Black Lake Aquatic Vegetation Survey 2014
Tip of the Mitt Watershed Council

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SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but can become a recreational nuisance when growth is excessive. 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. Residents around Black Lake, a 10,000-acre lake in the Northern Lower Peninsula of Michigan, have expressed concerns about nuisance aquatic plant growth and invasive species. In response, the Black Lake Association sponsored two comprehensive aquatic vegetation surveys, conducted in 2005 and 2014 by Tip of the Mitt Watershed Council.

The most recent survey was carried out in the summer and early fall of 2014. Watershed Council staff collected plant specimens, recorded abundance, and noted densities at 284 sites throughout Black Lake. In addition, aquatic plant communities were delineated through interpolation or extrapolation of sample site data or directly in the field using GPS units.

The 2014 survey documented 38 different aquatic plant taxa. An average of 3.9 taxa per site were collected, with a maximum of 13 taxa were found at a site. Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), and eelgrass (*Valisneria americana*) were the most commonly collected species. Two invasive wetland species, Eurasian Phragmites *(Phragmites australis*), also known as common reed, and purple loosestrife (*Lythrum salicaria),* were found during this survey. Both are plants of particular concern due to their ability to outcompete native vegetation and crowd wetlands and shorelines.

Little to no vegetation was found in 82% of Black Lake in 2014. Muskgrass and variable-leaf watermilfoil were the dominant plants in nearly 55% of the vegetated lake area, primarily in the northwest corner of the lake. Eelgrass, or mixed submergent species that generally included eelgrass, dominated the narrow ring of vegetation at the drop-off zone in the southern basin and along much of the eastern side. Approximately one-third of the vegetated area contained light density plant growth, while 15% had heavy-density growth. Most of the dense aquatic plant growth occurred in the northern basin of the lake and along the west side of the southern basin.

The extensive and dense vegetation in the northwest corner of Black Lake is attributed to shallow depths and nutrient inputs from inlet tributaries. Invasive zebra mussels and nutrient pollution from shoreline properties may also contribute to aquatic plant growth throughout Black Lake. Dense beds of variable-leaf watermilfoil were found to be widespread in the north basin, potentially constituting a recreational nuisance. Deep water (over 20’) was the primary factor contributing to the lack of vegetation throughout much of the southern basin.

Sampling methods used in the 2005 survey were replicated to allow for a comparative assessment of aquatic plant communities over time. However, the effort level was much less in 2005 when 145 sites were sampled, versus 284 in 2014. In addition, 10% fewer community delineation lines recorded in 2005. The 2014 survey documented 38 different aquatic plant taxa, including two newly found invasives species, versus 32 taxa in 2005. Little to no vegetation was found in 82% of Black Lake in 2014, versus 87% in 2005.

The Association should act immediately to control existing invasive species in the lake, as well as prevent the introduction of other exotic species. Shoreline areas should be surveyed on a regular basis to document evidence of nutrient pollution, erosion, riparian vegetation, and other factors the potentially contribute to nuisance aquatic plant growth. Problem areas identified during surveys should be addressed to prevent or reduce nuisance aquatic plant growth.

The Association should share results from this survey to maximize benefits and assist in lake management efforts. 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 (Valley et. al. 2004, Dibble et. al. 1996, Engel 1985). Like their terrestrial counterparts, aquatic plants provide primary production to the ecosystem and oxygen via photosynthesis. Aquatic plants utilize nutrients in the water and sediments that could otherwise be used by algae and potentially result in nuisance blooms. A number of aquatic plants, including bulrush, water lily, cattails, and pickerelweed help prevent shoreline erosion by absorbing wave energy and moderating currents (Madsen and Warncke 1983). In addition, soft sediments along the lake bottom are held in place by rooted aquatic plants (Engel 1985).

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. 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.

Control measures that reduce aquatic plants in a lake can have negative impacts on the lake ecosystem. Herbicide treatment causes oxygen loss, which can lead to fish and invertebrate mortality (Brooker and Edwards 1975). Phosphorus has been shown to increase following herbicide application (Morris and Jarman 1981). Blue-green algal blooms have been documented after herbicide treatment (Getsinger et al. 1982). Herbicides can be toxic to fish and invertebrates (Engel 1990), while mechanical harvesting of aquatic plants removes fish and invertebrates in the process (Wile 1978). Thus, aquatic vegetation control measures should be carefully considered in terms of impacts to the lake ecosystem.

Aquatic plant management is a critical component of lake management. In turn, aquatic vegetation surveys are necessary to effectively manage a lake's aquatic plant communities. With funding from the Black Lake Association (Association), Tip of the Mitt Watershed Council (TOMWC) surveyed the aquatic vegetation in Black Lake in 2005. The 2005 survey documented aquatic plant types, density, and distribution, which were included in a report to the Association, as well as options and recommendations for nuisance plant management. No invasive plant species were documented during the 2005 survey, but nuisance variable-leaf watermilfoil growth was found to be a problem in the northwest corner of the lake.

Based on a recommendation from the 2005 survey report, the Association worked with EnviroScience, Inc. to test biological control of nuisance variable-leaf watermilfoil using aquatic weevils (*Euhrychiopsis lecontei*). Unfortunately, the experiment met with limited success and the biological control approach was abandoned. In 2014, the Association contracted with TOMWC to perform a second comprehensive aquatic plant survey of Black Lake. Survey field methods, data management procedures, project results, and discussion of results for the 2014 survey 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. Based on digitization of aerial orthophotography from the Cheboygan County Equalization Department and the State of Michigan (both 2012), the shoreline of Black Lake measures 19.2 miles and lake surface area totals 10,135 acres. Black Lake extends approximately 6.4 miles in a southeast to northwest direction and is 2.0 to 3.6 miles wide throughout its length. 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 (Figure 1). 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 to Black Lake is the Black River, which flows in on the west side of the lake, 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 also flow into Black Lake, including Stony, Stewart, and Fisher Creeks in the south, Mud Creek in the west, and Cains Creek to the north. The Lower Black River is the only outlet, which is located in the northwestern corner of the lake.

The Black Lake Watershed encompasses approximately 357,307 acres, which includes the lake area (Figure 1). Land cover statistics were generated for the watershed using remote sensing data from the Coastal Great Lakes Land Cover project (NOAA 2010). Based on 2010 data, the majority of the watershed's land-cover is natural; consisting primarily of forest, wetlands, and grassland (Table 1). There is a small amount of agricultural land-cover in the watershed (4.2%) and little urban (1.8%). Both agricultural and urban land-cover changed by less than one percent between 1985 and 2010.

Figure 1. Black Lake: Features and Watershed.

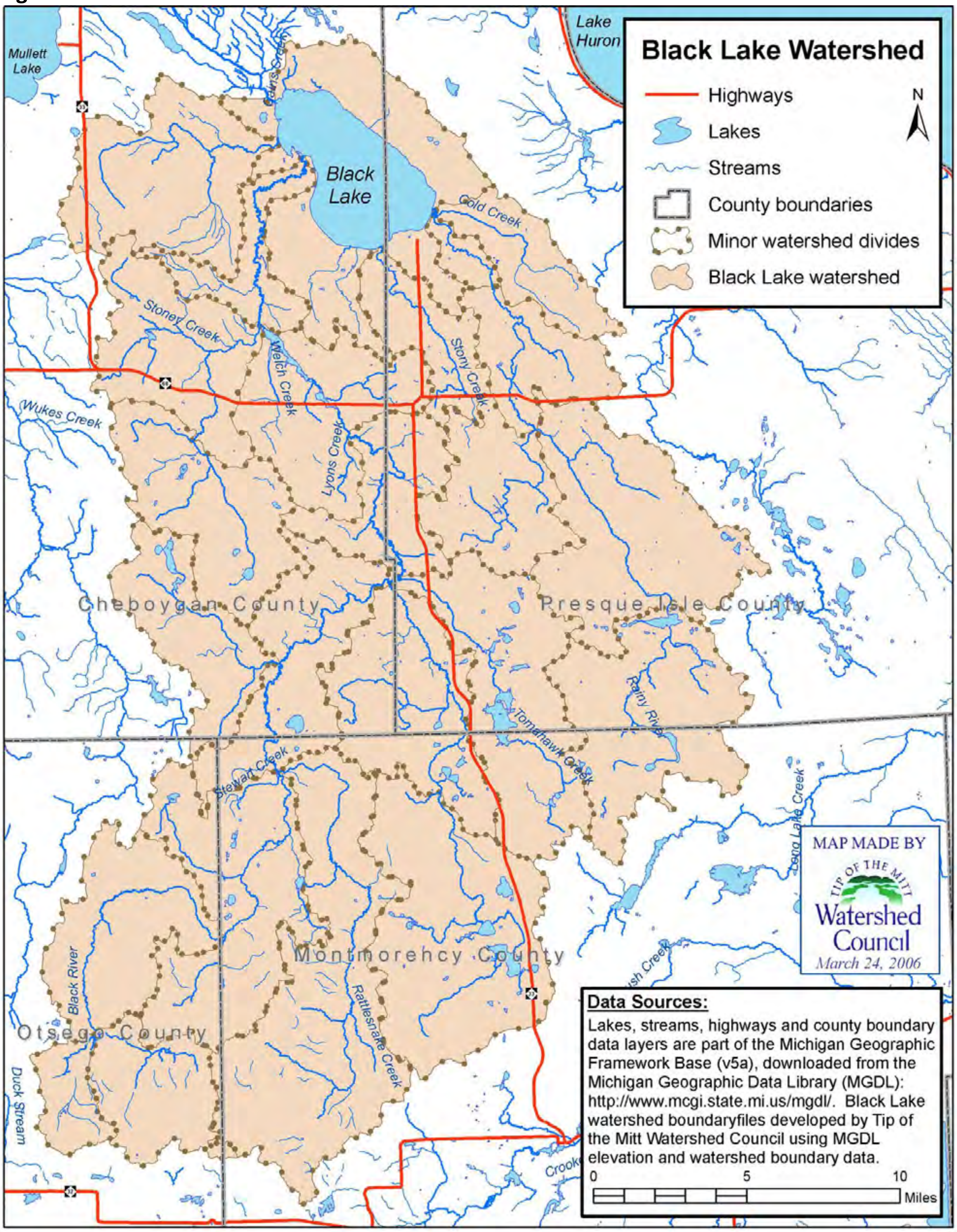


Table 1. Black Lake Watershed land-cover statistics.

