Long Lake Aquatic Vegetation Survey 2013
Tip of the Mitt Watershed Council

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SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but become a recreational nuisance when growth is excessive. Heavy aquatic plant growth can occur naturally given the correct combination of environmental variables (e.g., light and nutrient availability), but is accelerated due to factors such as nutrient pollution or the introduction of non-native species. Concerns regarding invasive Eurasian watermilfoil (*Myriophyllum spicatum*) and nuisance aquatic plant growth prompted the Cheboygan Long Lake Area Association (Association) to sponsor a series of aquatic plant surveys on Long Lake in Cheboygan County, Michigan.

The Tip of the Mitt Watershed Council (TOMWC) was contracted by the Association to perform a comprehensive aquatic plant survey in 2005, which resulted in the first comprehensive sampling and mapping of aquatic plant species and communities throughout the lake. The results of the 2005 survey helped guide efforts to control the Eurasian watermilfoil in 2006 and 2007 by stocking aquatic weevils (*Euhrychiopsis lecontei*). The Association contracted with TOMWC to conduct a second comprehensive aquatic plant survey in 2008 to assess the biological control efforts. Following a dramatic resurgence in Eurasian watermilfoil around the lake, the Association again contracted with TOMWC and a third comprehensive survey was performed in 2013.

The 2013 survey produced plant species and density data at 125 sites, as well as plant community maps for the lake. A total of 30 aquatic plant taxa were documented during the survey. Muskgrass (*Chara spp.*), Eurasian watermilfoil, and slender naiad (*Najas flexilis*) were the most commonly collected species. Plant community data showed that a majority of Long Lake (71%) contained little or no aquatic vegetation. Muskgrass was found to dominate plant communities in over 60% of the vegetated area, while Eurasian watermilfoil dominated 10%. Over 55% of plant community densities were classified as light growth, whereas heavy-density growth accounted for approximately 24%. Areas of heavy-density growth concentrated in the northwest end of the lake, along the western shoreline, and in the southeast corner. Eurasian watermilfoil was documented in many locations throughout all three basins of Long Lake. The largest and densest beds were found on the southwest side and in the southeast corner of the southern basin.

Areas of heavy-density plant growth were documented in both the 2008 and 2013 surveys, but the location of these areas shifted considerably. The beds of dense growth documented in 2008 along the western shore as well as in isolated pockets in the central basin and northern portion of the southeast basin were not found in 2013 or were much reduced in terms of size or density. Extensive areas of dense growth on the central-west side and southeast corner of the southeast basin were newly documented in the 2013 survey.

Invasive species and aquatic plant management efforts have influenced the aquatic plant communities of Long Lake. Biological control efforts by the Association resulted in the reduction and virtual elimination of Eurasian watermilfoil in three areas. However, in the absence of continued treatment, Eurasian watermilfoil resurged and colonized new areas. The occurrence of Eurasian watermilfoil at sample sites increased by 23% between 2008 and 2013. Although the lake area dominated by Eurasian watermilfoil dropped from 7.9 acres in 2005 to 5.7 acres in 2008, it increased dramatically in 2013, totaling to 11.7 acres. Invasive zebra mussels (*Dreissena polymorpha*) present in the lake potentially exacerbate nuisance plant growth by altering the natural lake ecosystem. Increased nutrient availability from sources such as fertilizers, septic leachate, and stormwater have probably also contributed to changes in aquatic plant growth in Long Lake.

The Association should share results from this survey to maximize benefits and assist in lake management efforts. Shoreline areas should be surveyed for evidence of nutrient pollution and problem areas addressed to prevent or reduce nuisance aquatic plant growth. TOMWC recommends that the Association continue with biological control of Eurasian watermilfoil using weevils because it has been effective in the past and is an environmentally safe and potentially long-term solution. Information and education efforts should be undertaken to promote an understanding of aquatic plant communities and the lake ecosystem among riparian property owners and other lake users, as well as encourage behaviors and practices that protect and improve lake water quality. Future surveys are recommended to collect the necessary data for determining trends over time, evaluating successes or failures of aquatic plant management projects, and documenting the locations and spread of non-native aquatic plant species.

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 probably experience declining fisheries due to habitat and food source losses. Aquatic plant loss may also result in decreased 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 (*Potamogeton crispus*) or Eurasian watermilfoil.

In spite of all the benefits associated with aquatic plants, some aquatic ecosystems suffer from overabundance, particularly where non-native nuisance species have been introduced. Excessive plant growth can create a recreational nuisance by making it difficult or undesirable to boat, fish, and swim, but it also has the potential to cause aquatic ecosystem disruptions. In lakes plagued by nuisance plant growth, it sometimes becomes necessary to develop and implement programs to control excessive growth and non-native species. Aquatic plant management is a critical component of lake management. Thus, an important step in developing a sound lake management program is to survey the aquatic plant communities to document species, abundance, density, and the presence of non-native species.

Due to concerns regarding invasive plant species, Eurasian watermilfoil in particular, the Cheboygan Long Lake Area Association (Association) contracted with Tip of the Mitt Watershed Council (TOMWC) to perform a comprehensive aquatic plant survey of Long Lake in 2005. A second survey was conducted in the summer of 2008 to assess changes in aquatic plant communities following the implementation of biological control of Eurasian watermilfoil infestations using an aquatic weevil. With the absence of continued treatment, Eurasian watermilfoil resurged and in 2013, the Association decided to again contract with TOMWC to assess the status of Eurasian watermilfoil, as well as the native plant communities. Survey field methods, data management procedures, project results, and discussion of results are contained in this report.

History

Although the exact year of introduction of Eurasian watermilfoil is uncertain, its presence in Long Lake was confirmed during an aquatic plant survey conducted by TOMWC in 2005. The 2005 survey documented 18 species of submerged aquatic plants, the most commonly occurring species including: *Vallisneria americana*, *Najas flexilis*, *Myriophyllum spicatum*, *Chara spp.*, and *Potamogeton amplifolius*. Over 90% of Long Lake was found to contain little or no vegetation in 2005 (Appendix A). In vegetated areas of the lake, approximately 50% was dominated by two species: *Valisneria americana* (~30%) and *Myriophyllum spicatum* (20%).

Following the 2005 aquatic plant survey, the Association began looking into aquatic plant control options. The association decided to address problematic Eurasian watermilfoil growth with biological control, using an aquatic weevil native to Michigan's lakes. The Association contracted with EnviroScience, Inc. to stock weevils and perform surveys to assess control efforts in 2006. Prior to stocking, Eurasian watermilfoil beds were surveyed by EnviroScience biologists who confirmed that weevils were already present and therefore, native to Long Lake. Weevils were stocked in Long Lake by EnviroScience, Inc. for two consecutive years with 15,500 weevils stocked in 2006 and an additional 28,000 stocked in 2007 (EnviroScience, Inc. 2008). Weevils were stocked at five locations throughout the lake and assessments were performed to gauge the project's effectiveness. Assessment surveys showed weevils present in different life stages, damage to Eurasian watermilfoil beds from weevils, and weevil populations exceeding critical densities that are required to effectively reduce Eurasian watermilfoil infestations.

In 2008, the Association arranged to have a second aquatic plant survey conducted by TOMWC to document changes in the lake's plant communities and assess biological control efforts. A total of 26 aquatic plant taxa at 175 sample sites were documented during the 2008 survey. Slender naiad (*Najas flexilis*), muskgrass (*Chara spp.*) and eel-grass (*Valisneria americana*) were the most commonly collected species and dominant at the greatest number of sample sites. Eurasian watermilfoil was the fourth most commonly collected and dominant species.

The 2008 survey showed that a majority of Long Lake (76%) contained little or no aquatic vegetation. The aquatic plant communities predominantly contained light-density growth with over 50% of the vegetated lake areas in the light or light-moderate categories. However, over 35% of the vegetated areas contained heavy growth. The largest Eurasian watermilfoil beds were found in the northern end of the lake and in the northeast corner of the southern-most basin.

The areal extent of aquatic vegetation in Long Lake increased dramatically (~15%) between the 2005 and 2008 surveys. This increase may be the result of differences in sampling intensity between surveys, natural variation, aquatic plant management efforts, increased nutrient availability, or ecosystem changes caused by non-native species. Biological control efforts by the lake association in 2006 and 2007 resulted in the reduction and virtual elimination of the largest, densest Eurasian watermilfoil bed in the lake. However, new Eurasian watermilfoil beds appeared and some of the smaller existing beds expanded since the 2005 survey.

