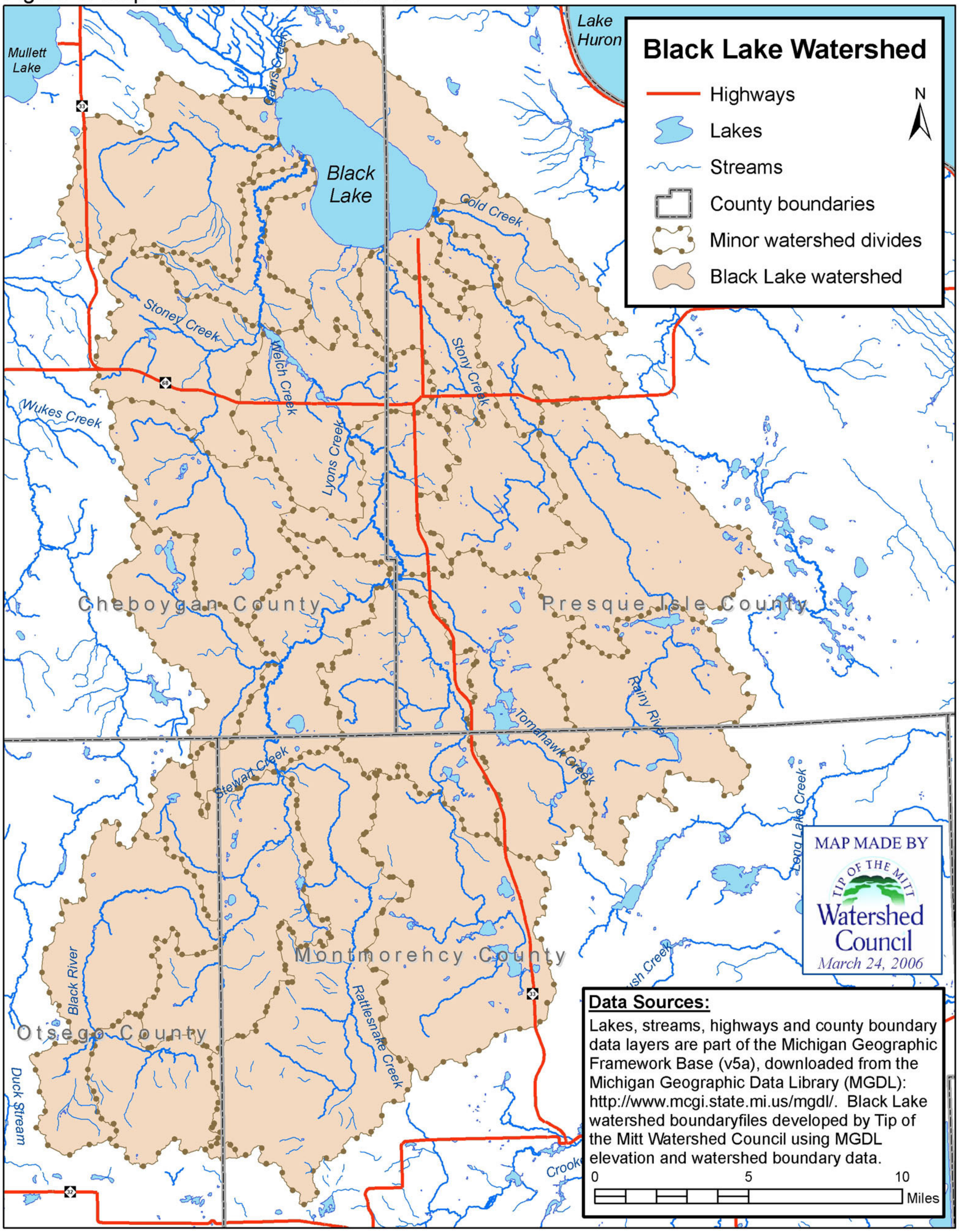
Land cover statistics were generated for the watershed using remotely sensed data from the year 2000, which was produced as part of the Coastal Great Lakes Land Cover project (Table 1). Based upon these statistics, it appears that the watershed is relatively pristine with a very small percentage of land cover classified as urban or agriculture (~4%).

Table 1. Black Lake Watershed Land Cover.

Land Cover Type	Acreage	Percent
Agriculture	10913.62	3.05
Barren	379.81	0.11
Forested	170984.01	47.85
Grassland	51416.75	14.39
Scrub/shrub	16370.44	4.58
Urban	4070.61	1.14
Water	89027.68	24.91
Wetlands	14178.25	3.97
TOTAL	357341.16	100.00

Results from data collected on Black 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. The DNR fisheries division surveyed Black Lake fish populations during 2005, but the report is not yet available.

Figure 1. Map of Black Lake watershed.



METHODS

Watershed Council staff began the field data collection component of the Black Lake aquatic plant survey on July 19, 2005 and completed the field work on August 9, 2005. The aquatic plant communities of Black 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 145 sample sites 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 currently inhabiting the lake. Transects from shallow to deep vegetated areas were sampled at intervals that varied depending upon plant community changes that were observable from the surface. In the shallow, well-vegetated northern section, transects were sampled all the way across the lake. 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 field notebook with waterproof paper. If no plants were encountered during sampling, 'no vegetation' was recorded in the field notebook.

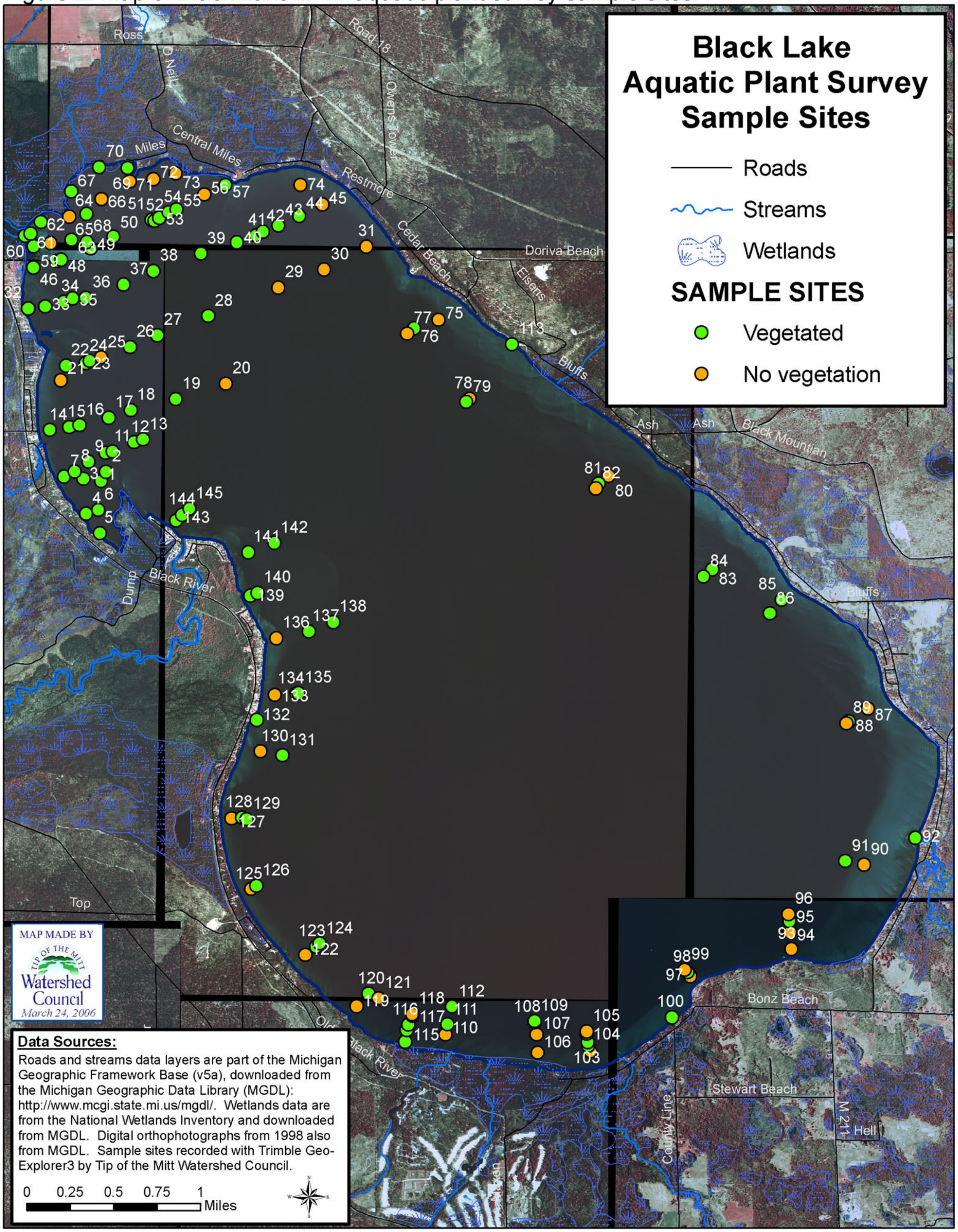
Generalized aquatic plant community mapping:

To supplement aquatic plant species data collected at sample sites and improve the accuracy of delineations between plant communities, additional notes and GPS data were recorded for large aquatic plant communities that were visible from the water surface. 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 describing plant communities, such as composition, extent, and density, were often written in the field notebook. 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. Map of Black Lake 2005 aquatic plant survey sample sites.



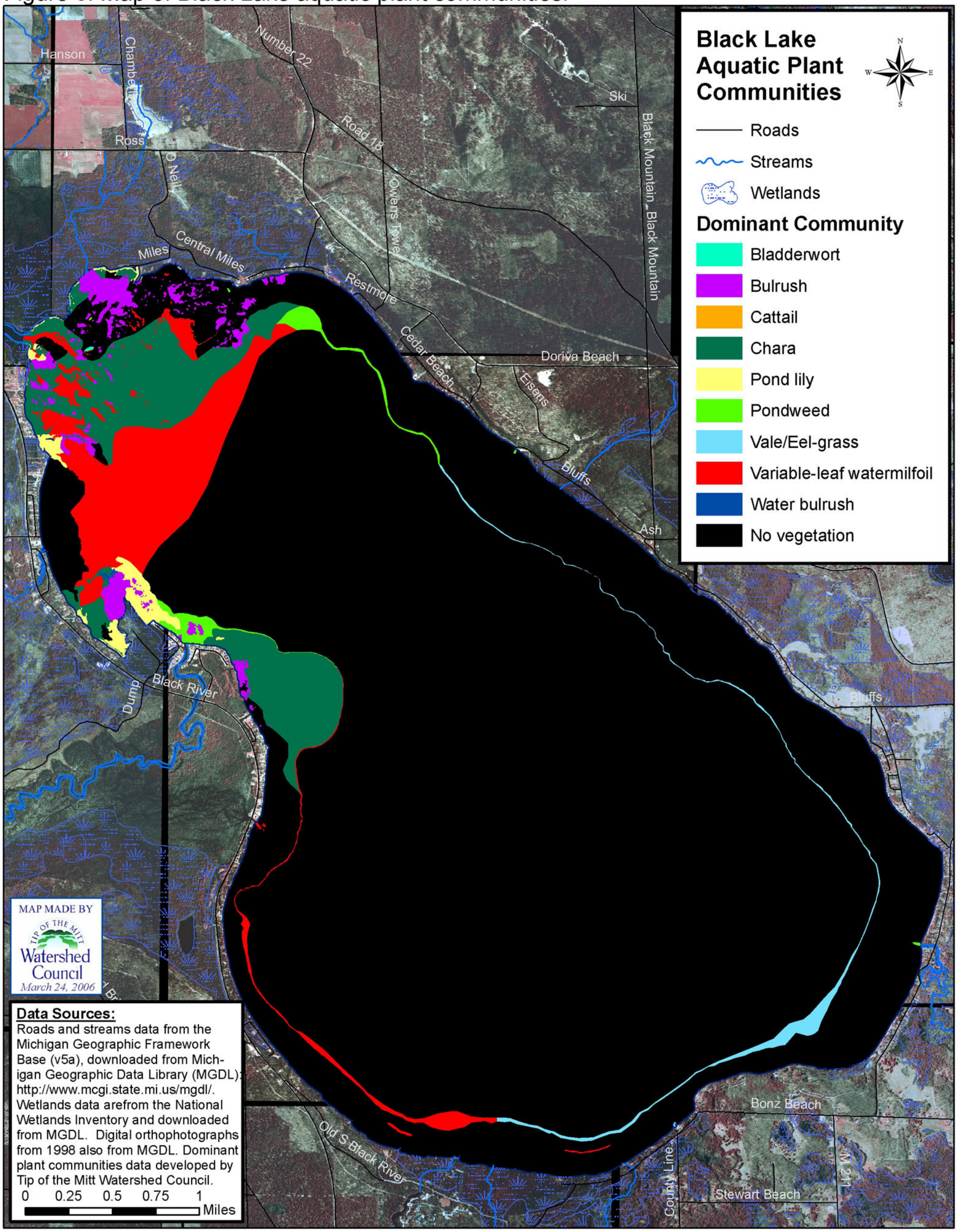
Data processing and map development:

GPS data collected in the field was 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 9.1. 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 taxa, dominant taxon, and dominant taxa 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. Map of Black Lake aquatic plant communities.



RESULTS

Sample site results:

Of the 145 locations sampled on Black Lake, aquatic plant specimens were collected, identified and photographed at 103 sites. The remaining 42 sites had little or no vegetation. A total of 26 different aquatic plant species were collected or documented at sample sites, with six additional species of emergent vegetation noted during general plant bed mapping (*Lythrum salicaria, Nymphaea odorata, Pontederia cordata, Potamogeton natans, Typhus latifolia, Zizania spp.*). All species found were native to Michigan. The number of species encountered at a site ranged from zero to 12, with an average of 3.7 for sites where vegetation was found.

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

Genus and species	Common Name	# of sites	Occurrence*
Myriophyllum heterophyllum	Variable-leaf watermilfoil	82	very common
Chara spp.	Muskgrass	60	very common
Vallisneria americana	American eelgrass	44	very common
Najas flexilis	Slender naiad	35	very common
Potamogeton gramineus	Variable-leaf pondweed	26	common
Elodea canadensis	Common waterweed	20	common
Potamogeton praelongus	White-stem pondweed	17	common
Utricularia vulgaris	Common bladderwort	17	common
Potamogeton zosteriformis	Flat-stem pondweed	13	common
Stuckenia pectinata	Sago pondweed	11	common
Potamogeton richardsonii	Richardson's pondweed	9	uncommon
Heteranthera dubia	Water stargrass	7	uncommon
Potamogeton friesii	Fries' pondweed	7	uncommon
Nuphar variegata	Yellow pond-lily	6	uncommon
Potamogeton amplifolius	Large-leaf pondweed	6	uncommon
Potamogeton robbinsii	Robbins' pondweed	3	rare
Sagittaria cuneata	Arum-leaf Arrowhead	3	rare
Stuckenia filiformis	Fine-leaf pondweed	3	rare
Ceratophyllum demersum	Coontail	2	rare
Megalodonta beckii	Water marigold	2	rare
Potamogeton illinoensis	Illinois pondweed	2	rare
Ranunculus spp.	Water buttercup	2	rare
Schoenoplectus acutus	Hard-stem bulrush	2	rare
Myriophyllum sibiricum	Common watermilfoil	1	rare
Schoenoplectus subterminalis	Water bulrush	1	rare
Scirpus pungens	Three-square bulrush	1	rare

*Occurrence categories determined by Watershed Council staff based on natural breaks: 1-5 = rare, 6-10 = uncommon, 11-30 = common, and 31+ = very common.