Land Cover Type	1985 acres	1985 percent	2010 acres	2010 percent	Change (acres)	Change (percent)
Agriculture	1,7493	4.9	15,070	4.2	-2,423	-0.7
Barren	283	0.1	250	0.1	-33	0.0
Forest	181,316	50.7	162,958	45.6	-18,358	-5.1
Grassland	19,391	5.4	27,957	7.8	8,566	2.4
Scrub/Shrub	19,203	5.4	30,507	8.5	11,304	3.2
Urban	5,636	1.6	6,485	1.8	849	0.2
Water	14,075	3.9	13,786	3.9	-289	-0.1
Wetland	99,910	28.0	100,294	28.1	383	0.1
TOTAL	357,307	100.0	357,307	100.0	NA	NA

The water quality of Black Lake has been monitored consistently for nearly three decades through the TOMWC's Comprehensive Water Quality Monitoring program (CWQM) and Volunteer Lake Monitoring program (VLM). Data from these programs date back to 1987. In general, data from these programs indicate that the Black Lake has good water quality and a healthy lake ecosystem.

VLM data revealed a trend of increasing water clarity over time. Averaged Secchi disc depths have increased from approximately 10 feet in 1987 to nearly 15 feet in 2014 (Figure 2). Water clarity is usually determined by two factors: suspended solids (sediments) and phytoplankton (free-floating unicellular algae). Decreases in the chlorophyll-a concentrations indicate that phytoplankton biomass has decreased, which explains the increase in water clarity (Figure 3).

In some situations, particularly where polluted runoff causes nuisance algae and plant growth, a decrease in chlorophyll-a concentrations can be desirable. Conversely, in nutrient-poor surface waters like Black Lake, declining chlorophyll levels can be problematic, altering the natural food web and lake ecosystem by reducing primary productivity. The invasive zebra mussels (*Dreissena polymorpha*) present in Black Lake are likely responsible for the increase in water clarity because they filter-feed on phytoplankton. However, there is evidence in recent data that chlorophyll-a concentrations may be rebounding (Figure 3).

Based on trophic status index data from the VLM program, Black Lake borders between a mesotrophic system and oligotrophic (Figure 4). Oligotrophic lakes are typically large, deep, clear, and nutrient poor. In general, oligotrophic lakes contain high quality waters, but paradoxically have a lackluster fishery due to low biological productivity. Mesotrophic lakes are moderately productive. Low total phosphorus concentrations support the trophic status interpretation from the VLM program data. CWQM program data show that total phosphorus has decreased throughout the last 20 years and are now consistently below 10 micrograms per

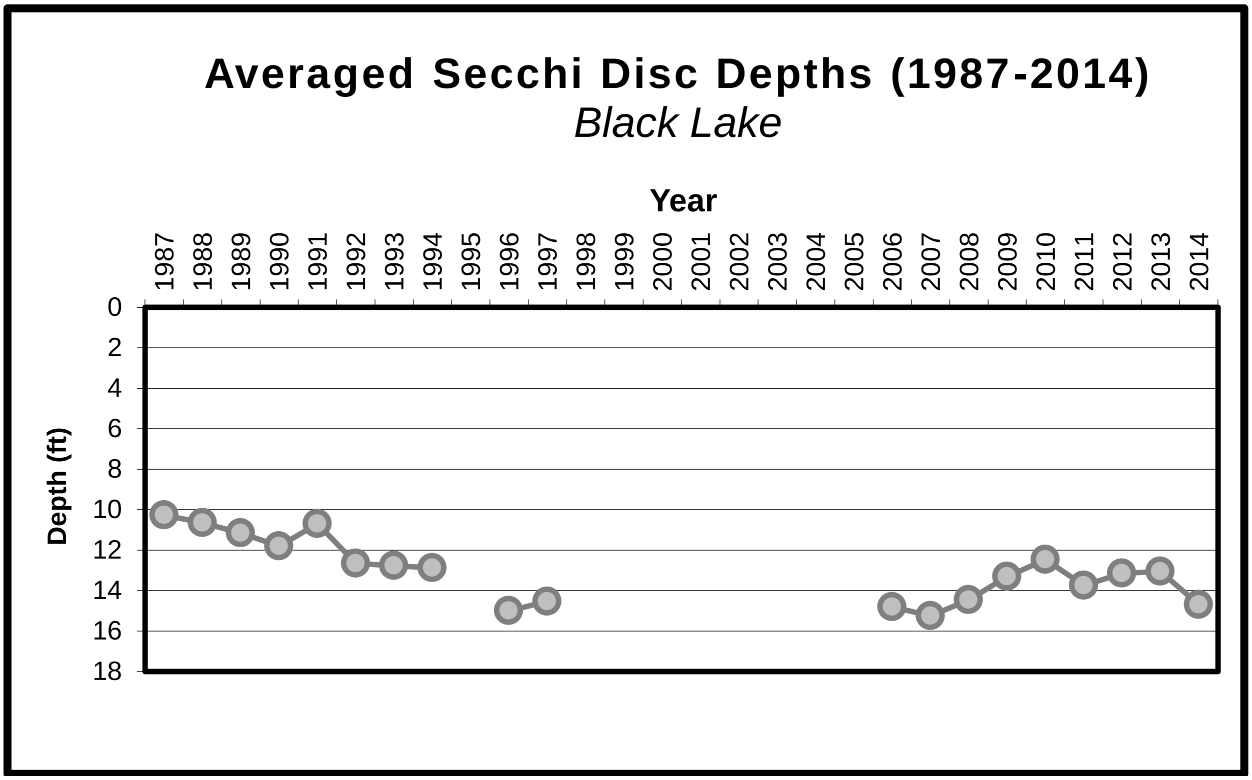


Figure 2. Secchi disc depth data from Black Lake (TOMWC 2014).

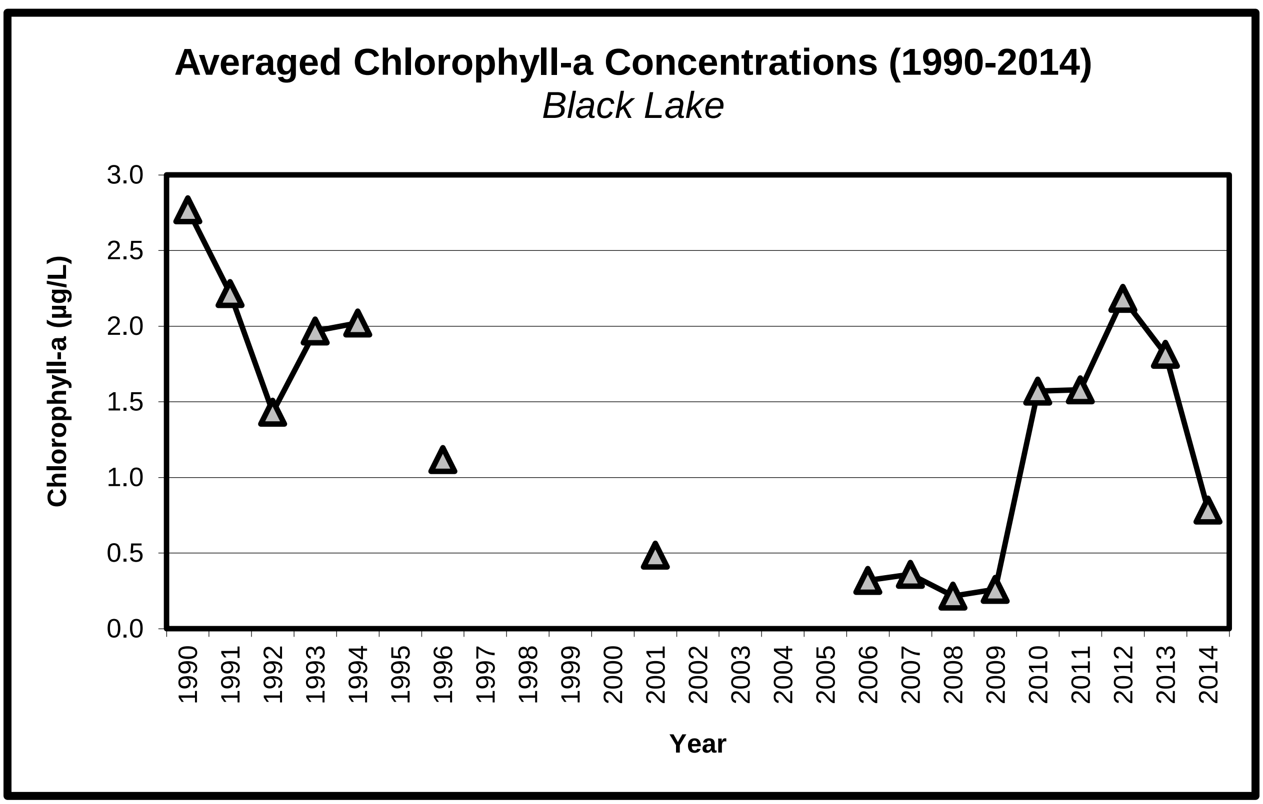


Figure 3. Chlorophyll-a data from Black Lake (TOMWC 2014).