Invasive species and nutrient pollution probably contributed to heavy-density aquatic plant growth documented during the 2008 survey. Eurasian watermilfoil, present in Long Lake at least since 2005, grows densely and displaces native aquatic plants. Invasive zebra mussels (*Dreissena polymorpha*), also present in the lake, potentially exacerbate nuisance plant growth by altering the natural lake ecosystem. Human development of the landscape and activity in nearshore areas has probably increased nutrient inputs into the lake, which contribute to aquatic plant growth.

Although biological control was effective at reducing existing infestations documented in the 2005 survey, Eurasian watermilfoil resurged following the 2008 survey in the absence of additional weevil stocking. In 2013, TOMWC performed a third comprehensive plant survey for the Association. The information gathered in the 2013 survey will help the association evaluate its aquatic plant management strategies and determine next steps.

Study Area

Long Lake is located in the northern tip of the Lower Peninsula of Michigan; in Aloha Township (T36N.-R1W-S1,2,3,11,12) in northeast Cheboygan County. The lake is composed of three distinct basins that are hereafter referred to as the northwest, central, and southeast basins (Figure 1). Based upon digitization of aerial orthophotography acquired from the Cheboygan County GIS (Geographical Information System) Department (2004), the shoreline of Long Lake measures 5.5 miles and the lake surface area totals 392 acres.

Long Lake is narrow, long, and relatively deep considering its surface area. Maps acquired from the Michigan Department of Natural Resources (DNR) Institute for Fisheries Research indicate that the deepest point in Long Lake is 61 feet, which is located in the northern end of the southeast basin. The northwest and central basins are shallower with maximum depths of approximately 35 and 30 feet, respectively. From northwest to southeast, the lake measures just over two miles and has a maximum width of less than 0.40 miles.

Long Lake is a drainage lake with water flowing into and out of the lake. Long Lake Creek is the only outlet, exiting the southeast side of the lake and draining into the Black River. There are no major inlet streams, though a large wetlands complex on the northwest end probably contributes water in addition to groundwater inputs that seep into the lake from nearshore areas.

The Long Lake Watershed, according to GIS files developed by the Watershed Council using watershed delineation and elevation data acquired from the State of Michigan, encompasses 1505 acres, which includes the lake area (Figure 1). Land cover statistics for the watershed were generated using remotely sensed data from the Coastal Great Lakes Land Cover project (Table 1). Based on these data, there is little urban landcover within the watershed (~3.5%) and even less agricultural (~0.3%). The majority of the watershed's landcover is natural; consisting of forest, water, wetlands, and grassland.

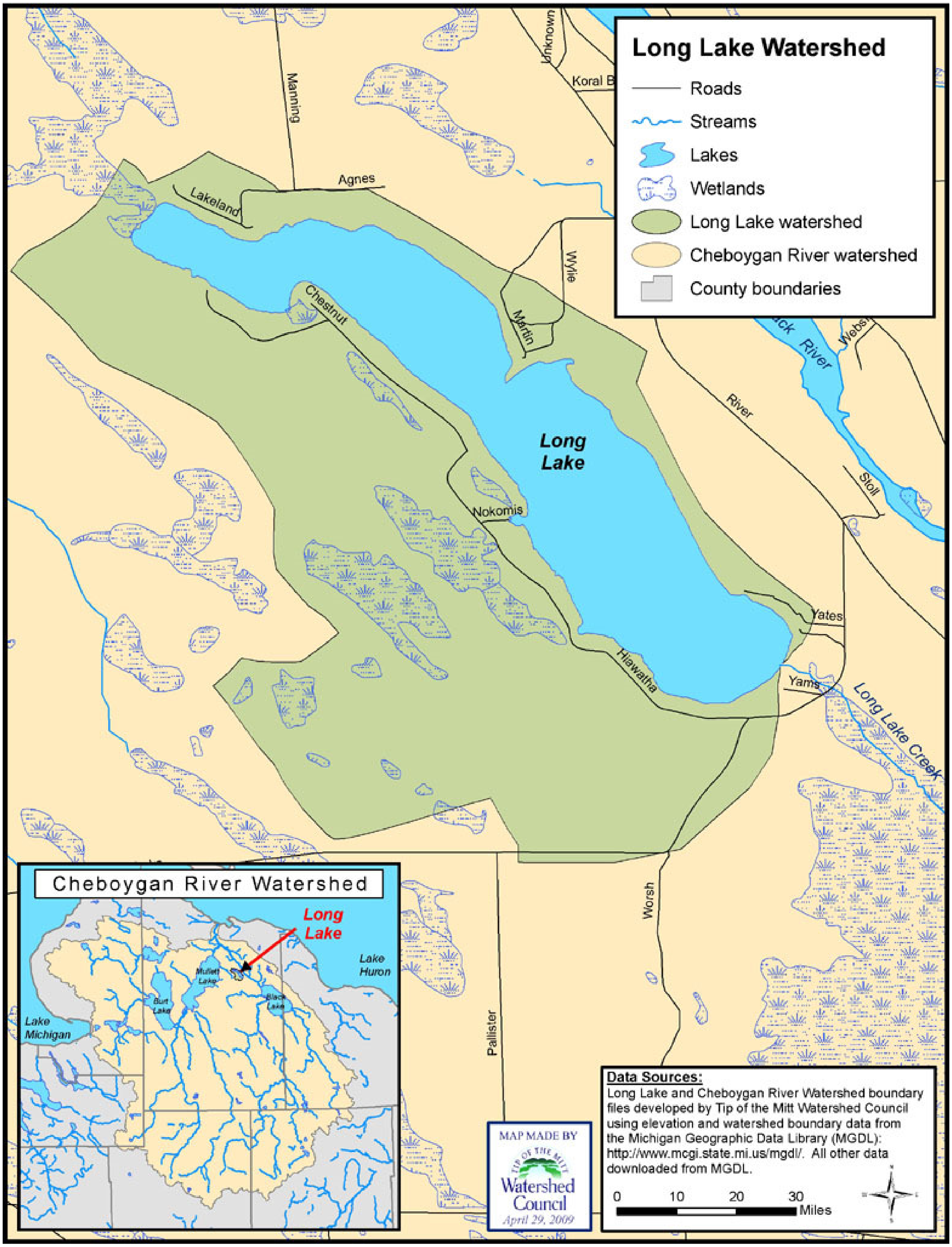


Figure 1. Map of the Long Lake Watershed.

Table 1. Long Lake Watershed land-cover statistics.

Land Cover Type	Acres (2001)	Percent (2001)	Acres (2006)	Percent (2006)	Percent Change (2001-2006)
Agriculture	7.99	0.53	4.50	0.30	-0.23
Forested	648.48	43.08	707.78	47.02	3.94
Grassland	206.29	13.70	88.40	5.87	-7.83
Scrub/shrub	40.58	2.70	54.32	3.61	0.91
Urban	46.41	3.08	52.01	3.46	0.37
Water	389.15	25.85	387.80	25.76	-0.09
Wetlands	166.33	11.05	210.43	13.98	2.93
TOTAL	1505.23	100.00	1505.23	100.00	NA

The water quality of Long Lake has been monitored for many years as part of the Volunteer Lake Monitoring program (VLM) and Comprehensive Water Quality Monitoring program (CWQM), which are coordinated by the Watershed Council. The water is very clear in Long Lake as indicated by averaged Secchi disc depths that have ranged from 15 to nearly 25 feet, which is typical for deep lakes in Northern Michigan. Water clarity is usually determined by two key factors: sediments and algae. The Secchi disc depth data indicate that the lake has low amounts of both (Figure 2). Little sediment in the water is desirable, but too little algae can impact the lake ecosystem because it is the base of the food chain. The invasive zebra mussels (*Dreissena polymorpha*) observed in Long Lake generally increase water clarity because they filter-feed on algae.

Based on trophic status index data from the VLM program, Long Lake generally falls into the oligotrophic category (Figure 3). Oligotrophic lakes are typically large, deep, clear, and nutrient poor. Generally, oligotrophic lakes contain high quality waters, but paradoxically have lackluster fisheries due to low biological productivity. Supporting data from the VLM program, total phosphorus data collected in the CWQM program show that concentrations have been around 10 parts per billion (PPB) or less since 1995, which is typical for oligotrophic lakes of northern Michigan (Figure 4).