Variable-leaf watermilfoil was the most commonly encountered species; collected at 82 sites (Table 2). Three other species, muskgrass, American eelgrass and slender naiad, were also very common, collected at more than 30 sites. Pondweeds dominated the 11 species placed in the common and uncommon categories, and 11 additional species from a mix of different genera were rarely encountered. Aquatic plant communities at the sample sites were dominated by variable-leaf watermilfoil and muskgrass (Table 3).

Table 3. Aquatic plant communities at sample sites.

Dominant Plants	Number of sites
Variable-leaf watermilfoil	31
Muskgrass	26
Eelgrass	11
Muskgrass mix	9
Pondweeds	9
Mixed	8
Bladderwort	3
Eelgrass mix	2
Slender naiad	1
Water bulrush	1
Water stargrass	1
Waterweed	1

Generalized results from interpreted data:

Statistics generated from GIS files reveal that 87% of Black Lake's 10,133 acres contain little or no aquatic vegetation (Table 4). Vegetated areas were divided into two categories: emergent vegetation (cattails, bulrush, etc.) and submergent vegetation (pondweeds, watermilfoils, etc.). Of the 1354 acres of Black Lake that possess aquatic vegetation, approximately 13% (170 acres) include emergent vegetation while the other 87% (1184 acres) contains submergent vegetation only.

Table 4. Lake and vegetated area statistics.

Lake & Vegetation	Surface Area (acres)	% of Total Surface Area
Black Lake	10132.55	100.00
Aquatic vegetation	1354.44	13.37
Little or no vegetation	8778.11	86.63
Emergent vegetation	170.21	1.68
Submergent vegetation	1184.23	11.69

In lake areas with submergent vegetation only, muskgrass (C*hara spp.*) and variable-leaf watermilfoil (*Myriophyllum heterophyllum*) were the dominant plant types, dominating over 90% of all plant communities (Table 5). Pondweed- and eelgrass-dominated communities accounted for most of the remaining vegetated areas in the lake.

Table 5. Submergent vegetation statistics.

Dominant type in aquatic plant community	**Lake surface area with dominant plant type (acres)**	**Percent of lake's submergent vegetation**
Bladderwort *Utricularia vulgaris*	0.53	0.05
Muskgrass *Chara spp.*	555.20	46.88
Pondweed *Potamogetonaceae*	48.45	4.09
Eelgrass *Vallisneria americana*	58.83	4.97
Variable-leaf watermilfoil *Myriophyllum heterophyllum*	519.19	43.84
Water bulrush *Scirpus subterminalis*	2.02	0.17

DISCUSSION

General:

The majority of Black Lake contains little or no aquatic plant life (>85% of the surface area), a phenomenon which is more pronounced in the southern basin. Well-vegetated areas occur primarily in the northern basin, particularly along the northwestern side of the lake. Lake depth, climatic variables, and human activity are probably the key factors that determine the distribution and density of the aquatic plant community in Black Lake.

Depth appears to have a large impact on the areal extent of plant growth in Black Lake. The absence of aquatic vegetation is much more pronounced in the deeper southern basin (Figure 3). 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. Black Lake possesses extensive areas greater than 20 feet deep, particularly in the southern basin. Thus, lake depth appears to be the variable that contributes most to the absence of aquatic plant life in the lake.

Results from field data collection reveal a pronounced absence of plants in shallow areas along the entire east side of the lake as well as the southern and southwestern sides (Figure 3). Prevailing winds from the northwest are the probable cause for shallow areas devoid of plants on the eastern and southeastern sides, because wind-generated wave action creates conditions adverse to plant growth. This absence of aquatic plant life on the east-southeast side of the lake has been documented in other aquatic plant surveys conducted in the area. Although prevailing winds do not explain the lack of aquatic vegetation in shallow areas in the southern and southwestern sides of the lake, winds do come from the east and northeast as well. The greater depths and larger size of the southern basin (2.4 miles across in northern basin versus 3.6 miles in the southern basin) may explain why shallow areas in the southwest have little aquatic vegetation compared with those of the northwest. In addition, the sharp drop-off in the southwest may play a part in the lack of aquatic plants.

Ecosystem disruptions may also affect aquatic plant distribution and density on Black Lake. 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. The invasive species of primary concern noted in this survey is the zebra mussel (*Dreissena polymorpha).*

Zebra mussels, which have European origins, were frequently observed during this survey and commonly 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 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 aquatic plants and increase the overall biomass of this portion of the aquatic plant community. A safe, reliable, comprehensive method for controlling zebra mussels has not been found.

Fortunately, non-native aquatic plant species were not encountered during this survey. However, variable-leaf watermilfoil (*Myriophyllum heterophyllum*), a native to Michigan's aquatic ecosystems, is present at levels in Black Lake that may be considered a nuisance. During the survey, both muskgrass (*Chara spp.*) and variable-leaf watermilfoil were encountered frequently. The difference between the two plants is that muskgrass grows along and is limited to the lake bottom, whereas variable-leaf watermilfoil occurs in large, dense beds that extend from the lake bottom to the water surface. Similar to problems experienced with some non-native plant species, variable-leaf watermilfoil has proliferated to the point that it is dominating plant communities and suppressing other aquatic plant species. Suppression of other native species could alter the aquatic ecosystem as it would impact other aquatic organisms that depend on the suppressed species during some part of their life cycle. In addition, the excessive watermilfoil growth hinders recreation, making it difficult to swim, boat and fish.

Although a native of Michigan aquatic ecosystems, variable-leaf watermilfoil is not necessarily a native to Black Lake. In the Eastern United States, variable-leaf watermilfoil is listed as a "native invasive" (USDA 2006). In fact, a considerable amount of research is being conducted in New Hampshire to study variable-leaf watermilfoil and methods to control its growth (NHDES 2006). However, no previous records of aquatic plant species in Black Lake were uncovered and thus, it is uncertain as to whether variable-leaf watermilfoil is native to the ecosystem or introduced.

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 a dominating (and potentially invasive) species like variable-leaf watermilfoil could have long-term impacts on the ecosystem. Although virtually impossible to completely eliminate a nuisance species from a large water body like Black Lake (and undesirable for native species), there are a variety of methods used to control nuisance plant growth. Options for nuisance aquatic plant growth are discussed in detail in the next section and are included at the end of the report in the form of a quick-reference matrix (Appendix B).

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.

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

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. Research currently being undertaken in New Hampshire is investigating the effectiveness of seven aquatic herbicides for selective control of variable-leaf watermilfoil (NHDES 2006).

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 that of 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. As far as Watershed Council staff are aware, this approach has not been used to control variable-leaf 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 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 blocks sunlight and prevents plant growth. Most of these methods require a permit from DEQ. 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. 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.

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.

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.

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 (i.e., 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 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 be effective. Surveys conducted before, during and after stocking efforts to gauge project progress result in additional costs. The purple loosestrife beetle is currently not commercially available, but instead, 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 control project in Michigan where weevils were stocked. 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.

At the request of a Black Lake shoreline resident, Watershed Council staff contacted EnviroScience to discuss the possibility of stocking weevils to control problematic growth of variable-leaf watermilfoil. To date, EnviroScience, Inc. has not stocked weevils to control variable-leaf watermilfoil growth, but seemed open to the idea. This conversation can be resumed at the request of the Black Lake Association.