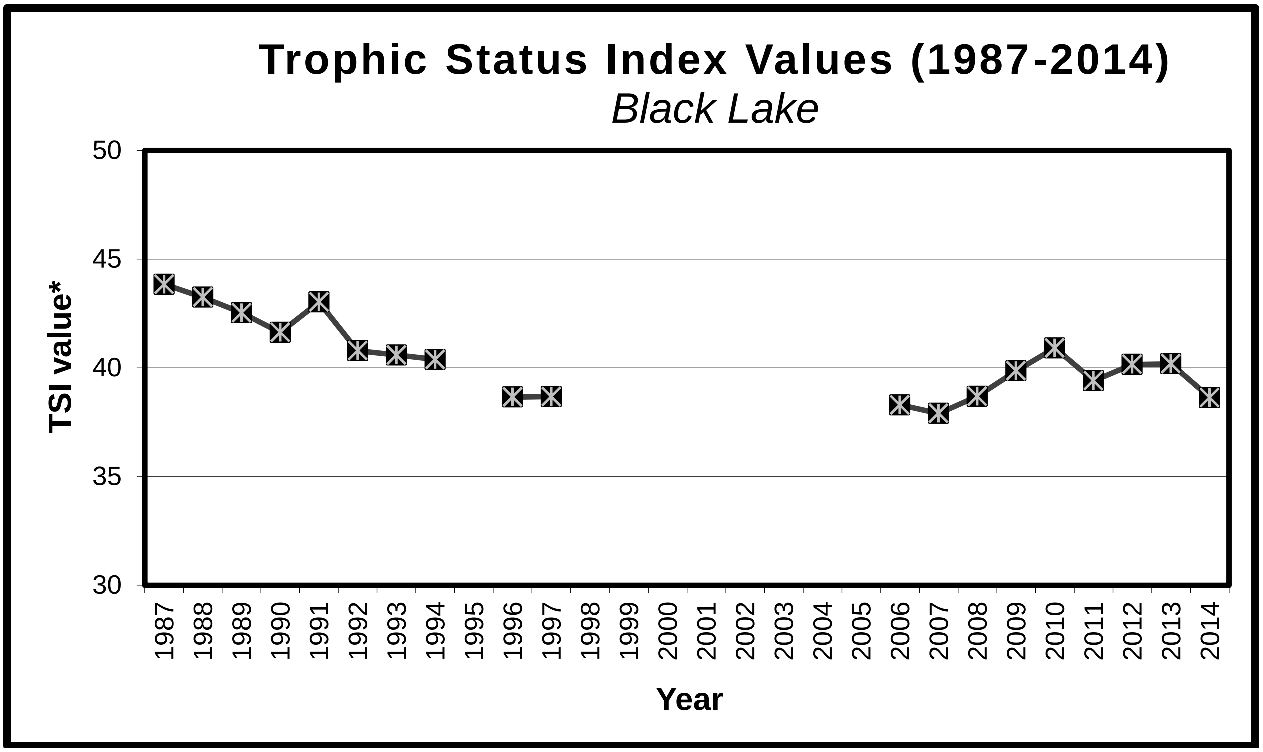
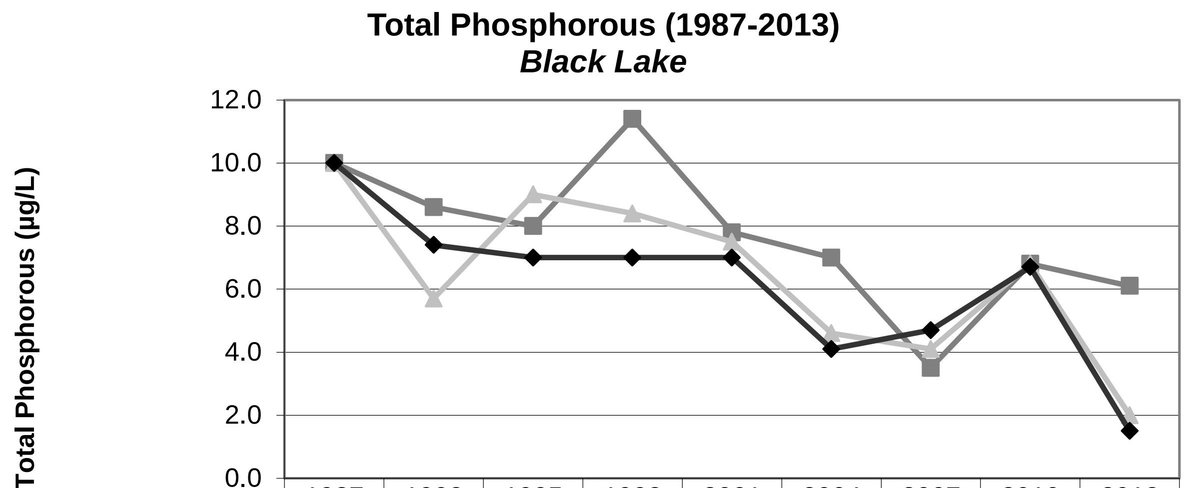


Figure 4. Trophic status index data from Black Lake (TOMWC 2013).
**Trophic Status Index values based on annual averaged Secchi disc depth data and represent the trophic status (biological productivity) of the lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive system), and 50+ = eutrophic (highly productive system).*

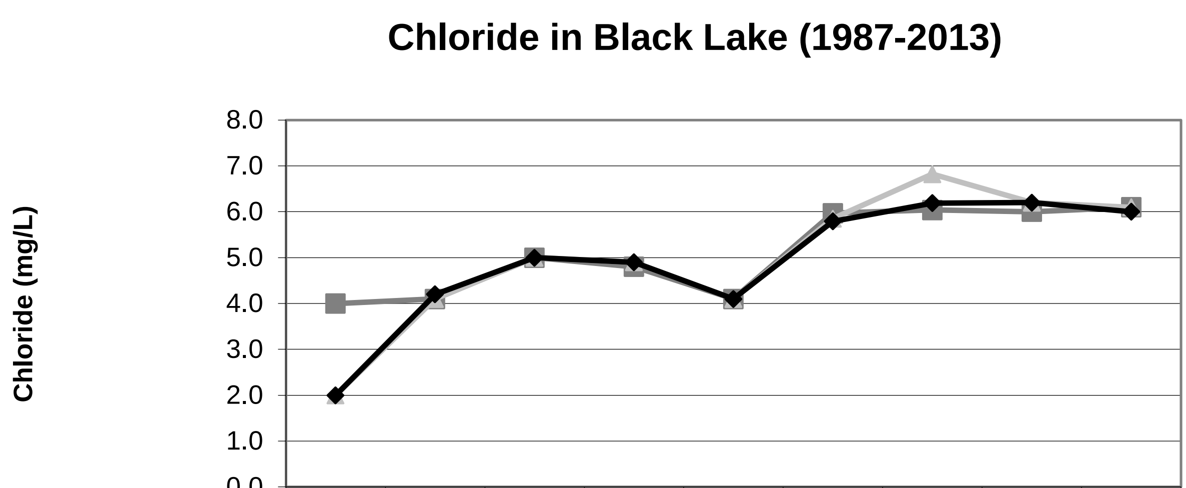
liter (µg/L), which is typical for oligotrophic lakes in Northern Michigan (Figure 5). The decrease is attributed to, at least in part, the introduction of zebra mussels. As zebra mussels filter phytoplankton from the water column, they also remove the phosphorus contained within the phytoplankton, which disrupts the natural nutrient cycle in the lake.

Chloride concentrations have risen from 2-4 µg/L in 1987 to around 6 µg/L in 2013 (Figure 6). In In spite of the increase, chloride levels are still far below the USEPA recommended limit of 230 mg/L for chronic toxicity and 860 mg/L for acute toxicity (USEPA, 2012). Nonpoint source pollution from roads and urban areas in the watershed, particularly those located directly on tributaries, is the likely source of the chloride increases. These increases can be indicative of more harmful pollutants that are associated with human activity, but not regularly monitored, contaminating the watershed's surface waters (e.g., automotive fluids, metals, pesticides, etc.).



	1987	1992	1995	1998	2001	2004	2007	2010	2013
Surface	10.0	8.6	8.0	11.4	7.8	7.0	3.5	6.8	6.1
Middle	10.0	5.7	9.0	8.4	7.5	4.6	4.1	6.8	2.0
Bottom	10.0	7.4	7.0	7.0	7.0	4.1	4.7	6.7	1.5

Figure 5. Total phosphorus trends in Black Lake 1992 to 2013 (TOMWC 2013).



	1987	1992	1995	1998	2001	2004	2007	2010	2013
Surface	4.0	4.1	5.0	4.8	4.1	6.0	6.0	6.0	6.1
Middle	2.0	4.1	5.0	4.9	4.1	5.9	6.8	6.2	6.1
Bottom	2.0	4.2	5.0	4.9	4.1	5.8	6.2	6.2	6.0

Figure 6. Chloride trends in Black Lake 1987 to 2013.

METHODS

The aquatic plant communities of Black Lake were sampled and mapped during July and September of 2014. Survey methods used during the survey were developed by TOMWC, incorporating the experience and knowledge of TOMWC surveyors, as well as elements of methods detailed in the Michigan Department of Environmental Quality's *Procedures for Aquatic Vegetation Surveys* (MDEQ, 2005). The methods were designed for comprehensive and detailed aquatic vegetation surveys that document aquatic plant species, community, and density information at specific sample sites while also mapping the areal extent and delineation of plant communities throughout the lake. Survey methods are described below and procedural details are in Appendix A.

Sampling

To document aquatic plant taxa, specimens were collected, identified, photographed and recorded in a notebook at 284 sample sites throughout the lake. 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. Trimble GeoExplorer3 and Trimble Juno SB GPS units were 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 four directions each site: north, south, east, and west. Sometimes the exact direction of the throw would diverge from a cardinal direction due to natural or man-made features; in these cases, notes were taken for the updated direction. 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 determined by the surveyor for each taxon at each toss and recorded as light (L), moderate (M), or heavy (H), but also included 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.

Abundance rankings were determined at each site by summing the number of times individual taxon were found during rake throws. A plant found in all four rake tosses would be considered Abundant, three tosses Common, two tosses Uncommon, and one toss Rare. The abundance rankings do not account for density, but rather indicate frequency of occurrence.

If a plant 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. Specimens representing each taxon found at the site were photographed.

To assist in mapping the aquatic vegetation in Black Lake, additional photographs were taken to document emergent vegetation. At each sample site located within or adjacent to emergent vegetation, pictures were taken of surrounding areas. Pictures were taken with either a Ricoh G700SE or Nikon Coolpix AW110 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 is 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 mapped directly on foot or at an offset distance that was recorded in the GPS unit. Plant specimens were not collected while mapping community lines with GPS. Occasionally wind, poor visibility, or other factors resulted in sinuous community lines which were noted in the GPS and later smoothed into more accurate, straight lines in a GIS.

In spite of sampling 284 sites, as well as subsequent community line mapping, small or isolated plant communities could have been missed. Plants were not sampled between sites in survey transects and conditions occasionally prevented community mapping between sites. 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 units were transferred to a computer in an ESRI shapefile format. 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: ArcView 10.3.

Information collected at sample sites and written in field notes was entered into a Microsoft Access 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 no or little vegetation, overall community density, and comments. Additional columns were added to the database for the number of taxa at each site. Field data were then exported to a Microsoft Excel spreadsheet, which was 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 sample site ESRI shapefiles allow GIS users to view all tabular data associated with the site.