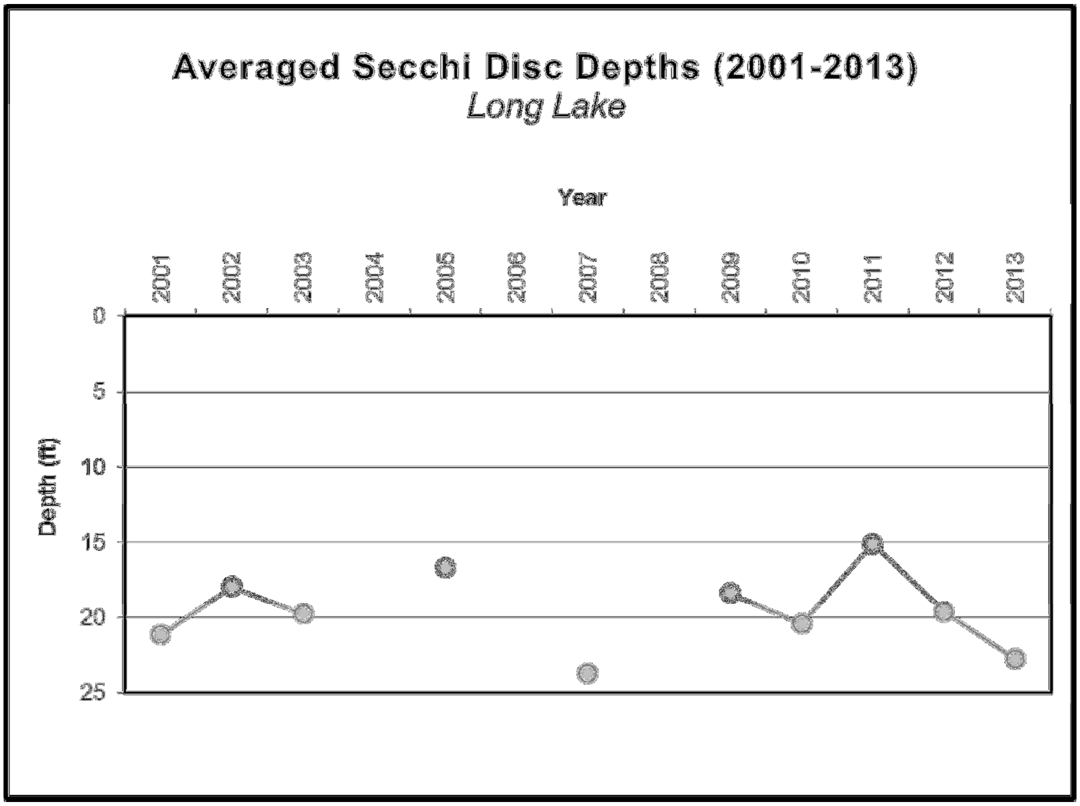


Figure 2. Chart of Secchi disc depth data from Long Lake.

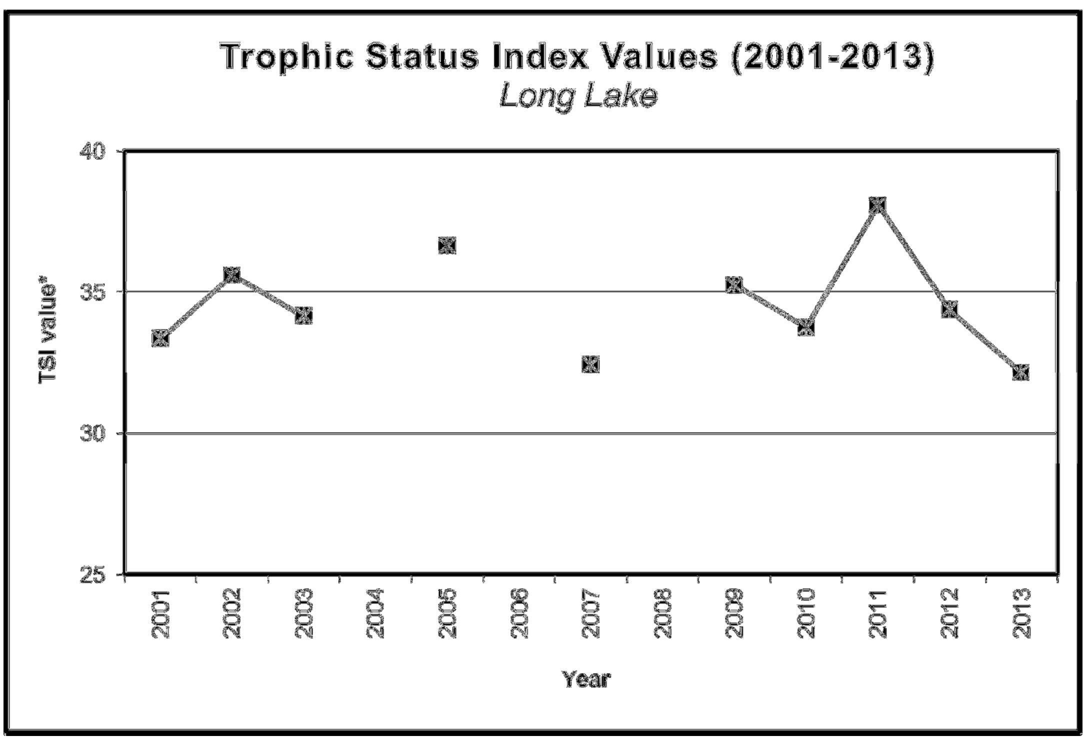
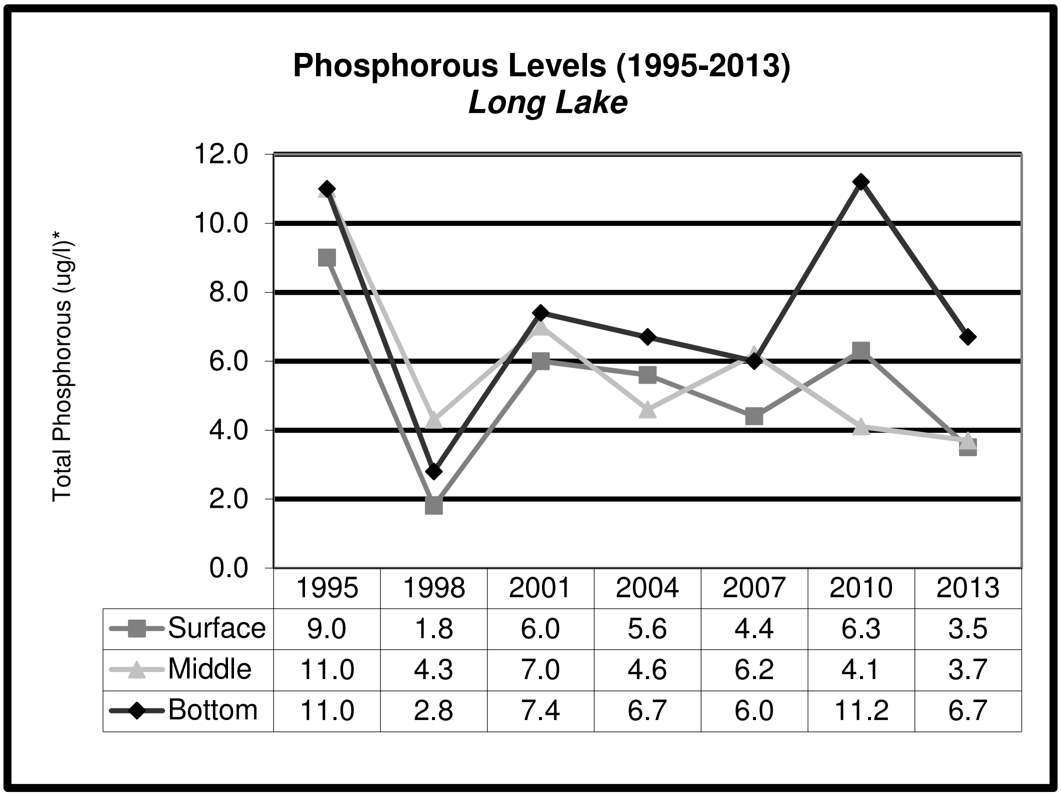


Figure 3. Chart of trophic status index data from Long Lake.