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.

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, specifically variable-leaf watermilfoil, is an issue of great concern for some Black Lake shoreline residents. Variable-leaf watermilfoil was encountered in both of the major basins in Black Lake, but was particularly abundant in the northwest section of the northern basin. If the dense beds of watermilfoil expand to encompass even greater areas, there could be a considerable impact on the aquatic plant community, potentially leading to ecosystem-wide changes. Fortunately, the expansive deep areas of Black Lake should prevent variable-leaf watermilfoil from becoming the nuisance that watermilfoils have become in shallow lakes.

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. Although potentially useful for controlling some aquatic plants in the lake, plant cutting and/or removal, whether by hand or machine, is not recommended for controlling watermilfoil as it could exacerbate the problem due to the plant’s ability to spread through fragmentation. Neither dredging nor lake drawdown are deemed appropriate for Black Lake due to the size of the lake, the areal extent of aquatic plant growth, the lack of structures for lake level control and the potential to severely impact the ecosystem. Diver-dredging could be appropriate technique for the circumstances as optimally, the entire plant is removed, but it is expensive and generally only applicable in small areas. Benthic barrier installation would also be appropriate for controlling aquatic plant growth in limited areas.

The remaining option for aquatic plant control is biological. An environmentally safe bio-control agent, the aquatic weevil (*Euhrychiopsis lecontei),* exists for variable-leaf watermilfoil, but has not been tested. The Watershed Council recommends that the Black Lake Association further investigate this option and discuss possibilities with EnviroScience Inc, developer of the MiddFoil® process for biological control of Eurasian watermilfoil using aquatic weevils. One option may be to perform a test by stocking a limited amount of weevils in a few areas in order to ascertain the effectiveness of the weevil on controlling variable-leaf watermilfoil growth. In addition, the Lake Association should keep up to date with research occurring in New Hampshire using nematodes as bio-control agents.

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 fairly long-term solution.

Providing that the Lake Association is interested in pursuing biological control, EnviroScience should be contacted as soon as possible. A typical weevil stocking program requires a great deal of advance planning and the experimental nature of this project may require even more time. EnviroScience can be contacted 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 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 Black 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 Black 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 introduced 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.

The quality of this study may have been affected by methodology, equipment and funding. There were a limited number of sample sites, which were not randomly selected. Equipment used in the field survey may not have been completely effective for collecting all plant types. In addition, time did not allow for all plant communities to be directly mapped. The greatest limitation, however, was funding; a very limited amount of funds were available to conduct such an extensive aquatic plant survey on a 10,000 acre lake.

Although 145 sites provided enough data to map major plant communities, some small or isolated plant communities may have been missed. 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 watermilfoil beds. Therefore, sample site selection was not completely random, which has consequences for statistical analysis and study repeatability. Future surveys would benefit from including additional sample sites and randomly selected sites.

Fairly rigorous sampling techniques and effort were employed, but there is a possibility that not all species were collected at each site. Certain aquatic plant species, such as *Potamogeton pusillus,* are difficult to collect with the sampling device that was used. Other types of sampling gear may improve chances of collecting a fully representative sample during future studies.

The mapping-grade GPS unit used for this survey has a reported accuracy of 1 to 3 meters, 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 and time constraints. Much of the aquatic plant community mapping was performed in a GIS by interpolation between sampling points or extrapolation from sampling points. To improve mapping accuracy of future surveys, it is recommended that more time be dedicated to thorough field data collection.

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 to guarantee a high-quality product. 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 Black Lake appears to be limited due to lake morphology and climatic variables. Human activity, the exotic zebra mussel, and excessive growth of variable-leaf watermilfoil are affecting native plant communities. Despite all these stressors, the aquatic plant community of Black Lake remains quite diverse with a total of 32 species documented in this survey.

Fortunately, non-native aquatic plant species were not found during this survey. However, variable-leaf watermilfoil was found to dominate a substantial portion of plant communities throughout the lake. If the watermilfoil spreads and maintains dense growth habits that were observed during this survey, other native plants will suffer, potentially resulting in long-term impacts to the lake ecosystem. Most forms of plant control are not suitable for the circumstances or have major drawbacks, but an environmentally safe bio-control agent, an aquatic weevil, may exist for variable-leaf watermilfoil. The weevil has not been tested, but this may be a good opportunity to do so. If successful, the aquatic plant community may come back into balance without negatively impacting the lake 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 Black Lake Association now has the ability to track changes in the aquatic plant community and adjust lake management practices accordingly.

LITERATURE AND DATA REFERENCED

Crow, G. E. and C. B. Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America. The University of Wisconsin Press. Madison, WI.

Garling, Donald and H. Wandell. 2005. Nuisance Aquatic Plant Control Using Algicides and Herbicides for 2005. Michigan State University Extension. East Lansing, MI. http://web1.msue.msu.edu/waterqual/

Gibbons, M. V. and H. L. Gibbons. 1994. A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans. Washington State Department of Ecology. Olympia, WA. http://www.ecy.wa.gov/biblio/93093.html

Great Lakes Environmental Research Laboratory. 2006. Aquatic Invasive Species. http://www.glerl.noaa.gov/res/Programs/ais/

Hauxwell, J. K. Wagner, and A. Mikulyuk. 2005. Getting It Right: Whole-lake Herbicide Debate Deserves a Dose of Science. Lake Tides. University of Wisconsin Extension. Stevens Point, WI. http://www.uwsp.edu/cnr/uwexlakes/laketides/

Korth, R. et al.2005. *Aquatic Plant Management in Wisconsin.* University of Wisconsin Extension. Stevens Point, WI. http://www.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp

Lovato, J. L., B. O. Fisher, and W. E. Brown. 1996. Migration of Aquatically Applied Herbicides from Surface Water to Ground Water. Lansing, MI.

Oleskiewicz, D. 2002. Copper in Our Waterways. Buckeye Basins. Ohio State University Extension. Caldwell, OH. http://east.osu.edu/anr/wm.html#BuckeyeBasins

Michigan Department of Information Technology, Center for Geographic Information. 2006. Michigan Geographic Data. Lansing, MI. http://www.mcgi.state.mi.us/mgdl/

Michigan Department of Environmental Quality. 2005. Management of Aquatic Plants. Lansing, MI. http://www.deq.state.mi.us/documents/deq-water-illm-management-aquatic-plants.pdf

Michigan Department of Environmental Quality. 2005. Plant Chemical Table. Lansing, MI. http://www.deq.state.mi.us/documents/deq-water-illm-plantchemicaltable.pdf

Michigan Department of Natural Resources. 2006. Inland Lake Maps. Lansing, MI. http://www.michigan.gov/dnr/0,1607,7-153-30301_31431_32340---,00.html

National Oceanic and Atmospheric Administration, Coastal Services Center. 2003. Coastal Great Lakes Land Cover Project. Charleston, SC. http://www.csc.noaa.gov/crs/lca/greatlakes.html

New Hampshire Department of Environmental Services (NHDES). 2006. Exotic Species Program Variable Milfoil Research Projects. Concord, NH. http://www.des.state.nh.us/wmb/exoticspecies/Federally_Funded_Research_Projects.html

Tip of the Mitt Watershed Council. 2005. Volunteer Lake Monitoring and Comprehensive Water Quality Monitoring Programs. Petoskey, MI. http://www.watershedcouncil.org/inlandlakes.html

USDA Forest Service. 2006. Eastern Region invasive plants, ranked by degree of invasiveness as based on information from States. Milwaukee, WI. http://www.fs.fed.us/r9/wildlife/range/weed/?open=Sec3B.htm

Unites States Geological Survey. 1990. 1/100,000 Topographic Maps. Reston, VA.