RESULTS

Sample Sites

Approximately 60% of sample sites were located in the more heavily-vegetated northern basin, from Five Mile Point northward (Figure 7). A total of 38 aquatic plant taxa were documented during the survey conducted on Black Lake; 28 taxa were documented at sample sites and 10 additional taxa were noted during community mapping. The additional taxa include: cattail (*Typha spp.*), sweet gale (*Myrica gale*), purple loosestrife (*Lythrum salicaria*), North American common reed (*Phragmites australis americanus*), Eurasian Phragmites (*Phragmites australis australis*), pickerelweed (*Pontedaria cordata*), floating-leaf pondweed (*Potamogeton natans*), hardstem bulrush (*Schoenoplectus acutus*), softstem bulrush (*Schoenoplectus tabernaemontani*), and three-square bulrush (*Schoenoplectus americanus*). The number of aquatic plant taxa encountered at a sample site ranged from zero to 13 with an average of 3.9 taxa per site. Two invasive plant species were encountered during this survey: Eurasian Phragmites (AKA Common Reed) and purple loosestrife.

Variable-leaf watermilfoil (*Myriophyllum* heterophyllum), muskgrass (*Chara spp.*), eelgrass (*Valisneria americana*), and slender naiad (*Najas flexilis*), were the most frequently collected species, documented at approximately 64%, 61%, 52%, and 48% of vegetated sites, respectively (Table 2). Other taxa that were commonly found include variable-leaf pondweed (*Potamogeton gramineus*), bladderwort (*Utricularia vulgaris*), waterweed (*Elodea canadensis*), and flat-stem pondweed (*Potamogeton zosteriformis*). These species were collected at 36%, 34%, 30%, and 27% of vegetated sites respectively. The remaining plant taxa were documented at less than 20% of vegetated sites. The pondweed family (*Potamogetonaceae)* was the most speciose with a total of 13 pondweed species documented during the Black Lake survey.

The plants most commonly collected were also those that were abundant at the greatest percent of sample sites. However, whereas variable-leaf watermilfoil was collected at the greatest number of sample sites, muskgrass was the most abundant plant. Muskgrass was found to be abundant at 33% of vegetated sites, followed by variable-leaf watermilfoil, eelgrass, and slender naiad at 23%, 10%, and 8% respectively (Table 3). The next most abundant plants were flat-stem pondweed, bladderwort, variable-leaf pondweed, and coontail (*Ceratophyllum demersum*). The remaining plant taxa were abundant at less than 1% of vegetated sites.

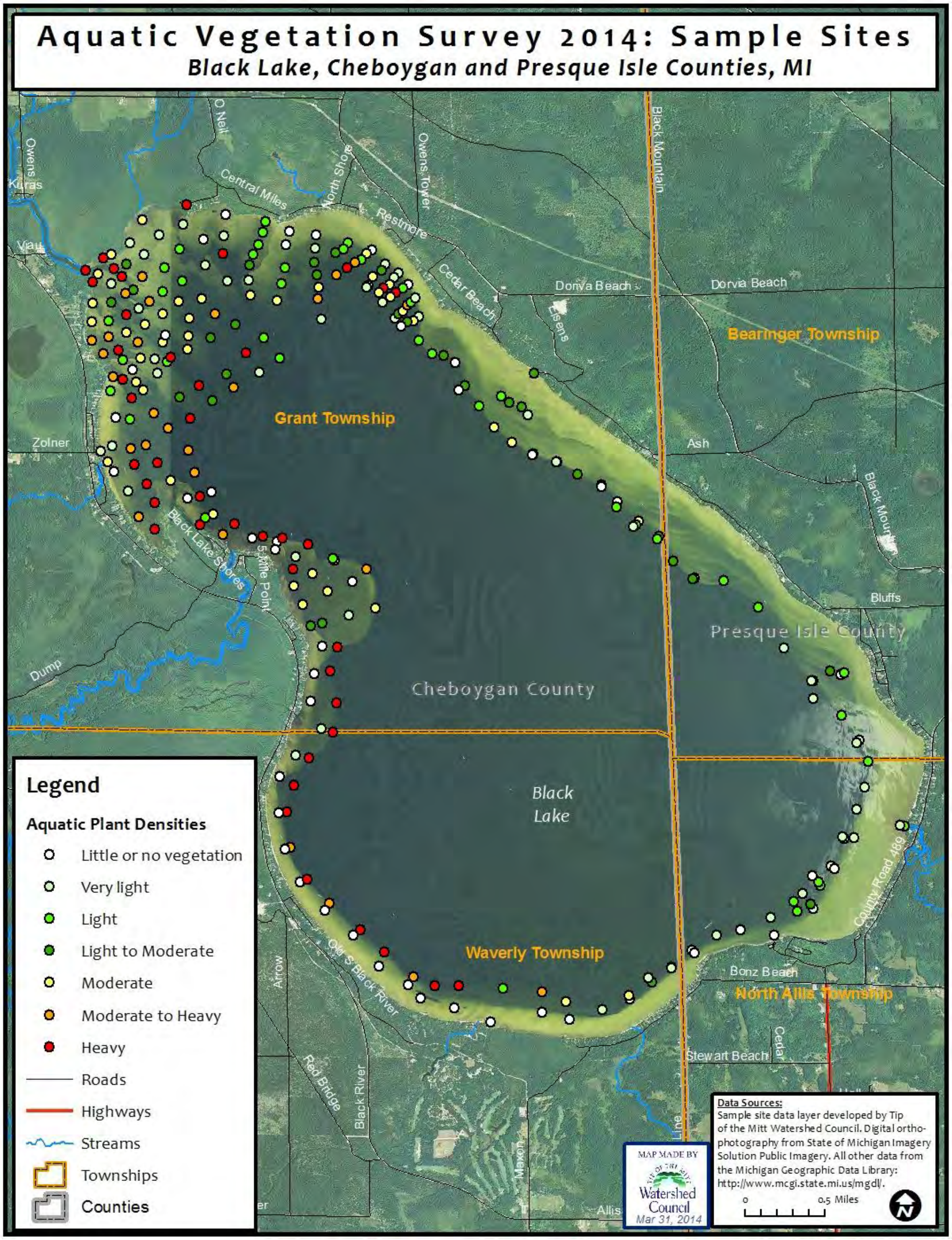


Figure 7. Sample sites for 2014 aquatic plant survey.

Table 2. Aquatic plant taxa occurrence at sample sites.

Scientific Name	Common Name	Total # of Sites	Total % Sites*
Myriophyllum heterophyllum	Variable-leaf Watermilfoil	153	64.0
Chara spp.	Muskgrass	146	61.1
Valisneria americana	Eelgrass	124	51.9
Najas flexilis	Slender Naiad	115	48.1
Potamogeton gramineus	Variable-leaf Pondweed	87	36.4
Utricularia vulgaris	Bladderwort	82	34.3
Elodea canadensis	Waterweed	72	30.1
Potamogeton zosteriformis	Flat-stem Pondweed	65	27.2
Ceratophyllum demersum	Coontail	46	19.2
Stuckenia pectinata	Sago Pondweed	36	15.1
Potamogeton richardsonii	Richardson's Pondweed	31	13.0
Bidens beckii	Water Marigold	25	10.5
Heteranthera dubia	Water Stargrass	25	10.5
Potamogeton amplifolius	Broad-leaf Pondweed	22	9.2
Potamogeton praelongus	White-stem Pondweed	18	7.5
Myriophyllum sibiricum	Northern Watermilfoil	12	5.0
Potamogeton friesii	Fries' Pondweed	9	3.8
Nuphar variegata	Yellow Pond Lily	8	3.3
Sagittaria spp.	Arrowhead	8	3.3
Stuckenia filiformis	Fine-leaf Pondweed	6	2.5
Najas spp.	Naiad (species unknown)	4	1.7
Potamogeton illinoensis	Illinois Pondweed	3	1.3
Potamogeton robbinsii	Robbins' Pondweed	3	1.3
Potamogeton spp.	Pondweed (species unknown)	3	1.3
Ranunculus spp.	Water Crow-foot	2	0.8
Nymphaea odorata	White Water Lily	1	0.4
Potamogeton pusillus	Small Pondweed	1	0.4
Sparganium spp.	Bur Reed (species unknown)	1	0.4

**Percent of sites based on only those sites with vegetation (=239).*

Table 3. Aquatic plant taxa abundance at sample sites.

Scientific Name	Common Name	Abundant % Sites*	Common % Sites*	Un-common % Sites*	Rare % Sites*
Chara spp.	Muskgrass	32.6	9.2	10.9	8.4
Myriophyllum heterophyllum	Variable-leaf Watermilfoil	23.0	12.6	13.4	15.1
Valisneria americana	Eelgrass	10.0	9.2	15.1	17.6
Najas flexilis	Slender Naiad	7.5	8.8	10.5	21.3
Potamogeton zosteriformis	Flat-stem Pondweed	4.2	4.6	4.6	13.8
Utricularia vulgaris	Bladderwort	2.9	4.6	7.9	18.8
Potamogeton gramineus	Variable-leaf Pondweed	2.5	4.6	10.9	18.4
Ceratophyllum demersum	Coontail	1.3	1.7	2.9	13.4
Elodea canadensis	Waterweed	0.8	1.3	3.8	24.3
Potamogeton richardsonii	Richardson's Pondweed	0.4	0.8	4.2	7.5
Heteranthera dubia	Water Stargrass	0.4	2.5	2.5	5.0
Potamogeton amplifolius	Broad-leaf Pondweed	0.4	0.4	4.2	4.2
Myriophyllum sibiricum	Northern Watermilfoil	0.4	0.4	0.8	3.3
Potamogeton friesii	Fries' Pondweed	0.4	0.4	0.8	2.1
Potamogeton illinoensis	Illinois Pondweed	0.4	0.0	0.4	0.4
Potamogeton robbinsii	Robbins' Pondweed	0.4	0.0	0.0	0.8
Ranunculus spp.	Water Crow-foot[†]	0.4	0.0	0.0	0.4
Potamogeton pusillus	Small Pondweed	0.4	0.0	0.0	0.0
Stuckenia pectinata	Sago Pondweed	0.0	0.0	4.6	10.5
Bidens beckii	Water Marigold	0.0	0.8	3.8	5.9
Potamogeton praelongus	White-stem Pondweed	0.0	0.4	0.4	6.7
Nuphar variegata	Yellow Pond Lily	0.0	0.0	0.8	2.5
Sagittaria spp.	Arrowhead[†]	0.0	0.4	0.8	2.1
Stuckenia filiformis	Fineleaf Pondweed	0.0	0.4	0.4	1.7
Najas spp.	Naiad[†]	0.0	0.4	0.4	0.8
Potamogeton spp.	Pondweed[†]	0.0	0.0	0.0	1.3
Nymphaea odorata	White Water Lily	0.0	0.0	0.0	0.4
Sparganium spp.	Bur Reed[†]	0.0	0.0	0.0	0.4

**Abundance based on number of rake throws the plant is collected at each vegetated site. 4 = Abundant, 3 = Common, 2 = Uncommon, 1 = Rare.* [†] *Species not determined.*

The distribution of plant community densities at sample sites leaned toward light-density growth (Table 4). Approximately 45% of sample sites had aquatic plant community densities that fell into the light categories (very light, light, and light to moderate), whereas heavy-density growth was limited to 15% of sites. There were no sites with very heavy growth. The majority of sites with heavy-density growth were found in the extensive shallow areas of the North Basin and in drop-off areas along the southwest shoreline (Figure 7).