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



	1995	1998	2001	2004	2007	2010	2013
Surface	9.0	1.8	6.0	5.6	4.4	6.3	3.5
Middle	11.0	4.3	7.0	4.6	6.2	4.1	3.7
Bottom	11.0	2.8	7.4	6.7	6.0	11.2	6.7

Figure 4. Chart of phosphorus data from Long Lake.

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

Surveys by MDNR show that Long Lake supports a mixed warm-water fishery. Fish species collected during a 2004 survey include black crappie, bluegill, brown bullhead, largemouth bass, northern pike, pumpkinseed sunfish, rock bass, smallmouth bass, walleye, and white sucker. Additional forage fish collected during the survey include bluntnose minnow, logperch, mimic shiner, northern redbelly dace, sand shiner, and spottail shiner. Over 300,000 walleye were stocked in Long Lake from 1996 to 2006.

METHODS

Aquatic plants were documented in all vegetated areas of Long Lake during July of 2013. Consistent with Michigan Department of Environmental Quality procedures, the aquatic plant communities were surveyed using rake tows and through visual observations (MDEQ, 2005). After completing the field survey, data collected in the field were processed and used to produce maps displaying the lake's aquatic plant communities.

Sampling

Specimens were collected, identified, photographed and recorded in a notebook at 125 sample sites throughout the lakes to document aquatic plant taxa. Sample site locations were not random, but rather selected with the intent of collecting representative information on all aquatic plant communities currently inhabiting the lake. Most sampling was conducted along transects across the lake that were spaced at regular intervals. In expansive, deep areas, transects began near the shoreline and continued linearly into deeper waters until plants were no longer found. The distance between sample points along transects varied depending upon plant community changes that were visible from the surface. In areas where plant communities were not visible, sample sites were selected based on interpretation of signals from the depth-finder or at regular intervals along the transect.

At each sample site, the boat was anchored, water depth noted, and GPS data recorded. Water depth was monitored using Hummingbird depth finders. A Trimble GeoExplorer3 unit was used to record sample site locations. Plant specimens were collected using a sampling device consisting of two garden rake heads fastened together back to back with a length of rope attached. Using the sampling device, multiple throws were made at each site, collecting from all sides of the boat. Sampling continued until the collector was satisfied that plant taxa present at the site were represented in the sample. Rigorous sampling techniques and effort were employed, but some species may have been missed.

Specimens were identified to the lowest taxonomic level possible and representative samples of each species were laid out and photographed with a slip of paper indicating the number assigned to that site. Taxon density was subjectively determined (in relation to all plant taxa collected in the sample) and recorded as light (L), moderate (M), or heavy (H), but also including the sub-categories of very light (VL), light-moderate (LM), moderate-heavy (MH) and very heavy (VH). In general, the category “very heavy” was assigned when plant growth was so heavy that it reached the surface and formed a continuous mat. At the other end of the spectrum, “very light” indicated sparse vegetation where only a few stems or pieces were found. Overall plant density for the site was determined and noted using the same categorization system.

If a specimen could not be identified immediately, it was stored in a sealed bag and identified later with the aid of taxonomic keys, mounted herbarium specimens, and, if necessary, assistance from other aquatic plant experts. All taxa names, relative taxa densities, overall site density and comments were recorded in a field notebook. If no plants were encountered during sampling, ‘no vegetation’ was recorded in the field notebook.

To assist in mapping the aquatic vegetation, additional photographs were taken to document emergent vegetation. At each sample site located within or adjacent to emergent vegetation, pictures were taken of surrounding areas. Pictures were taken with a Ricoh G700SE digital GPS camera.

Community Mapping

Aquatic plant communities can be delineated simply by interpolating or extrapolating between sample points, but the accuracy of such delineations are greatly improved by noting and mapping precise locations where one plant community type ends and another begins. Therefore, additional data were collected to improve the accuracy of delineations between distinct plant communities in the lake. During sampling, plant community details observed at or near sample sites were recorded in the field notebook. Plant communities that were visible from the boat were described in terms of species composition, areal extent, shape, and density. Changes in plant communities between sample sites and the absence of vegetation in any direction were also noted.

Distinct submerged aquatic plant beds and emergent vegetation were mapped with a GPS. Where feasible, the perimeter of submerged plant beds was followed as closely as possible in the boat and GPS data collected at major vertices to develop polygons representing the plant beds. The depth finder was also used to delineate plant communities as signals show transitions between vegetated and non-vegetated areas. Emergent plants growing directly along the shoreline were frequently mapped at an offset distance that was recorded in the GPS unit. Plant specimens were not collected while mapping community lines with GPS.

In spite of sampling at 125 sites and subsequent community line mapping, some small or isolated plant communities could have been missed. Plants were not sampled between sites in survey transects and plant community mapping may have not occurred in those areas either if conditions did not allow. Upon several occasions, plant community mapping was impeded by poor visibility, whether from wave turbulence, turbidity, or simply water depth and attenuation of sunlight. Additionally, emergent plant bed mapping may contain errors resulting from misinterpretation of GPS data and associated comments collected in the field.

Data Processing and Map Development

GPS data collected with the Trimble GeoExplorer3 were post-processed and exported into a GIS file format using GPS Pathfinder Office 3.10 software. GPS data from the Trimble Juno SB were transferred to a computer as shapefiles. GIS data layers developed using the GPS data consisted of point layers representing sample sites and polygon layers representing plant communities. All GIS work was performed using ESRI GIS software: ArcMap and ArcCatalog 10.2.

Information collected at sample sites and written in field notes was entered into a database. A record was entered into the database for each sample site, using the sample site number as the unique identifier. Field data were entered as separate attributes in the database table, including water depth, taxa names and densities, areas of little/no vegetation, overall community density, and comments. Additional columns were added to the database for the number of taxa, the dominant taxa, and the dominant community at each site. Field data in the spreadsheet were imported into a GIS and joined to the sample site GIS point data layer. The joined data were exported to a new GIS point data layer containing attribute information collected at each sample site.

Delineations of aquatic plant communities recorded with GPS were used to develop polygons representing community types occurring in the lake. If borders between plant communities were not mapped directly with GPS in the field, then divisions between plant communities were determined by interpolating between or extrapolating from sample sites. Field notes from sample sites were also consulted during on-screen delineation of plant communities. After developing polygons, area statistics for specific plant communities and associated densities were calculated.

Final products include both maps and statistics generated from digital map layers. Presentation-quality maps were developed to depict sample site locations, plant community densities at sample sites, dominant plant communities, and plant community densities. In addition, the ArcMap project file allows GIS users to view all tabular data associated with the site.

RESULTS

Sample Sites

A total of 25 aquatic plant taxa were documented during the sampling conducted at 125 sites on Long Lake (Table 2). Additionally, five emergent taxa were noted in comments or mapped with GPS, but not represented in the spreadsheet columns: bur-reed (Sparganium spp.), cattail (*Typha spp.*), sedges (*Carex spp.*), sweet gale (*Myrica gale*), and water horsetail (*Equisetum fluviatile*). The number of aquatic plant taxa encountered at a site ranged from zero to 11 with an average of 3.9 taxa per sample site. One invasive plant species were encountered during this survey: Eurasian watermilfoil.

Table 2. Aquatic plant taxa occurrence at sample sites.