Appendix A: Sample Site Data.

Site ID	Depth (feet)	Coontail	Muskgrass	Waterweed (Elodea)	Water Stargrass	Water Marigold	Variable-leaf Watermilfoil	Common watermilfoil	Slender naiad
1	2.8	No	VH	No	No	No	VL	No	No
2	2.9	No	L	No	No	No	M	No	No
3	4.3	No	No	No	No	No	VH	No	No
4	1.7	No	H	No	No	No	VL	No	No
5	4.7	L	No	H	No	No	M-H	No	M
6	2.1	No	VH	No	No	No	H	No	M
7	2.8	No	L	No	No	No	VL	No	No
8	3.6	No	VL	No	No	No	L	No	No
9	5.7	No	No	No	No	No	VH	No	No
10	9.8	M	No	No	No	No	H	No	No
11	11.1	M	No	No	No	No	H	No	No
12	14.5	VL	No	No	No	No	L	No	No
13	15.8	No	No	L	No	No	L	No	No
14	2.4	No	VL	No	No	No	VL	No	VL
15	5.7	No	VL	No	No	No	VL	No	No
16	8.6	No	No	No	No	No	VH	No	No
17	10	No	VL	No	No	No	VL	No	VL
18	11.8	No	No	No	No	No	M	No	No
19	14.8	No	No	VL	No	No	VL	No	No
20	21.9	No	No	No	No	No	No	No	No
21	3.4	No	No	No	No	No	No	No	No
22	5.7	No	L-M	No	No	No	M-H	No	L-M
23	6	No	M	No	No	No	M	No	No
24	6.3	No	No	No	No	No	VH	No	No
25	3.3	No	No	No	No	No	No	No	No
26	8.8	No	M	No	No	No	L-M	No	L-M
27	7.9	No	L	No	No	No	M	No	No
28	17.9	No	No	No	No	No	VL	No	No
29	16.9	No	No	No	No	No	No	No	No
30	17.5	No	No	No	No	No	No	No	No
31	7.9	No	VL	No	No	No	No	No	VL
32	2.5	No	H	No	No	No	L	No	L-M
33	3.2	No	No	No	No	No	VH	No	No
34	2.7	No	H	No	No	No	VL	No	No
35	4.6	No	No	No	No	No	VH	No	No
36	5.7	No	VH	No	No	No	VL	No	No
37	5.5	No	H	No	No	No	VL	No	No
38	9.7	No	L-M	No	No	No	No	No	No
39	5.6	No	VL	No	No	No	No	No	No
40	4.9	No	H	No	No	No	No	No	No
41	8.6	No	No	No	No	No	VH	No	No
42	5.9	No	L	No	No	No	VL	No	No
43	8.7	No	No	No	No	No	H	No	VL
44	7	No	VL	No	No	No	VL	No	VL
45	4.2	No	No	No	No	No	No	No	No
46	2.4	No	VH	No	No	No	VL	No	L-M
47	4.4	No	No	No	No	No	VH	No	No
48	4	No	VH	No	No	No	VL	No	No
49	1.2	No	L	No	No	No	No	No	No
50	4.2	No	M	No	No	No	L	No	VL
51	7.3	No	M-H	No	No	No	L	No	No

Site ID	Yellow Pond-lily	Largeleaf pondweed	Fries's pondweed	Variable-leaf Pondweed	Illinois pondweed	Whitestem pondweed	Robbins' pondweed	Richardson pondweed	Flatstem pondweed
1	No	No	No	No	L	No	No	No	No
2	No	No	No	L	No	No	No	No	No
3	No	VL	No	No	No	No	No	No	No
4	No	L	No	M	No	No	No	No	No
5	L-M	H	L-M	No	No	No	No	M	H
6	No	M-H	VL	M-H	No	No	No	No	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	VL	No	No	No
10	No	No	No	No	No	L-M	No	No	M-H
11	No	No	No	No	No	M-H	M-H	No	No
12	No	No	No	No	No	No	No	No	No
13	No	No	No	No	No	No	No	No	No
14	No	No	No	No	No	No	No	No	No
15	No	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	No	No	No	No	No	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	L	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	VL	No	No	No
27	No	No	No	No	No	No	No	No	No
28	No	No	No	No	No	No	No	No	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	H	No	No	No	No	No	No	No
33	No	L	No	No	No	No	No	No	No
34	No	No	No	No	No	No	No	No	No
35	No	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	No	No
38	No	No	No	No	No	No	No	No	No
39	No	No	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	M	No	No	No	No	No
45	No	No	No	No	No	No	No	No	No
46	No	No	No	L	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	No	No	No	No	No	No
51	No	No	No	No	No	No	No	No	No

Site ID	Water Buttercup	Arum-leaf Arrowhead	Hard-stem Bulrush	Swaying Bulrush	3-square Bulrush	Fine-leaf Pondweed	Sago Pondweed	Common Bladderwort	Eel-grass
1	No	No	No	No	No	No	No	H	No
2	No	No	No	H	No	No	No	No	No
3	No	No	No	No	No	VL	No	No	No
4	No	No	No	No	No	No	No	No	M
5	VL	No	No	No	No	No	No	M-H	L
6	No	No	No	No	No	No	No	No	H
7	No	No	No	No	No	No	No	M-H	No
8	No	No	No	No	No	No	No	No	No
9	No	No	No	No	No	No	No	VL	No
10	No	No	No	No	No	No	No	No	No
11	No	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	No	No
14	No	No	No	No	No	No	No	No	No
15	No	No	No	No	No	No	No	L	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	No	No	No	No	No	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	L	L	L
23	No	No	No	No	No	No	No	L	VL
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	L
27	No	No	No	No	No	No	No	No	No
28	No	No	No	No	No	No	No	No	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	H
33	No	No	No	No	No	No	No	No	L
34	No	No	No	No	No	No	No	No	No
35	No	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	No	No
38	No	No	No	No	No	No	No	No	No
39	No	No	No	No	No	No	No	No	No
40	No	No	L-M	No	No	No	L-M	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	L	No
44	No	No	No	No	No	No	M	No	VL
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	VL
48	No	No	No	No	No	No	No	No	No
49	No	No	No	No	No	No	L	No	No
50	No	No	No	No	No	No	No	No	No
51	No	No	No	No	No	No	No	No	No