Table 4. Aquatic plant densities at sample sites.

Density Category	Number of Sites	Percentage of Sites
Little/no vegetation	45	15.8
Very Light	52	18.3
Light	43	15.1
Light to Moderate	32	11.3
Moderate	43	15.1
Moderate to Heavy	27	9.5
Heavy	42	14.8
Very Heavy	0	0.0
TOTAL	284	100.0

Plant Communities

Aquatic plant community mapping showed that 8,342 of the 10,135 acres (82%) of Black Lake contained little or no aquatic vegetation. Of the 1,793 acres with vegetation, approximately 90% consisted of submergent plant species (Table 5). Two submergent species, muskgrass and variable-leaf watermilfoil, were the dominant plants in nearly 55% of the vegetated lake area (Table 6). Over a third of the vegetated area in Black Lake contained very light- to light-density plant growth while heavy growth covered less than 24% (Table 7).

Table 5. Generalized aquatic vegetation statistics.

Lake and Vegetation	Lake Area (acres)	Lake Area (percent)
Black Lake surface area	10,135	100.0
Little or no vegetation	8,342	82.3
Lake area with aquatic vegetation:	1,793	17.7
a. Emergent species dominant*	174	9.7
b. Submergent species dominant*	1,611	89.8
c. Mixed emergent and submergent species*	9	0.5

**Refers to percent of surface area with aquatic vegetation (i.e., 1794 acres).*

Table 6. Dominant aquatic plant community statistics.

Dominant Community Type	Vegetated Lake Area (acres)	Vegetated Lake Area (percent)
Muskgrass	602	33.56
Watermilfoil	378	21.08
Pondweed and Watermilfoil	202	11.26
Bulrush	141	7.86
Mixed Submergent	122	6.80
Muskgrass and Naiad	109	6.08
Eelgrass, Pondweed, and Watermilfoil	86	4.79
Bladderwort	77	4.29
Mixed Emergent	41	2.29
Pondweed	35	1.95
TOTAL	1,793	100.00

Table 7. Density statistics for aquatic plant communities.

Density Category	Lake Area (acres)*	Lake Area (percent)*
Very Light	253	14.1
Light	353	19.7
Light to Moderate	115	6.4
Moderate	390	21.7
Moderate to Heavy	255	14.2
Heavy	428	23.9
Very Heavy	0	0.0
TOTAL	1794	100.0

**Refers to percent of surface area with aquatic vegetation (i.e., 1794 acres).*

Extensive muskgrass-dominated communities occurred in the shallow waters (~2-8 feet of depth) of the northwest corner of the lake near the Lower Black River outlet (Figure 8). The community transitioned to variable-leaf watermilfoil dominant further out from the outlet, in depths ranging from 8 to 20’. Eelgrass, or mixed submergent communities that generally included eelgrass, dominated the narrow ring of vegetation at the drop-off zone in the southern basin and along the eastern shoreline. The majority of emergent vegetation occurred along the shallow edges of the lake, extending further from shore in the North Basin due to shallow depths.

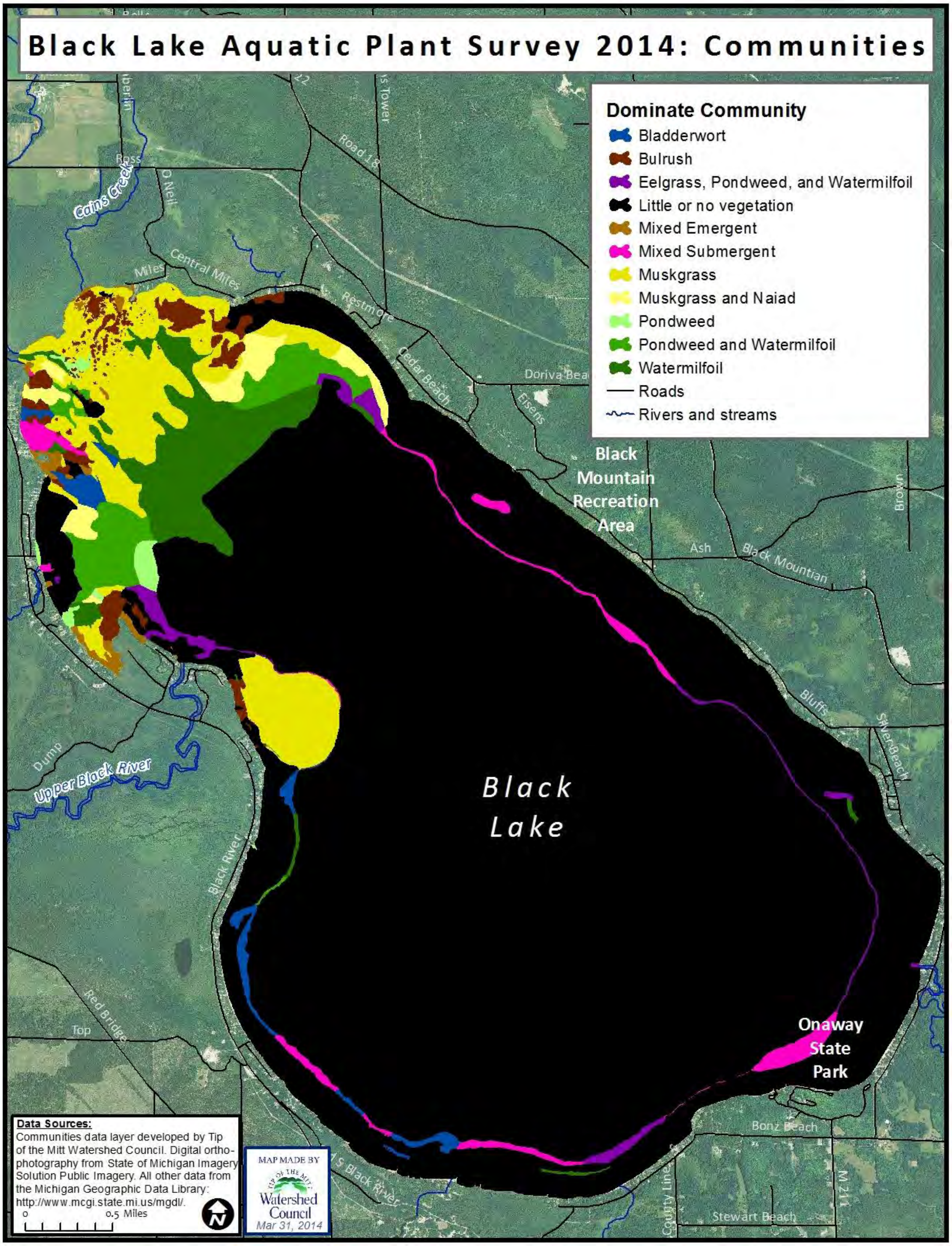


Figure 8. Aquatic plant communities in Black Lake.

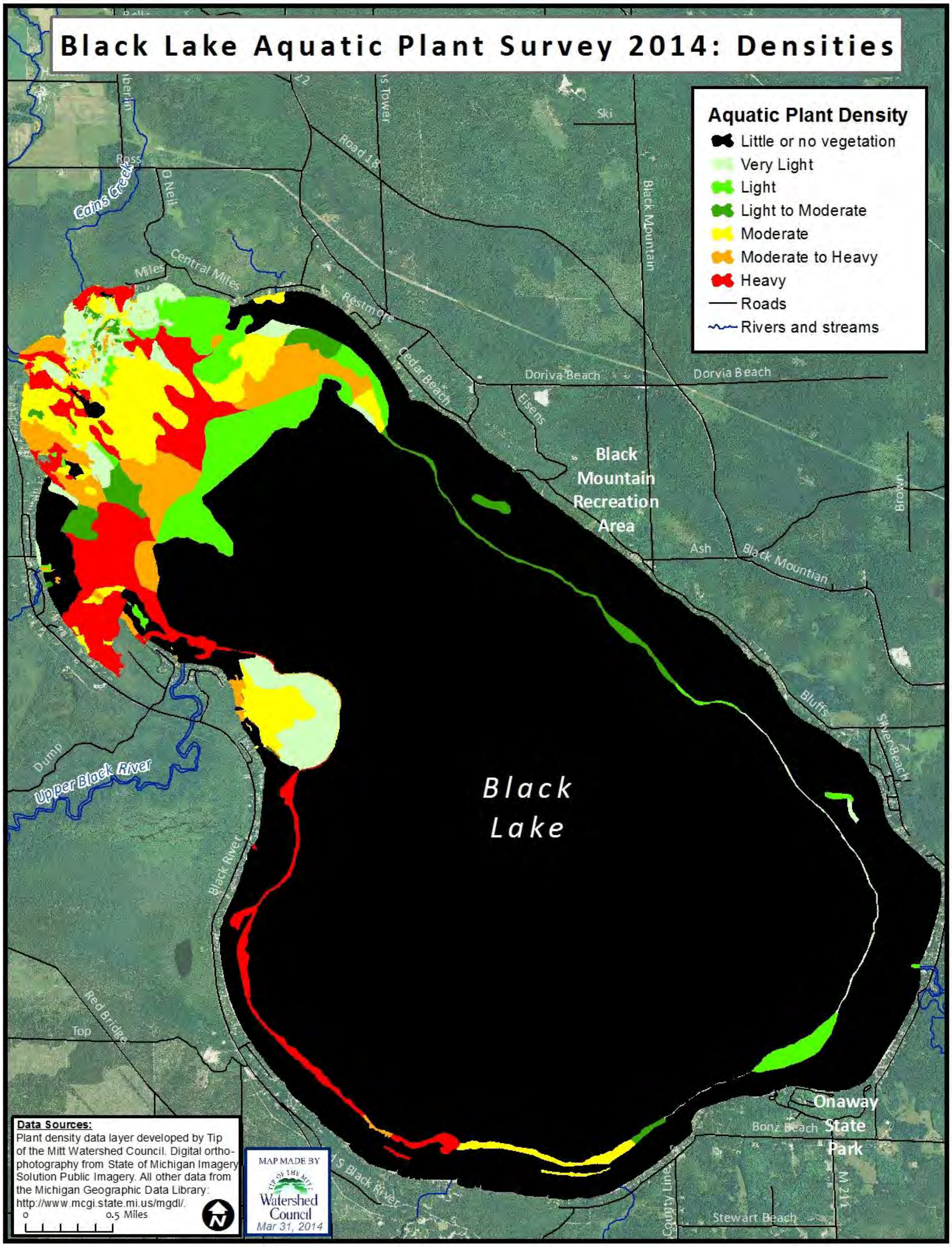


Figure 9. Aquatic plant densities in Black Lake.