Genus and species	Common Name	Number of sites	Percent of sites
Chara spp.	Muskgrass	99	79.2
Myriophyllum spicatum	Eurasian watermilfoil	63	50.4
Najas flexilis	Slender naiad	63	50.4
Vallisneria americana	Eelgrass	57	45.6
Potamogeton spp.	Unknown Pondweed	43	34.4
Potamogeton friesii	Fries' pondweed	29	23.2
Potamogeton gramineus	Variable pondweed	26	20.8
Potamogeton amplifolius	Broad-leaved pondweed	24	19.2
Elodea Canadensis	Elodea	15	12.0
Stuckenia pectinata	Sago pondweed	10	8.0
Myriophyllum sibiricum	Common watermilfoil	9	7.2
Potamogeton praelongus	Whitestem pondweed	9	7.2
Potamogeton illinoensis	Illinois pondweed	7	5.6
Potamogeton natans	Floating-leaf pondweed	7	5.6
Sagittaria spp.	Arrowhead (Arum)	5	4.0
Nuphar variegata	Yellow pond-lily	4	3.2
Brasenia schreberi	Watershield	3	2.4
Heteranthera dubia	Water-stargrass	3	2.4
Myriophyllum heterophyllum	Variable watermilfoil	3	2.4
Nymphaea odorata	White pond-lily	3	2.4
Potamogeton pusillus	Small pondweed	3	2.4
Potamogeton richardsonii	Richardsons' pondweed	2	1.6
Megalodonta beckii	Water marigold	1	0.8
Potamogeton strictifolius	Narrow-leaf pondweed	1	0.8
Potamogeton zosteriformis	Flatstem pondweed	1	0.8

Muskgrass (*Chara spp.*), Eurasian watermilfoil, and slender naiad (*Najas flexilis*) were the most commonly encountered species; collected at approximately 79%, 50%, and 50% of vegetated sites respectively (Table 2). Four other taxa were collected at 20 sites or more and considered common: eel-grass (*Valisneria americana*), Fries' pondweed (*Potamogeton friesii*), variable-leaf pondweed (*Potamogeton gramineus*), and broad-leaved pondweed (*Potamogeton amplifolius*). Seventeen plant taxa occurred uncommonly (occurring at less than 20 sites). The plants that dominated or co-dominated plant communities at the greatest number of sample sites included muskgrass, pondweeds, and watermilfoils (Table 3). Typical for lakes in this region, the pondweed family (*Potamogetonaceae)* was the most speciose with 11 pondweed species documented during this survey.

Table 3. Aquatic plant taxa dominance at sample sites.

Aquatic Plant Taxa	**Number of sites where dominant***	**Percent of sites where dominant***
Eelgrass and Muskgrass	1	0.8
Eelgrass and Pondweed	5	4.0
Eelgrass and Watermilfoil	2	1.6
Eelgrass, Muskgrass, and Pondweed	5	4.0
Eelgrass, Muskgrass, and Watermilfoil	2	1.6
Eelgrass, Naiad, and Pondweed	1	0.8
Eelgrass, Pondweed, and Watermilfoil	2	1.6
Multiple species	6	4.8
Muskgrass	40	32.0
Muskgrass and Naiad	1	0.8
Muskgrass and Pondweed	10	8.0
Muskgrass and Watermilfoil	3	2.4
Muskgrass, Pondweed, and Watermilfoil	2	1.6
Muskgrass, Pond-lily, and Watershield	1	0.8
Naiad	1	0.8
Naiad and Watermilfoil	1	0.8
Pond-lily	1	0.8
Pond-lily and Arrowhead	1	0.8
Pondweed	15	12.0
Pondweed and Watermilfoil	4	3.2
Water-stargrass	1	0.8
Watermilfoil	7	5.6
Little or no vegetation	13	10.4
TOTAL	125	100.0

Plant Communities

Based on plant community mapping, 279 of the 391 acres (~71%) of Long Lake contained little or no aquatic vegetation (Figure 5). Muskgrass was found to dominate plant communities in over 60% of the vegetated area (Table 4). Communities dominated by Eurasian watermilfoil followed at just over 10%. Pondweed-dominated plant communities accounted for approximately 9% of the vegetated lake area.

Table 4. Dominant aquatic plant communities: acres and percent.

Dominant Community Type	Lake Surface Area (acres)	Percent of Vegetated Area
Arrowhead and Pondweed	0.34	0.30
Arrowhead and Pond-lily	0.65	0.58
Bulrush	0.46	0.41
Bulrush and Cattail	0.06	0.05
Bur-reed	0.03	0.03
Cattail	0.10	0.09
Eelgrass	0.82	0.74
Eelgrass and Pondweed	2.01	1.80
Eelgrass, Muskgrass, and Pondweed	4.14	3.70
Eelgrass, Naiad, and Pondweed	5.28	4.72
Eelgrass and Watermilfoil	0.27	0.24
Eurasian watermilfoil	11.67	10.42
Multiple species	1.10	0.99
Muskgrass	67.31	60.12
Muskgrass and Pondweed	3.49	3.12
Muskgrass and Pond-lily	0.03	0.02
Muskgrass, Naiad, and Pondweed	0.66	0.59
Muskgrass, Pondweed, and Watermilfoil	0.01	0.01
Naiad	0.39	0.35
Pond-lily	0.45	0.40
Pond-lily and Watershield	1.28	1.15
Pondweed	10.09	9.01
Pondweed and Pond-lily	0.03	0.02
Pondweed and Watermilfoil	0.80	0.71
Sedge	0.02	0.01
Water-stargrass	0.02	0.02
Water Horsetail	0.01	0.01
Watershield	0.44	0.40
TOTAL	111.96	100.00

Aquatic plant community densities leaned toward light-density growth (Table 5). Over 55% of plant community densities fell into the light categories (VL, L, and LM). Moderate growth covered just over 20% of the lake surface area and heavy-density growth (MH, H, and VH) accounted for approximately 24%. Areas of heavy-density growth concentrated in the northwest end of the lake, along the western shoreline, and in the southeast corner (Figure 6).

Table 5. Aquatic plant densities.

Density Category	**Lake Surface Area (acres)**	**Percentage of vegetated area**
Very Heavy	1.46	1.30
Heavy	12.31	10.99
Moderate to Heavy	13.48	12.04
Moderate	22.80	20.37
Light to Moderate	9.01	8.05
Light	43.90	39.21
Very Light	9.00	8.04
No vegetation	279.44	NA

Eurasian watermilfoil was documented in many locations throughout all three basins of Long Lake. The largest and densest beds were found on the southwest side and in the southeast corner of the southern basin (Figure 5 and 6). Eurasian watermilfoil dominated approximately 11.7 acres of the lake's plant communities and it was a co-dominant species in an additional 0.6 acres.

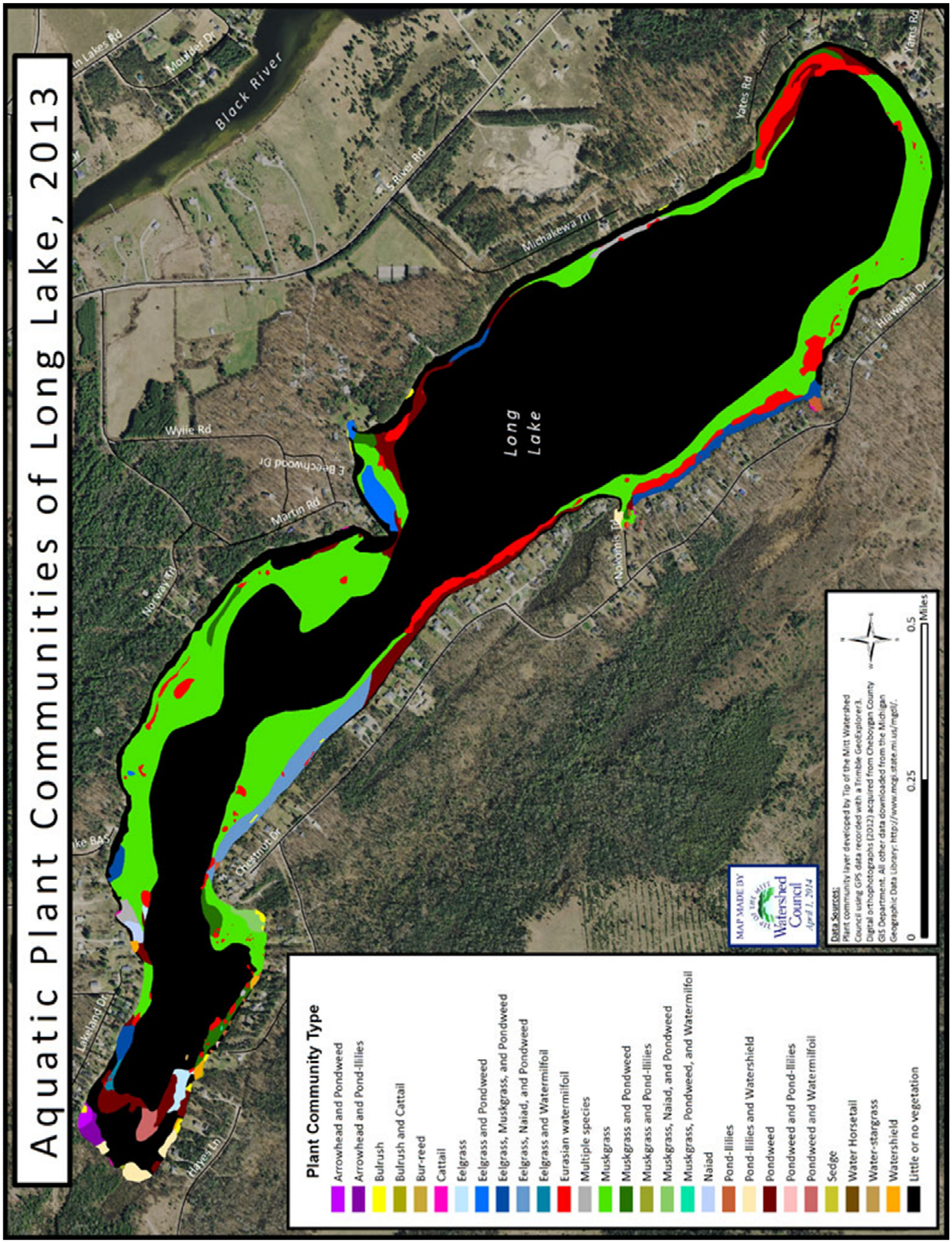


Figure 5. Aquatic plant communities in 2013 survey.