Site ID	Vegetated	# of Taxa	Density	Dominant Taxa	Dominant Taxon
1	Yes	5	H	Chara	Muskgrass
2	Yes	4	H	Schoenoplectus subterminalis	Water bulrush
3	Yes	3	H	Myriophyllum heterophyllum	Watermilfoil
4	Yes	5	M-H	Chara	Muskgrass
5	Yes	12	H	Elodea canadensis, Potamogeton amplifolius & zosteriformis	Mixed
6	Yes	7	M-H	Chara, Myriophyllum heterophyllum, Vallisneria americana	Mixed
7	Yes	3	VL-L	Utricularia	Bladderwort
8	Yes	2	VL	Myriophyllum heterophyllum	Watermilfoil
9	Yes	3	VH	Myriophyllum heterophyllum	Watermilfoil
10	Yes	4	M-H	Myriophyllum heterophyllum	Watermilfoil
11	Yes	4	M	Myriophyllum heterophyllum	Watermilfoil
12	Yes	2	VL-L	Myriophyllum heterophyllum	Watermilfoil
13	Yes	2	VL	Myriophyllum heterophyllum	Watermilfoil
14	Yes	3	VL	Myriophyllum heterophyllum, Chara, Najas flexilis	Muskgrass/Watermilfoil
15	Yes	3	VL	Utricularia	Bladderwort
16	Yes	1	VH	Myriophyllum heterophyllum	Watermilfoil
17	Yes	3	VL	Myriophyllum heterophyllum, Chara, Najas flexilis	Mixed
18	Yes	1	L-M	Myriophyllum heterophyllum	Watermilfoil
19	Yes	2	VL	Myriophyllum heterophyllum, Elodea	Watermilfoil
20	No	0	None	None	None
21	No	0	None	None	None
22	Yes	7	L-M	Myriophyllum heterophyllum	Watermilfoil
23	Yes	4	VL	Chara, Myriophyllum heterophyllum	Muskgrass/Watermilfoil
24	Yes	2	VH	Myriophyllum heterophyllum	Watermilfoil
25	No	0	None	None	None
26	Yes	5	L	Chara	Muskgrass
27	Yes	2	L-M	Myriophyllum heterophyllum	Watermilfoil
28	Yes	1	VL	Myriophyllum heterophyllum	Watermilfoil
29	No	0	None	None	None
30	No	0	None	None	None
31	No	0	None	None	None
32	Yes	5	M-H	Chara, Potamogeton amplifolius, Vallisneria americana	Mixed
33	Yes	3	VH	Myriophyllum heterophyllum	Watermilfoil
34	Yes	2	L	Chara	Muskgrass
35	Yes	1	VH	Myriophyllum heterophyllum	Watermilfoil
36	Yes	2	L	Chara	Muskgrass
37	Yes	2	L	Chara	Muskgrass
38	Yes	1	VL	Chara	Muskgrass
39	Yes	1	VL	Chara	Muskgrass
40	Yes	3	L	Chara	Muskgrass
41	Yes	1	H	Myriophyllum heterophyllum	Watermilfoil
42	Yes	2	VL	Chara	Muskgrass
43	Yes	3	M	Myriophyllum heterophyllum	Watermilfoil
44	Yes	6	L	Stuckenia pectinata, Potamogeton gramineus	Pondweed
45	No	0	None	None	None
46	Yes	4	M	Chara	Muskgrass
47	Yes	2	VH	Myriophyllum heterophyllum	Watermilfoil
48	Yes	2	M-H	Chara	Muskgrass
49	Yes	2	VL	Chara, Stuckenia pectinata	Muskgrass/Pondweed
50	Yes	3	L	Chara	Muskgrass
51	Yes	2	L	Chara	Muskgrass

Site ID	Depth (ft)	Coontail	Muskgrass	Waterweed (Elodea)	Water Stargrass	Water Marigold	Variable-leaf Watermilfoil	Common watermilfoil	Slender naiad
52	3.2	No	VL	No	No	No	No	No	No
53	5.7	No	H	No	No	No	M	No	No
54	6.7	No	No	No	No	No	VH	No	No
55	5.8	No	L	No	No	No	VL	No	M
56	4.1	No	No	No	No	No	No	No	No
57	2.8	No	L-M	No	No	No	VL	No	No
58	2.7	No	No	No	No	No	No	No	No
59	2.2	No	H	No	No	No	VL	No	L-M
60	1.8	No	M-H	VL	No	No	VL	No	No
61	5.6	No	No	No	No	No	VH	No	No
62	1.6	No	VH	No	No	No	VL	No	No
63	2.4	No	H	No	No	No	L	No	VL
64	2.4	No	No	No	No	No	No	No	No
65	2.5	No	VL	No	No	No	L	No	No
66	3.3	No	No	No	No	No	No	No	No
67	2.2	No	M-H	No	No	No	L	No	L
68	3.4	No	H	No	No	No	L	No	No
69	1.7	No	VH	No	No	No	VL	No	L
70	2.3	No	H	No	No	No	L	No	No
71	1.8	No	No	No	No	No	No	No	No
72	2.2	No	No	No	No	No	No	No	No
73	2.1	No	No	No	No	No	No	No	No
74	3	No	No	No	No	No	No	No	No
75	4.7	No	No	No	No	No	No	No	No
76	16	No	No	L-M	No	No	M	No	VL
77	21.2	No	No	No	No	No	No	No	No
78	5.6	No	No	No	No	No	No	No	No
79	25.3	No	No	L-M	No	No	No	No	No
80	5.6	No	No	No	No	No	No	No	No
81	15.4	No	No	L	No	No	No	No	No
82	19.9	No	No	No	No	No	No	No	No
83	7.8	No	VL	No	No	No	No	No	No
84	19.9	No	L	L	L	No	VL	No	VL
85	4	No	VL	No	No	No	No	No	No
86	10.9	No	M	No	No	No	No	No	VL
87	6.1	No	No	No	No	No	No	No	No
88	12.5	No	VL	No	No	No	L	No	VL
89	22.4	No	No	No	No	No	No	No	No
90	3.3	No	No	No	No	No	No	No	No
91	21.6	No	No	No	No	No	L	No	No
92	2.8	No	No	VL	No	No	L-M	No	No
93	4.8	No	No	No	No	No	No	No	No
94	10.6	No	No	No	No	No	No	No	No
95	14.7	No	No	No	No	No	No	No	No
96	17.2	No	No	No	No	No	No	No	No
97	6.7	No	No	No	No	No	No	No	No
98	12.5	No	No	No	No	No	L-M	No	No
99	30	No	No	No	No	No	No	No	No
100	1.9	No	No	VL	No	No	VL	No	L
101	2.6	No	No	No	No	No	No	No	No
102	7.2	No	L-M	No	No	No	VH	No	No
103	9.3	No	L	No	No	No	No	No	No

Site ID	Yellow Pond-lily	Largeleaf pondweed	Fries's pondweed	Variable-leaf Pondweed	Illinois pondweed	Whitestem pondweed	Robbins' pondweed	Richardson pondweed	Flatstem pondweed
52	No	No	No	No	No	No	No	No	No
53	No	No	No	No	No	No	No	No	No
54	No	No	No	No	No	No	No	No	No
55	No	No	No	No	No	VL	No	No	No
56	No	No	No	No	No	No	No	No	No
57	No	No	No	M	No	No	No	No	No
58	No	No	No	No	No	No	No	No	No
59	No	No	No	L	No	No	No	No	No
60	No	No	No	VL	No	No	No	No	No
61	No	No	No	No	No	No	No	No	No
62	No	No	VL	H	No	No	No	No	No
63	No	No	No	No	No	No	No	No	No
64	No	No	No	No	No	No	No	No	No
65	No	No	No	M	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	No	No	No	No	No	No	No	No	No
69	No	No	No	No	No	No	No	VL	No
70	No	No	No	No	L-M	No	No	No	No
71	No	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	No	No	No	No	No	No	No	No	No
75	No	No	No	No	No	No	No	No	No
76	No	No	No	No	No	No	No	L	H
77	No	No	No	No	No	No	No	No	No
78	No	No	No	No	No	No	No	No	No
79	VL	No	No	VL	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	No	No	No	No	No	No	No	No	No
83	No	No	No	No	No	No	No	No	No
84	No	No	No	L	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	No	No	No	No
88	No	No	No	M	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	H	No
93	No	No	No	No	No	No	No	No	No
94	No	No	No	No	No	No	No	No	No
95	No	No	No	No	No	No	No	No	No
96	No	No	No	No	No	No	No	No	No
97	No	No	No	No	No	No	No	No	No
98	No	No	No	No	No	No	No	No	No
99	No	No	No	No	No	No	No	No	No
100	M-H	No	No	M-H	No	No	No	M-H	L
101	No	No	No	No	No	No	No	No	No
102	No	No	No	H	No	M-H	No	No	No
103	No	No	No	No	No	No	No	No	No