Eurasian *Phragmites (Phragmites australis australis)*, an invasive wetland plant, was documented at two locations along the north shore of Black Lake, approximately one mile east of the Lower Black River outlet, on the east side of the bay off of Miles Road (Figure 10). The two infestations were about 200’ apart. The western infestation was categorized as moderate-density growth, extending 13 feet along the shoreline and five feet deep. The eastern infestation was a moderate density mix of native and invasive *Phragmites* covering 175 feet of shoreline and five feet deep. The combined acreage of the infestations was less than 0.1 acres.

Another invasive wetland plant, Purple loosestrife (*Lythrum salicaria*), was found toward the north end of the west shoreline, about a ¼ mile south of the Lower Black River outlet (Figure 10). Purple loosestrife was documented along approximately 300 feet of shoreline, sometimes intermixed with other emergent and riparian plant species. The total area of the infestation amounted to less than 1/10th of an acre.

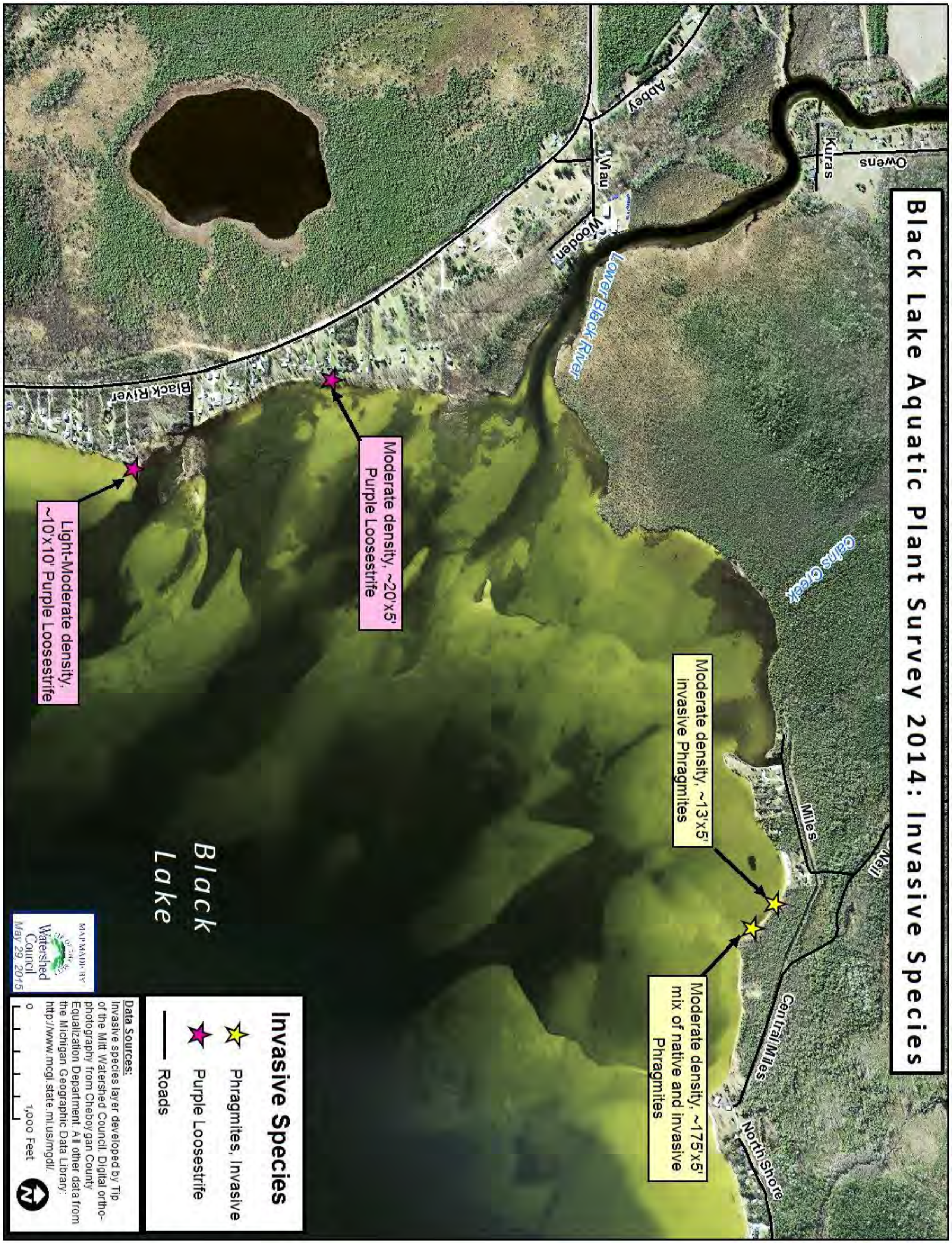


Figure 10. Invasive *Phragmites* and purple loosestrife locations on Black Lake.

DISCUSSION

This was the second comprehensive aquatic vegetation survey of Black Lake, the first conducted in 2005. Sampling methods were replicated to allow for a comparative assessment of aquatic plant communities over time. However, it should be noted that the 2014 survey was more detailed, with 284 sites compared to 145 sites in 2005. Furthermore, 384 line features delineating plant communities were recorded with a GPS during the 2014 survey versus 348 line features in 2005.

A diverse assemblage of native plants inhabit Black Lake with a total of 38 aquatic plant taxa documented during the survey, versus 32 species in the 2005 survey. *Potamogeton pusillus, Sparganium spp., Myrica gale, Phragmites australis australis*, and *Schoenoplectus tabernaemontani* were additional plant taxa documented during the 2014 survey, while *Schoenoplectus subterminalis* was found only during the 2005 survey (note that *Zizania aquatica* was reported by residents during 2005 survey but not found by surveyors during either survey). Plant diversity in Black Lake was above average compared with data from other lakes surveyed in the area (Table 8). The percentage of sample sites with dense aquatic vegetation in Black Lake was less than the average for Northern Michigan lakes (Table 8).

The 2014 survey results show that 82% of Black Lake contained little or no vegetation, compared with 87% in 2005. This may reflect an actual decrease in the extent of plant communities in the lake by 5%, but could be the result of greater sampling and mapping efforts during the 2014 survey. The extensive lake area with little or no vegetation documented during both surveys is largely due to water depth. Similar to other lakes surveyed by TOMWC, aquatic plants were generally not found at depths exceeding 20 feet in Black Lake (Figure 7). This phenomenon is particularly noticeable in the southern basin due to the expansive deep areas.

Prevailing wind direction is another important determinant of aquatic plant distribution. Past surveys in this region show that prevailing winds from the northwest tend to create lightly or non-vegetated areas in the eastern and southeastern sides of lakes (as a result of wind and wave action). Impacts from winds tend to be more pronounced in lakes with a long fetch or in lake areas that are highly exposed. The effect of prevailing winds was apparent on the east side of Black Lake, though there were areas of little or no vegetation along the southern and southwestern shoreline areas as well. This points out that other factors beyond depth and prevailing winds contribute to a lake’s plant distribution, such as substrate types, nutrient availability, water clarity, and water currents.

Table 8. Aquatic vegetation survey statistics from Northern Michigan Lakes.

Lake Name	Survey Year	Lake Size (acres)	Max Depth (ft)	Total Taxa In Lake	Taxa Average Per Site	Vegetated Lake Area	Densely Vegetated Sites†
Adams	2010	43	18	27	4.9	99%	66%
Bellaire	2013	1810	95	27	2.9	18%	8%
Black	2014	10,133	50	38	3.9	18%	15%
Clam	2013	446	27	28	4.1	69%	43%
Crooked	2008	2,351	50	28	2.8	56%	13%
Hanley	2014	89	27	29	6.3	94%	34%
Intermediate	2014	1,570	70	30	2.7	23%	1%
Long	2013	398	61	30	3.9	29%	11%
Douglas	2012	3,780	80	30	5.3	47%	15%
Millecoquin	2005	1,116	12	20	6.0	95%	61%
Mullett	2007	17,205	144	42	3.1	19%	13%
Paradise	2008	1,947	17	24	5.0	58%	28%
Pickerel	2008	1,083	70	20	1.5	24%	5%
Walloon	2013	4,620	100	32	1.8	22%	3%
Wycamp	2006	689	7	35	4.9	83%	24%
AVERAGE	NA	NA	NA	29	3.9	50%	23%

†Includes sites with plant density classified as heavy or very heavy.

The spatial distribution of dense aquatic vegetation in the lake was similar to that found during the 2005 survey, occurring primarily in the northwest corner. Shallow depths, nutrient inputs from inlet tributaries, and nutrient pollution from adjacent shoreline properties all likely contribute to the dense aquatic vegetation in this area.

The dense growth in the northwest corner of the lake consisted primarily of plant communities dominated by variable-leaf watermilfoil, a mix of submergent species that included variable-leaf watermilfoil, or emergent plants, such as bulrush, cattail, and pickerel weed. Similar to findings in the 2005 survey, dense beds of native variable-leaf watermilfoil were found to be widespread and at levels that may be considered a nuisance to recreation.

Two invasive plant species were found in 2014, whereas none were documented in 2005. Eurasian Phragmites and purple loosestrife, both wetland species, were found in just a few locations, all in the northwest corner of the lake. Considering the repercussions associated with the spread of these highly invasive species, in terms of negative impacts to the lake ecosystem, recreation, and the local economy, it is important to respond rapidly and implement control measures to control these problematic invasive species.

Recommendations

1. 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 Eurasian watermilfoil 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.