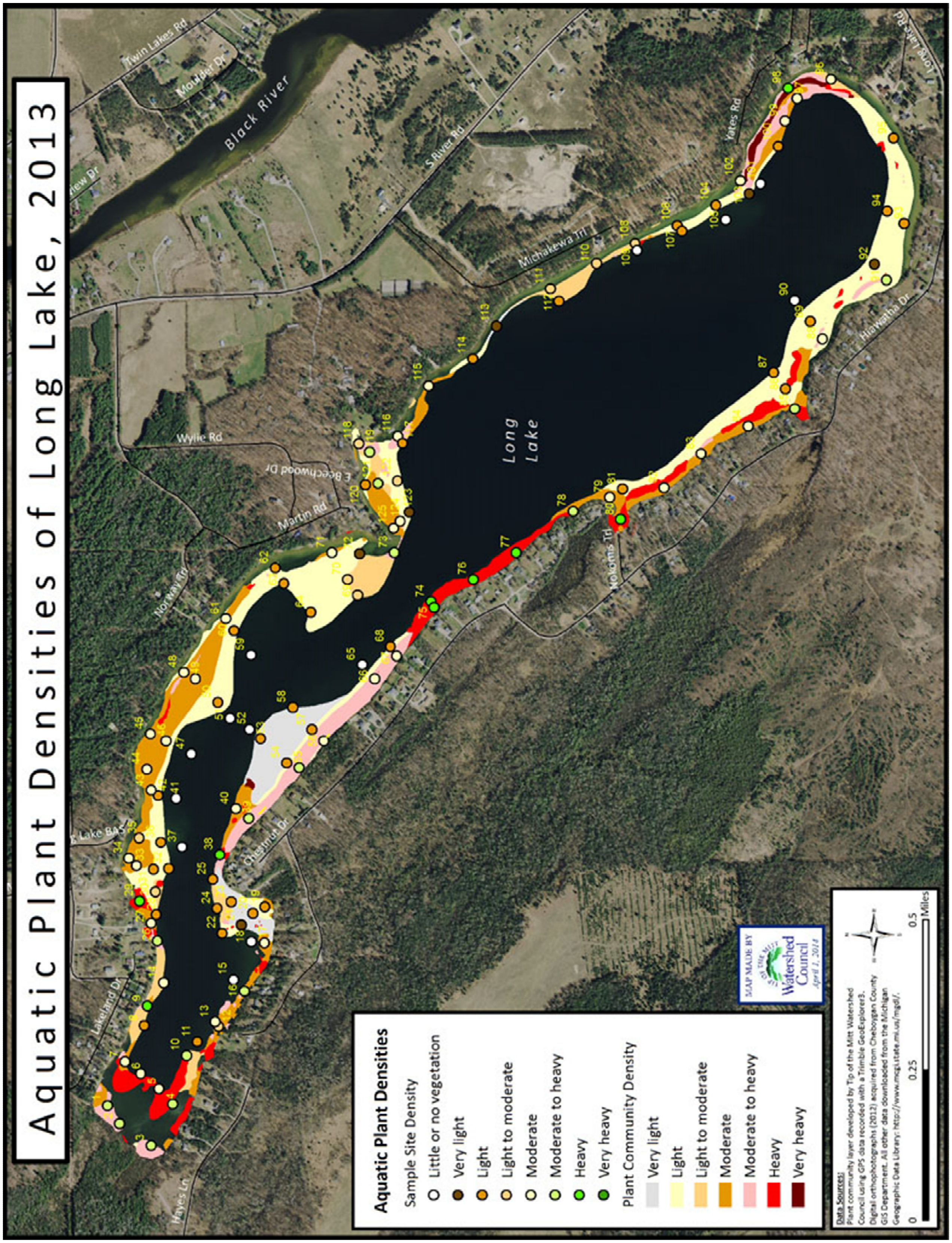


Figure 6. Aquatic plant densities from 2013 survey.

DISCUSSION

Similar to past surveys, results revealed that large areas of Long Lake contain little or no vegetation, but that a diverse assemblage of native plant species exists in the lake. In terms of surface area, this survey found that 71% of the lake contains little or no vegetation, compared to 75% in 2008. In vegetated areas, a total of 30 aquatic plant taxa were documented during the survey, compared to 26 taxa in 2008. The aquatic plant diversity in Long Lake is below the average for Northern Michigan Lakes surveyed by TOMWC, but the number of taxa found at each site falls in the middle (Table 6). Plant community types in both surveys were similar (Figure 5 and Appendix A).

Table 6. Aquatic plant survey statistics from area lakes.

Lake name*	Acreage	Maximum depth (ft)	Lake area with vegetation	Sites with dense vegetation[†]	Number of total taxa	Number of taxa per site
Adams	43	18	99%	65%	27	4.9
Black	10,133	50	13%	25%	32	3.7
Crooked/Pickerel	3,447	70	46%	11%	31	2.4
Long	398	61	29%	7%	30	3.9
Douglas	3,780	80	47%	15%	30	5.3
Millecoquin	1,116	12	95%	61%	20	6.0
Mullett	17,205	144	19%	13%	42	3.1
Paradise	1,947	17	58%	28%	24	5.0
Walloon	4,620	100	22%	3%	32	1.8
Wycamp	689	7	83%	24%	35	4.9
AVERAGE	NA	NA	51%	26%	30	4.0

**Lakes included all surveyed by TOMWC staff.*
[†]Includes sites with plant density classified as heavy or very heavy.

Areas of heavy-density plant growth were documented in both the 2008 and 2013 surveys, but the location of these areas shifted considerably. The beds of dense growth documented in 2008 along the western shore as well as in isolated pockets in the central basin and northern portion of the southeast basin were not found in 2013 or were much reduced in terms of size or density (Figure 6 and Appendix C). During both surveys, heavy-density growth was found at the north end of the northeast basin and the northwestern shore of the southeast basin. Extensive areas of dense growth on the central-west side and southeast corner of the southeast basin were newly documented in the 2013 survey.

Increased nutrient availability from sources such as fertilizers, septic leachate, and stormwater have probably also contributed to changes in aquatic plant growth in Long Lake. Data from TOMWC monitoring programs do not show increases in nutrient concentrations in Long Lake (Figure 4), but all these data are collected at one point in open water, far removed from the shoreline. Nutrient pollution originating from shoreline properties fuels aquatic plant growth in nearshore areas. Elevated nutrient inputs from riparian areas might not appear in the water quality monitoring data due to nutrient uptake by aquatic plants along the shoreline.

Invasive species and aquatic plant management efforts have influenced the aquatic plant communities of Long Lake. Eurasian watermilfoil was first documented in Long Lake during the 2005 aquatic vegetation survey (Appendix C). Biological control efforts by the Association in 2006 and 2007 resulted in the reduction and virtual elimination of the largest, densest Eurasian watermilfoil bed, which was located on the southwest side of the central basin. In addition, the Eurasian watermilfoil beds in the north end of the northeastern basin and in the northeast corner of the southeast basin largely disappeared between 2008 and 2013. However, in the absence of continued treatment with weevils, Eurasian watermilfoil has resurged and colonized new areas. In 2013, the invasive watermilfoil was found to dominate extensive areas throughout the southwest side and southeast corner of the southeastern basin, as well as many smaller pockets scattered throughout all three basins.