Site ID	Water Buttercup	Arum-leaf Arrowhead	Hard-stem Bulrush	Swaying Bulrush	3-square Bulrush	Fine-leaf Pondweed	Sago Pondweed	Common Bladderwort	Eel-grass
52	No	No	No	No	No	No	No	No	No
53	No	No	No	No	No	L	No	No	No
54	No	No	No	No	No	No	No	No	No
55	No	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	L
58	No	No	No	No	No	No	No	No	No
59	No	No	No	No	No	No	No	No	L-M
60	No	No	No	No	No	No	No	No	VL
61	No	No	No	No	No	No	No	No	No
62	No	No	No	No	No	No	No	No	M-H
63	No	No	No	No	No	No	No	VL	No
64	No	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	No	No	No	No	No	No	No	VH	L
69	No	No	No	No	No	No	No	No	M-H
70	No	No	No	No	No	No	No	No	No
71	No	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	No	No	No	No	No	No	No	No	No
75	No	No	No	No	No	No	No	No	No
76	No	No	No	No	No	No	No	No	L-M
77	No	No	No	No	No	No	No	No	No
78	No	No	No	No	No	No	No	No	No
79	No	No	No	No	No	No	No	No	M-H
80	No	No	No	No	No	No	No	No	No
81	No	No	No	No	No	No	No	No	M-H
82	No	No	No	No	No	No	No	No	No
83	No	No	No	No	No	No	No	No	No
84	No	No	No	No	No	No	No	No	M-H
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	No	No	No	No
88	No	No	No	No	No	No	No	No	H
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	M
92	No	M	No	No	No	No	M	No	No
93	No	No	No	No	No	No	No	No	No
94	No	No	No	No	No	No	No	No	No
95	No	No	No	No	No	No	No	No	L-M
96	No	No	No	No	No	No	No	No	No
97	No	No	No	No	No	No	No	No	No
98	No	No	No	No	No	No	No	No	M-H
99	No	No	No	No	No	No	No	No	No
100	No	M-H	No	No	M-H	No	M-H	No	H
101	No	No	No	No	No	No	No	No	No
102	No	No	No	No	No	No	No	No	L
103	No	No	No	No	No	No	No	No	No

Site ID	Vegetated	# of Taxa	Density	Dominant Taxa	Dominant Taxon
52	Yes	2	L	Chara	Muskgrass
53	Yes	1	VL	Chara	Muskgrass
54	Yes	3	L-M	Chara	Muskgrass
55	Yes	1	VH	Myriophyllum heterophyllum	Watermilfoil
56	Yes	4	L	Najas flexilis	Naiad
57	No	0	None	None	None
58	Yes	4	L	Potamogeton gramineus	Pondweed
59	No	0	None	None	None
60	Yes	5	M	Chara	Muskgrass
61	Yes	5	L	Chara	Muskgrass
62	Yes	1	VH	Myriophyllum heterophyllum	Watermilfoil
63	Yes	5	H	Chara	Muskgrass
64	Yes	4	L-M	Chara	Muskgrass
65	No	0	None	None	None
66	Yes	3	VL	Potamogeton gramineus	Pondweed
67	No	0	None	None	None
68	Yes	3	L	Chara	Muskgrass
69	Yes	4	M	Utricularia	Bladderwort
70	Yes	4	H	Chara	Muskgrass
71	Yes	3	VL	Chara	Muskgrass
72	No	0	None	None	None
73	No	0	None	None	None
74	No	0	None	None	None
75	No	0	None	None	None
76	No	0	None	None	None
77	Yes	6	L-M	Potamogeton zosteriformis	Pondweed
78	No	0	None	None	None
79	No	0	None	None	None
80	Yes	0	L	Vallisneria americana	Eelgrass
81	No	0	None	None	None
82	Yes	2	VL-L	Vallisneria americana	Eelgrass
83	No	0	None	None	None
84	Yes	1	VL	Chara	Muskgrass
85	Yes	6	L	Vallisneria americana	Eelgrass
86	Yes	1	VL	Chara	Muskgrass
87	Yes	2	L	Chara	Muskgrass
88	No	0	None	None	None
89	Yes	5	L	Vallisneria americana	Eelgrass
90	No	0	None	None	None
91	No	0	None	None	None
92	Yes	2	VL	Vallisneria americana	Eelgrass
93	Yes	5	H	Potamogeton richardsonii	Pondweed
94	No	0	None	None	None
95	No	0	None	None	None
96	Yes	1	L	Vallisneria americana	Eelgrass
97	No	0	None	None	None
98	No	0	None	None	None
99	Yes	2	L	Vallisneria americana	Eelgrass
100	No	0	None	None	None
101	Yes	11	VH	Vallisneria americana	Eelgrass
102	No	0	None	None	None
103	Yes	5	H	Myriophyllum heterophyllum	Watermilfoil

Site ID	Depth (ft)	Coontail	Muskgrass	Waterweed (Elodea)	Water Stargrass	Water Marigold	Variable-leaf Watermilfoil	Common Watermilfoil	Slender Naiad
104	14.2	No	L	No	No	No	No	No	VL
105	18.7	No	No	No	No	No	No	No	No
106	3	No	No	No	No	No	No	No	No
107	9.2	No	No	No	No	No	No	No	No
108	12.7	No	No	No	No	No	H	No	No
109	16.5	No	No	L	VL	No	No	No	No
110	4.1	No	No	No	No	No	No	No	No
111	9.2	No	M	No	No	No	H	No	L
112	15.6	No	No	L-M	VL	No	H	No	No
113	1.50	No	No	L	No	No	L-M	No	No
114	2.3	No	No	No	No	No	No	No	No
115	7.1	No	No	No	No	No	VH	No	No
116	6.2	No	VL	No	No	No	VL	No	No
117	11.8	No	No	M	M	No	H	No	No
118	19.5	No	No	No	No	No	No	No	No
119	2.9	No	No	No	No	No	No	No	No
120	8.7	No	M	No	No	L	H-VH	No	VL
121	23.2	No	No	No	No	No	No	No	No
122	3.2	No	No	No	No	No	No	No	No
123	8.7	No	L-M	M	No	No	H	No	No
124	17.6	No	VL	No	No	No	No	No	No
125	2.9	No	No	No	No	No	No	No	No
126	16.8	No	No	No	No	No	H	No	No
127	3.5	No	No	No	No	No	No	No	No
128	8	No	No	No	No	No	VH	No	No
129	13.4	No	No	M-H	VH	No	H	No	No
130	5	No	No	No	No	No	No	No	No
131	12.5	No	L	No	No	No	H	L	L
132	2	No	No	No	No	No	VH	No	No
133	4.4	No	No	No	No	No	No	No	No
134	8.9	No	M	M	No	No	L	No	L-M
135	17.3	No	No	M-H	H	VL	No	No	No
136	2.1	No	No	No	No	No	No	No	No
137	5.4	No	VL	No	No	No	No	No	VL
138	9.9	No	No	L	No	No	No	No	L-M
139	2.5	No	M-H	No	No	No	H	No	M
140	4.3	No	VL	No	No	No	VL	No	VL
141	3.8	No	VL	No	No	No	No	No	VL
142	9.4	No	No	M-H	No	No	H	No	M
143	1.8	No	No	No	M-H	No	L	No	M-H
144	2.9	No	No	No	No	No	No	No	M
145	12.7	No	No	No	No	No	VL	No	No