2. 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.

3. Develop an aquatic plant management plan. The Association should consider developing an aquatic plant management plan to enhance lake management efforts over the long-term. The aquatic plant community is a vital component of the aquatic ecosystem, such that good aquatic plant management translates to good lake ecosystem management. The Association has already taken an important step in aquatic plant management by sponsoring two comprehensive aquatic plant surveys. 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.

4. Control invasive *Phragmites* and purple loosestrife. This survey documented two invasive *Phragmites* infestations on the north shore of the lake and two purple

loosestrife locations were found on the north end of the west shoreline. Due to the plant's history of outcompeting native vegetation and becoming a nuisance in other lakes, the Association should implement control efforts as soon as possible. Early detection and rapid response are critical for effective control, while also economically efficient and inflicting relatively little collateral damage to native species. Known infestations should be revisited frequently to assess efforts and continue with treatment as necessary. Additionally, the Association should regularly survey other lake areas for the presence of these aquatic invasive plants and implement control measures as necessary to prevent their spread.

5. Regularly survey the lake for other priority invaders. Other aquatic invasive species documented in nearby lakes and rivers include Eurasian watermilfoil (*Myriophyllum spicatum*) and curly leaf pondweed (*Potamogeton crispus*). These invaders have been documented in Long Lake, Mullett Lake, and the Lower Black River, and therefore, have high potential of infesting Black Lake. It is important that the Association regularly survey the lake for these and other invasive species to facilitate early detection and rapid response efforts.

6. Monitor boat launches for aquatic invasive species. Volunteers from the Association can help prevent the introduction of aquatic invasive species and educate lake users by monitoring boat launches. Volunteers can inform and educate lake users about the impacts of invasives species and encourage them to take the necessary steps to prevent their spread, such as cleaning boats and trailers. It is important that monitoring be carried out during busy weekends, such as Memorial Day and the Fourth of July when boat launches are used the most and the potential for invasive species introduction is at its greatest.

7. Preserve the lake ecosystem and natural diversity. Black Lake contains a vibrant native aquatic plant population that may be considered a nuisance by many shoreline residents and other lake users. While pursuing nuisance 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.

8. Investigate potential nutrient pollution issues. Nutrient pollution from shoreline properties can lead to excessive plant growth and should be controlled wherever and whenever possible. The 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. Shoreline surveys are an effective tool for locating sources of nutrient pollution. 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. Shoreline surveys should be carried out once every 3-5 years to document conditions and address any problem areas; the last one conducted on Black Lake was in 2005.

9. Regularly survey the aquatic plants of Black Lake. To effectively manage the aquatic plant community of Black Lake, periodic aquatic plant surveys should be conducted. Future surveys will provide 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. 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. Aquatic Vegetation Survey Standard Operating Procedure.

Aquatic Vegetation Survey Standard Operating Procedure

Tip of the Mitt Watershed Council

Last updated: 4/24/15

Summary

This Standard Operating Procedure (SOP) was developed by Tip of the Mitt Watershed Council (TOMWC) incorporating the experience and knowledge of TOMWC surveyors, as well as elements of methods detailed in the Michigan Department of Environmental Quality's *Procedures for Aquatic Vegetation Surveys*. This SOP is designed for comprehensive and detailed aquatic vegetation surveys that document aquatic plant taxa, abundance, density, and community information at specific sample sites while also delineating and mapping the areal extent of plant communities throughout the lake. These surveys can be and typically have been conducted by one person, but if resources are available (i.e., extra boat, GPS, camera, surveyor, etc.), then two or more people or crews can work on the surveys simultaneously.

Periodic aquatic vegetation surveys should be conducted on lakes to effectively manage the aquatic plant communities. Surveys are necessary to establish baseline data, 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.

Equipment and Preparation

1. <u>Sampling Device.</u> A heavy grapple-type device is needed to sample aquatic macrophytes at sample sites. Although many types of samplers have been developed, one of the most commonly used consists of two rake heads clamped together. Securely fasten a rope of approximately 30 feet in length to the sampler (1/4" to 3/8" diameter preferable). Secure the other end of the rope to the boat when using the sampler.
2. <u>Datasheets.</u> Information collected at sample sites must be recorded on a field datasheet (Appendix A). Attributes recorded on the datasheet include lake name, site identification number, macrophyte species names, macrophyte densities, water depth at the site, and overall community density at the site. If available, print five to ten datasheets on waterproof paper to use if it rains.
3. <u>Global Position System (GPS)</u>. A precise mapping-grade handheld GPS unit with attribute input capabilities is needed to accurately record the location of sample sites, delineate aquatic macrophyte communities, and record locations of other observations about macrophyte species and communities. The GPS unit should have an accuracy of five meters or less and capability of collecting both point and line data. The GPS should allow for inputting relevant information, such as site identification number, that is associated

with the feature being mapped. Ideally, the GPS unit has the capability of exporting field data into a format that can be readily used in a Geographical Information System (GIS).

4. Camera. A camera is required to photo-document the macrophyte species found at a site, as well as visible aquatic plant communities at the site (e.g., a nearby patch of pond-lilies). A camera with GPS capabilities is preferable because it provides a back-up for the handheld GPS unit and photographs from a GPS camera can usually be directly displayed in a GIS.
5. Boat. A small motor boat is generally required to perform aquatic vegetation surveys, though oars may be sufficient for some small lakes. A stable boat with open workspace is ideal for collecting samples, sorting samples, and displaying specimens for photographs. Boats in the 13-15' length range are preferable because they provide enough space to perform the work, but yet are highly maneuverable and generally have a shallow draft. Maneuverability is important for delineating aquatic plant communities while the draft is important for sampling and mapping in nearshore or other shallow areas. An electric motor trim is preferred for regular adjustments needed while sampling or mapping shallow areas. Ideally, the boat will also have a compass installed, though a handheld compass can be used if needed.
6. Polarized sunglasses. Polarized sunglasses are among the most important items for effectively surveying aquatic vegetation. Beyond protecting the surveyor's eyes from solar radiation, polarized sunglasses allow the surveyor to see more clearly and deeper into the water. Polarized glasses greatly assist in determining what macrophyte species are present in the water, the density of growth, and where divisions between communities lie.
7. Personal Safety and Safety Equipment. Personal flotation devices are required to be on board when operating or riding in a boat and should be worn at all times, particularly if working alone. A waterproof marine radio is recommended for emergencies. In lieu of a marine radio, a cell phone can also be used for emergencies, but should be kept in a waterproof case. Maintain a stocked first aid kit on the boat at all times. Sun protection is recommended (sunscreen, hat, sunglasses, etc.) and insect repellant may be needed in some situations. Weather conditions should be evaluated each day prior to performing surveys. If thunderstorms or winds above 10 miles per hour are predicted, then the survey should be delayed. If a thunderstorm approaches while on the water, halt the survey immediately, drive the boat to the nearest public shoreline property and take refuge in a safe area until the storm passes over.
8. Lake Maps and Planning. For planning purposes, acquire and review maps of the lake prior to conducting the survey. Lake maps with bathymetry (depth contours) will help determine which areas will have to be surveyed, typically those less than 20 feet deep. Sources of bathymetry maps include the Michigan Department of Natural Resources (http://www.michigan.gov/dnr/0,4570,7-153-67114_67115-67498--,00.html) and the Sportsman's Connection (http://www.sportsmansconnection.com/). Lake areas can also be assessed with aerial imagery in a GIS or using internet-based mapping services such as Google Earth.
9. Additional Equipment. Only use pencils or waterproof pens for recording data on datasheets. Large sealable plastic bags are needed to hold and transport specimens that

cannot be identified in the field. At least one large (5-gallon) bucket or other container is recommended to help with sorting grapple samples.

Sampling Procedures

1. Sample Lines. Aquatic macrophyte populations are methodically sampled by collecting specimens at sites in sample lines. The sample lines are spaced at regular intervals throughout all lake areas capable of supporting aquatic vegetation (typically less than 20’ in depth). Sample lines begin at the shoreline and continue linearly into deeper waters until plants are no longer found (for an example, see Appendix B). In shallow lake areas, the sample line continues to the opposite side of the lake. Landmarks on both shorelines should be identified prior to beginning a sample line to stay on track. Alternatively, a GPS unit can be used to maintain the sample line course. Although highly variable, the distance between sample lines is typically 500’ or less. Upon completing a sample line, the surveyor follows a zigzag path to the starting point of the next sample line to observe (both by eye and depth finder) aquatic macrophyte species and communities in between sample lines. Changes in plant communities, the presence of invasive plant species, or other relevant information that the surveyor observes in the area between sample lines is included in the field notes and recorded with a GPS when applicable. Additional sample sites between sample lines are sometimes required.
2. Sample Points. To assist in delineating and mapping the lake’s plant communities, sample sites should be chosen at transition points between communities when possible. Therefore, the distance between sample points along a sample line varies depending upon plant community changes that are visible to the naked eye from the surface. In areas where plant communities are not visible due to depth, turbidity, or other factors, select sample sites based on plant community transitions observed in depth-finder signals. Although experience improves one’s ability to interpret depth-finder signals, the presence and height of aquatic macrophytes are usually obvious in the depth-finder output display, which provides the necessary information to identify transitional areas between plant communities. Continue sampling at points along the sample line until vegetation is no longer found. Keep in mind that lake bottom morphology can vary, such that aquatic vegetation may disappear due to depth and reappear in shallow areas further out in the lake. Therefore, it is very important to review the bathymetry of all lake areas prior to sampling to ensure all areas capable of supporting macrophyte growth are sampled. Due to a variety of reasons, including irregularities in the shape of the lake shoreline, variability in lake depths, isolated plant communities, or the presence of invasive plant species, additional sample sites outside of the sample lines may be necessary to adequately document and map the lake’s plant communities.
3. Sampling: the following are step-by-step instructions for each sample site.
    a. At each sample site, the boat must first be securely anchored.
    b. Record water depth at the site on the field datasheet based on depth-finder readings. Because the surveyor will often sample in transitional areas in terms of both plant communities and water depth, the depth readings may change frequently at the site, so record the average depth at the site.