Sample site and plant community data from 2013 showed large increases in the occurrence and extent of Eurasian watermilfoil in Long Lake. The occurrence of Eurasian watermilfoil at sample sites and the acreage of Eurasian watermilfoil-dominated communities varied little between the 2005 and 2008 surveys, but there was a considerable increase in 2013. During the earlier surveys, Eurasian watermilfoil was found at approximately 27% of sample sites, compared to 50% of sites in the 2013 survey. Although the lake area dominated by Eurasian watermilfoil dropped from 7.9 acres in 2005 to 5.7 acres in 2008, it increased dramatically to 11.7 acres in 2013.

Invasive zebra mussels may have contributed to the increase in the vegetated area of the Long Lake. Zebra mussels filter feed on free-floating phytoplanktonic algae, which increases water transparency and allows sunlight to penetrate deeper; thus, increasing habitat availability for higher aquatic plants. Furthermore, zebra mussels secrete nutrient-rich waste on the lake bottom, which further stimulates the growth of rooted aquatic plants. Data from the Tip of the Mitt Watershed Council Volunteer Lake Monitoring program do not support this supposition as there have been no clear trends in terms of water transparency (Figure 2). However, the Association reported that zebra mussels were in the lake as of 1993, which would likely have led to noticeable changes in water clarity prior to volunteer data collection, with more subtle changes occurring present day.

Recommendations

1. Share the results of this survey. The results of this study should be widely dispersed to get a maximum return on the Association's investment. Sharing the results with members, non-member lake users, government officials, and others will inform the public about problems occurring in the lake and progress of the Association's efforts at aquatic plant and lake management. An informed public will be more supportive of the Association's efforts to manage the lake ecosystem and its aquatic plants. 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.

2. Develop an aquatic plant management plan. Although the Association has expended considerable resources to control the Eurasian watermilfoil, an aquatic plant management plan has yet to be developed. The aquatic plant community is a vital component of the aquatic ecosystem, such that good aquatic plant management translates to good lake ecosystem management. 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.

3. Investigate potential nutrient pollution issues. Nutrient pollution can lead to excessive plant growth and should be controlled wherever and whenever possible. Shoreline surveys provide valuable information regarding locations and potential sources of nutrient pollution. In addition, information gathered from a shoreline survey can be used to work with lakeshore property owners to verify nutrient pollution, identify sources, and correct any problems. There is a record at the Watershed Council office of a shoreline survey being conducted on Long Lake in 2002, but the actual report has not been uncovered. If the association has a copy of the report, then the information contained within could be used to address nutrient pollution issues in the lake. However, the information from the 2002 survey is dated and it would behoove the association to sponsor another shoreline survey to document current conditions. Regardless of availability of shore survey data, the Lake Association can make positive steps toward controlling nutrient pollution by communicating and working with shoreline property owners. In particular, property owners around the lake should be encouraged to properly maintain septic systems, replace old or failing septic systems, reduce or eliminate fertilizer use, compost and mulch far from the shoreline, and prevent stormwater from flowing directly into the lake.

4. Continue efforts to control Eurasian watermilfoil in the lake. Data from the 2008 and 2013 surveys show the long-term effectiveness that is possible when using weevils as a biological control method. The largest and densest Eurasian watermilfoil found in the 2005 survey on the southwest side of the central basin had virtually disappeared in 2008 and had not resurged as of 2013. Additional beds of the invasive watermilfoil in the north end of the northwest and southeast basins largely disappeared between the 2008 and 2013 surveys. However, many other lake areas have become infested in the absence of continued treatment and the overall extent of Eurasian watermilfoil dominated areas has increased considerably. Therefore, due to the initial successes in controlling the invasive watermilfoil using weevils, combined with the fact that they are a completely environmentally safe and potentially long-term solution, we recommend that the Association continue using biological control to address Eurasian watermilfoil

problems. The current weevil population in Long Lake could conceivably control existing and new watermilfoil growth, but should be augmented to increase the probability of effective control. Please note that biological control methods generally require patience as it can take a few years to show results.

5. Preserve the lake ecosystem and natural diversity. Nuisance aquatic plant growth, both native and non-native, is an issue of concern for many shoreline residents and other lake users. Although invasive species occur, most of the vegetated lake area contains a vibrant, healthy aquatic plant population. With regards to plant management and control options, the Association should strive to protect the diverse assemblage of plants present in the lake, which are critical for sustaining a healthy fishery and maintaining a healthy aquatic ecosystem. In addition, a healthy community of diverse native plants makes it more difficult for invasive species to become established and proliferate.

6. Educate and inform lake users. Human activity in a multitude of forms typically has the greatest impact on a lake's aquatic plant communities. Therefore, effectively managing the lake's aquatic plants requires information and education outreach projects that target shoreline property owners, watershed residents, and all 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.

7. Regularly survey the aquatic plants of Long Lake. To effectively manage the aquatic plant community of Long Lake, periodic aquatic plant surveys should be conducted. The Lake Association has already followed this recommendation, sponsoring three surveys in the space of eight years. However, future surveys are necessary to examine trends, evaluate success or failure of aquatic plant management projects, and document the locations and spread of non-native aquatic plant species. Although dependent upon many different variables, surveying the aquatic plant community on a 5-10 year basis is generally sufficient.