Site ID	Yellow Pond-lily	Largeleaf pondweed	Fries's pondweed	Variable-leaf Pondweed	Illinois pondweed	Whitestem pondweed	Robbins' pondweed	Richardson pondweed	Flatstem pondweed
104	No	No	No	No	No	No	No	No	No
105	No	No	No	No	No	No	No	No	No
106	No	No	No	No	No	No	No	No	No
107	No	No	No	No	No	No	No	No	No
108	No	No	No	No	No	No	No	No	No
109	No	No	No	No	No	M	M	No	No
110	No	No	No	No	No	No	No	No	No
111	No	No	No	No	No	No	No	No	No
112	No	No	No	No	No	L	No	No	No
113	No	No	No	No	No	L	M-H	No	No
114	No	No	No	L	No	No	No	H	No
115	No	No	No	No	No	No	No	No	No
116	No	No	No	No	No	VL	No	No	No
117	No	No	No	No	No	No	No	No	No
118	No	No	No	L	No	L	No	No	No
119	No	No	No	No	No	No	No	No	No
120	No	No	No	No	No	No	No	No	No
121	No	No	No	M	No	L-M	No	No	M-H
122	No	No	No	No	No	No	No	No	No
123	No	No	No	No	No	No	No	No	No
124	No	No	No	L	No	H	No	No	VL
125	No	No	No	No	No	No	No	No	No
126	No	No	No	No	No	No	No	No	No
127	No	No	No	No	No	H	No	No	No
128	No	No	No	No	No	No	No	No	No
129	No	No	No	No	No	VL	No	No	No
130	No	No	No	No	No	No	No	No	M-H
131	No	No	No	No	No	No	No	No	No
132	No	No	M-H	L	No	M-H	No	L	M-H
133	No	No	No	H	No	No	No	No	No
134	No	No	No	No	No	No	No	No	No
135	No	No	No	M-H	No	No	No	No	H
136	No	No	L-M	No	No	No	No	No	M-H
137	No	No	No	No	No	No	No	No	No
138	No	No	No	No	No	No	No	No	No
139	No	No	H	H	No	No	No	No	No
140	M	No	No	H	No	No	No	No	VL
141	No	No	No	No	No	No	No	No	No
142	No	No	No	No	No	No	No	No	No
143	L	No	No	M	No	M	No	VL	M-H
144	M	No	L-M	No	No	No	No	L	No
145	No	No	No	No	No	No	No	No	M-H

Site ID	Water Buttercup	Arum-leaf Arrowhead	Hard-stem Bulrush	Swaying Bulrush	3-square Bulrush	Fine-leaf Pondweed	Sago Pondweed	Common Bladderwort	Eel-grass
104	No	No	No	No	No	No	No	No	H
105	No	No	No	No	No	No	No	No	No
106	No	No	No	No	No	No	No	No	No
107	No	No	No	No	No	No	No	No	No
108	No	No	No	No	No	No	No	No	H
109	No	No	No	No	No	No	No	No	M-H
110	No	No	No	No	No	No	No	No	No
111	No	No	No	No	No	No	No	No	No
112	No	No	No	No	No	No	L-M	No	M-H
113	No	No	No	No	No	No	No	No	H
114	No	No	No	No	No	No	No	No	No
115	No	No	No	No	No	No	No	No	No
116	No	No	No	No	No	No	No	No	No
117	No	No	No	No	No	No	No	No	M
118	No	No	No	No	No	No	No	No	VL
119	No	No	No	No	No	No	No	No	No
120	No	No	No	No	No	No	No	H	M-H
121	No	No	No	No	No	No	No	No	No
122	No	No	No	No	No	No	No	No	No
123	No	No	No	No	No	No	No	H	L
124	No	No	No	No	No	No	No	No	VL
125	No	No	No	No	No	No	No	No	No
126	No	No	No	No	No	No	L	M	H
127	No	No	No	No	No	No	No	No	No
128	No	No	No	No	No	No	No	No	No
129	No	No	No	No	No	No	No	VL-L	No
130	No	No	No	No	No	No	No	No	No
131	No	No	No	No	No	No	No	M-H	M
132	No	No	No	No	No	No	L	No	No
133	No	No	No	No	No	No	No	No	No
134	No	No	No	No	No	No	No	M-H	L
135	No	No	No	No	No	No	No	No	L
136	No	No	No	No	No	No	No	No	No
137	No	No	No	No	No	No	No	No	No
138	No	No	No	No	No	No	VL	No	L
139	No	No	No	No	No	No	No	M	No
140	No	No	No	No	No	No	No	No	No
141	No	No	No	No	No	No	No	No	No
142	No	No	No	No	No	No	No	No	L
143	No	H	M-H	No	No	H	H	No	H
144	No	No	No	No	No	No	No	No	No
145	No	No	No	No	No	No	No	No	VL

Site ID	Vegetated	# of Taxa	Density	Dominant Taxa	Dominant Taxon
104	Yes	3	L	Vallisneria americana	Eelgrass
105	No	0	None	None	None
106	No	0	None	None	None
107	No	0	None	None	None
108	Yes	4	L-M	Myriophyllum heterophyllum, Vallisneria americana	Eelgrass/Watermilfoil
109	Yes	4	L	Vallisneria americana	Eelgrass
110	No	0	None		
111	Yes	4	M	Myriophyllum heterophyllum	Watermilfoil
112	Yes	7	M-H	Myriophyllum heterophyllum	Watermilfoil
113	Yes	5	M-H	Potamogeton richardsonii, Vallisneria americana	Pondweed
114	No	0	None		
115	Yes	2	VH	Myriophyllum heterophyllum	Watermilfoil
116	Yes	2	VL	Chara, M. heterophyllum	Muskgrass/Watermilfoil
117	Yes	6	M-H	Myriophyllum heterophyllum	Watermilfoil
118	Yes	1	None	Vallisneria americana	Eelgrass
119	No	0	None	None	None
120	Yes	9	M-H	Myriophyllum heterophyllum	Watermilfoil
121	No	0	None	None	None
122	No	0	None	None	None
123	Yes	8	H	Myriophyllum heterophyllum, Utricularia, Potamogeton praelongus	Mixed
124	Yes	2	VL	Chara, Vallisneria americana	Muskgrass/Eelgrass
125	No	0	None		
126	Yes	5	H	Myriophyllum heterophyllum, Potamogeton praelongus, Vallisneria americana	Mixed
127	No	0	None	None	None
128	Yes	2	H	Myriophyllum heterophyllum	Watermilfoil
129	Yes	5	M-H	Heteranthera dubia	Water stargrass
130	No	0	None	None	None
131	Yes	11	M	Myriophyllum heterophyllum	Watermilfoil
132	Yes	3	H-VH	Myriophyllum heterophyllum	Watermilfoil
133	No	0	None	None	None
134	Yes	8	L-M	Potamogeton zosteriformis	Pondweed
135	Yes	6	L-M	Elodea canadensis	Waterweed
136	No	0	None	None	None
137	Yes	2	VVL	Chara, Najas flexilis	Muskgrass/Naiad
138	Yes	6	L-M	Potamogeton gramineus, Potamogeton friesii	Pondweed
139	Yes	7	H-VH	Myriophyllum heterophyllum, Potamogeton gramineus	Mixed
140	Yes	3	VL	Chara, Najas flexilis	Muskgrass/Naiad
141	Yes	2	VL	Chara, Najas flexilis	Muskgrass/Naiad
142	Yes	8	M	Myriophyllum heterophyllum	Watermilfoil
143	Yes	11	VH	Vallisneria americana, Sagittaria cuneata, Stuckenia filiformis, Stuckina pectinata	Mixed
144	Yes	2	L	Potamogeton zosteriformis, Najas flexilis	Pondweed
145	Yes	2	VL	Vallisneria americana, Myriophyllum heterophyllum	Eelgrass/Watermilfoil

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.

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
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	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.