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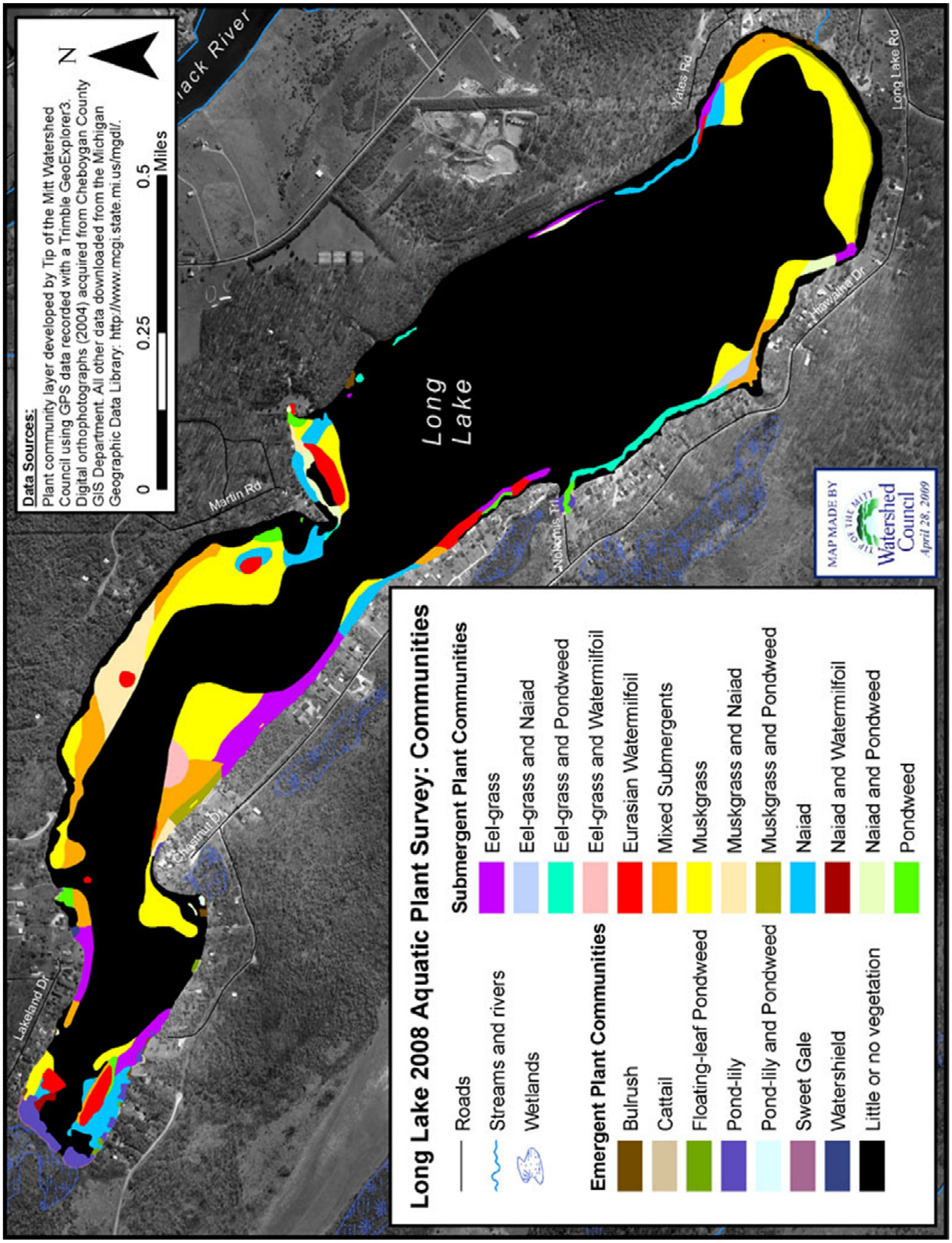
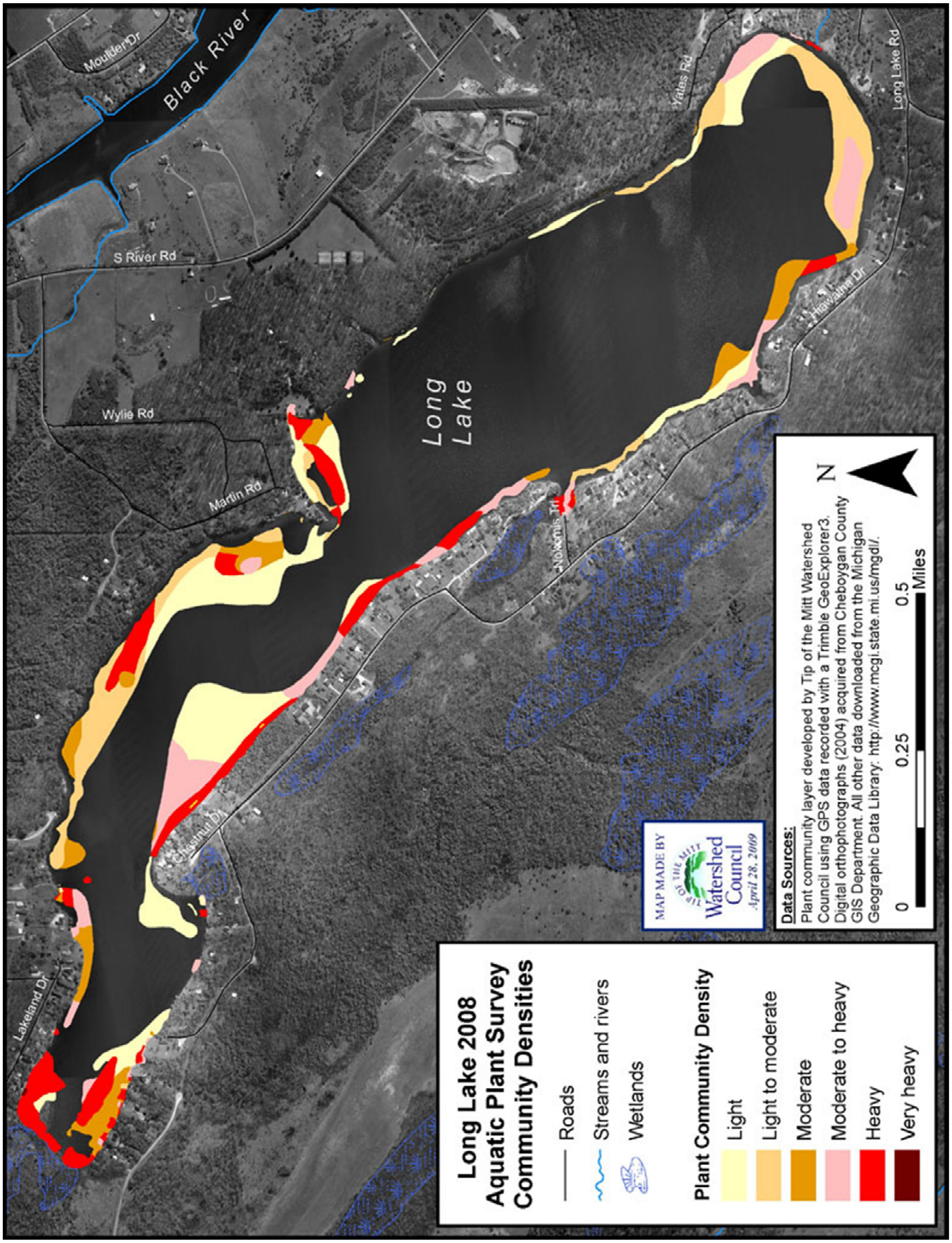
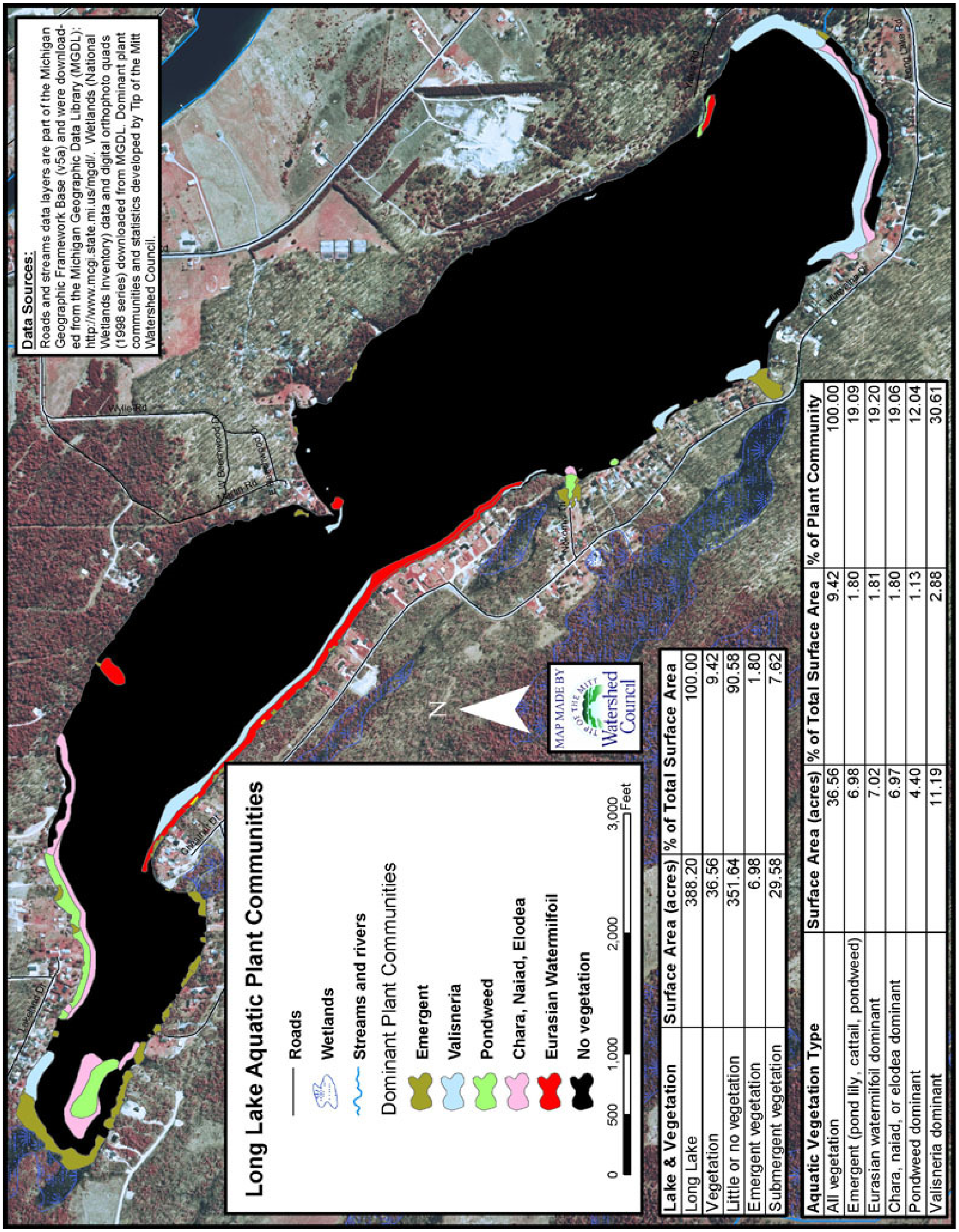
Appendix A. 2008 aquatic plant communities map for Long Lake.



Appendix B. 2008 aquatic plant densities map for Long Lake.



Appendix C. 2005 aquatic plant communities map for Long Lake.



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

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