c. Fill in the descriptive site information on the field datasheet. If visible, take a look at the macrophyte community around the boat and write relevant comments on the field datasheet (e.g., “muskgrass dominant to north” or “vegetation continues 20’ in and then no vegetation to shore”). Also, note any observations made in plant species or communities since the last sample site (e.g., “dense vegetation began ~100’ back toward last site”).
d. Record the site location in the GPS as a point feature. Type the site identification number into the GPS and save the feature to internal memory.
e. Sample plants at the site with a grapple. Ensure that plant grapple is tied securely to the boat. Throw the grapple in four directions: shoreward, outward, and parallel to shore in each direction, noting cardinal directions (north, south, east, and west). Alert other crew and check that there are no bodies or equipment behind you before you throw to avoid injury or damage. Throw the grapple as far as able in the required direction and allow it to sink to the lake bottom. Steadily pull the grapple along the lake bottom until reaching the boat (Warning! Do not pull too quickly or grapple may be pulled over plants instead of through plants). Carefully pull the grapple with plants up from the lake bottom and into the boat. Grab any specimens that fall off the grapple and remain within reaching distance of the boat. Taxa by taxa, write names on the datasheet, along with densities using the following system: Very Heavy = grapple full of plants and vegetation reaches surface; Heavy = grapple full of plants; Moderate = grapple half full of plants; Light = grapple tongs lined lightly with plants though not accumulated; Very Light = virtually no plants on grapple; Moderate-Heavy = in between Moderate and Heavy; Light-Moderate = in between Light and Moderate density; No Vegetation = grapple empty. Assign the densest taxa the overall density of the grapple (i.e. if a grapple is overall heavy, the dominate taxa will be assigned heavy). Keep one specimen for each taxa found in the sample and place apart. Repeat for the other sides of the boat, keeping one specimen of each unique taxa. Determine if there are plant species observed at the site that are not represented in the collected specimens. Continue sampling with the grapple until you are satisfied that all plant taxa present at the site are represented in the sample. If no plants are encountered during sampling, write ‘no vegetation’ for that site on the datasheet and move to the next sample site. Note: if required directions (shoreward, outward, and parallel to shore in each direction) do not match well with cardinal directions, utilize intercardinal directions and note on the datasheet.
f. Identify specimens to the lowest taxonomic level possible and lay out in open area of boat. Write the name of each taxa on the field data sheet. Write “unknown” in a row on the datasheet for each taxa that you are unable to identify. Count the number of throws each taxa was documented to determine and record occurrence at the site using the following system:
    i. Abundant (A) = taxa specimens found on all four sides of the boat.
    ii. Common (C) = taxa specimens found on three sides of the boat.
    iii. Uncommon (U) = taxa specimens found on two sides of the boat.
    iv. Rare (R) = taxa specimens found on one side of the boat.

Include taxa found in additional grapple tosses.

g. Using the density of plants noted in each rake throw, determine the overall plant density at the site using the average density of the four throws (i.e., if two throws are heavy density and two throws are light density, the average density would be moderate).
h. Place completed datasheet next to display specimens that were used to determine occurrence and photograph the specimens and datasheet together. To assist in map development of aquatic plant communities, take additional photographs of surrounding areas at sample sites located within or adjacent to emergent vegetation. Write the photograph numbers on the datasheet.
i. Place any specimens that cannot be identified in a plastic sealable bag and add an ounce or two of lake water to keep specimen moist. Write the lake name, site identification number, and sample date on a scrap piece of paper with pencil or waterproof pen and place inside the sealable bag. Only use one bag per site.
j. Return all other plants collected at the site to the lake.

4. <u>Community Mapping.</u> Aquatic plant communities can be delineated simply by interpolating or extrapolating between sample points, but the accuracy of such delineations is greatly improved by noting and mapping precise locations where one plant community type ends and another begins. Therefore, additional data are collected to improve the accuracy of delineations between distinct plant communities in the lake. The following methods are used to gather information helpful for delineating plant communities, some of which have previously been mentioned.
   a. During sampling, write plant community details observed at or near the sample site on the field datasheet in the comments section including the absence of vegetation in any direction.
   b. Upon completing a sample line, return to the shoreline where you started in the direction of where you intend on starting your next sample line and review the area between sample lines in a zigzag motion to observe (both by eye and depth finder) aquatic macrophyte species and communities. Note changes in plant communities, the presence of invasive plant species, or other relevant information observed in the area between sample lines on field datasheet or in separate field notes, and record with a GPS when applicable.
   c. Note changes in plant communities between sample sites on the field datasheet and record the precise location on the GPS (with description of the feature inputted into the GPS) when feasible.
   d. Delineate lake areas that lack vegetation by following visible lines between vegetated and non-vegetated areas and recording it in the GPS as a line feature. In lake areas that are too deep to support aquatic macrophytes, utilize the depth-finder display to locate the line between vegetated and non-vegetated areas (typically between 17 and 20 feet of depth). Follow this vegetation/depth line and record it with the GPS as a line feature. Begin GPS data recording when the delineation line is located, immediately pause the GPS data recording, and then restart/pause each time the community line is crossed while zigzagging back and forth. Other deep-water macrophyte community transitions visible in

the depth finder (e.g. tall plants growing up through the water column such as white-stem pondweed versus low-growing plants like slender naiad) can be mapped using the same technique. These line features should include descriptive comments, such as “no vegetation toward shore” or “vegetation/depth line”.

e. Delineate emergent plant communities by following the edge of the plant bed as closely as possible and recording it in the GPS as a line feature. Keep in mind that the GPS unit collects point data along the line (i.e., vertices) in time intervals that generally range between one and five seconds. Therefore, pause at each point along the line where the direction shifts to ensure all vertices are recorded. Remember to include descriptive comments in the GPS about the line feature, such as taxa name and density (e.g., “Nuphar variegata H inside” or “Pond-lilies L to shore”).

f. Density categorization for community mapping is more subjective than the sample site procedure and based on the following:
   i. Very Heavy (VH) = >90% of the area mapped with vegetation.
   ii. Heavy (H) = 70-90% of the area mapped with vegetation.
   iii. Moderate-Heavy (MH) = >60-70% of the area mapped with vegetation.
   iv. Moderate (M) = 40-60% of the area mapped with vegetation.
   v. Light-Moderate (LM) = 30-40% of the area mapped with vegetation.
   vi. Light (L) = 10-30% of the area mapped with vegetation.
   vii. Very Light (VL) = <10% of the area mapped with vegetation.

g. Plant communities can be mapped with the GPS while in the boat as depth permits. In shallow areas, it is sometimes necessary to get out of the boat and map a plant bed on foot. Ideally, use waders to collect data on foot, but at a minimum, protective footwear should be worn. Beware of soft, mucky substrate as you can get stuck or sink completely under the water. Emergent plant beds that extend up on to dry land can be mapped on foot if the land is public.

h. If it is not feasible to map macrophyte communities directly due to soft substrate, private property or other reasons, the delineations can be mapped at an offset distance with comments in the GPS describing the offset. Follow the direction and shape of the macrophyte community feature as closely as possible and record it as a line feature in the GPS (often this means that you are simply following a parallel course to the shoreline). Include descriptive comments, such as “3square bulrush H at shore 5-20’ wide” or “pond-lily M from shore 20’ out with Typha spp. H x 5’ at shore”.

i. Whenever possible take GPS photographs that show plant delineations, which will help interpret comments and map the delineations more precisely, particularly if mapping with an offset distance.

5. Laboratory Identification. Upon returning from fieldwork, identify the unknown taxa from sample sites with the aid of taxonomic keys and mounted herbarium specimens. Recommended taxonomic keys include *Aquatic and Wetland Plants of Northeastern North America* by G. E. Crow and *C. B.* Hellquist and *Michigan Flora* by E. Voss. Note that unknown specimens should be identified within one week of collection because the condition of specimens will deteriorate with time. If necessary, make arrangements to

send samples to other aquatic plant experts via mail. Warning! Empty all water from bags sent via mail to avoid problems with USPS – simply place a moist paper towel in the bag with the specimens. After successfully identifying specimens, update the "unknown" entries on the appropriate field datasheets with the correct taxonomic information.

6. Data Management. File field datasheets and transfer GPS data and digital photographs to computer daily following fieldwork. Ensure that a file back-up system is in place to safeguard GPS data and digital photographs. Input information on field datasheets into a template aquatic vegetation survey Microsoft Access® database (database template stored on the TOMWC server). Review 10% of data entered from spreadsheets for quality control. If data entry errors are found, review all data entered for that field day to check for errors and fix. Store the database, GPS data, and digital photographs in in the TOMWC GIS Projects directory. If a Projects directory does not exist for the lake being surveyed, create a new projects folder by copying the template in the GIS/Projects folder. All data should be stored in the GIS/Projects/data folder.
7. GIS Data Layer Development: Sample Sites. After survey is completed, export all fieldsheet data from the database into a Microsoft Excel® spreadsheet. Start a new working project document in the GIS and add the GPS point data. Select all features from point data file that represent sample sites (one point per sample site only). Export to a new shapefile with an appropriately descriptive title (e.g., LongLake_VegSurvey2013_SampleSites.shp). Add the spreadsheet with field datasheet information to the GIS project file. Join the spreadsheet to the GIS sample site point file and export to create a new shapefile with an appropriately descriptive title (e.g., LongLake_VegSurvey2013_SampleSites_Data.shp).
8. GIS Data Layer Development: GPS Photographs. Use the Geo Tagged Photos to Points tool in ESRI ArcGIS (or other equivalent software) to create a new point shapefile that associates all GPS photographs with physical locations on the lake. Give the new shapefile an appropriately descriptive title (e.g., LongLake_VegSurvey2013_Photos.shp).
9. GIS Data Layer Development: Communities.
    a. Add all GIS data to the project file: original GPS point and line data from the field, sample site point file with field data, and GPS photograph point file. For the GPS photo file, right click to select" properties", select "display", check the box for "support hyperlinks using field:", and select the appropriate field that provides the link/path to the photographs.
    b. Add the most accurate lake shoreline polygon shapefile available (preferably made based on recent digital orthophotography) to the project file and export to create a new polygon shapefile in the GIS with an appropriately descriptive title (e.g., LongLake_VegSurvey2013_Communities.shp).
    c. Add the following text fields to the communities shapefile: "Dominant", "OtherSpp", and "Density". "Dominant" is the dominant community within the polygon and should include the common name of the dominant species. Be consistent with which common names are used, the spelling of the common names, and how they are ordered (generally in alphabetical order). "OtherSpp" attribute should be populated with any other non-dominant species that field

GPS data indicate are in the polygon. “Density” is the density as indicated in the field GPS line data.

d. Start editing the communities shapefile and use the split tool to create polygons representing macrophyte beds and no vegetation areas based on the GPS line data collected in the field. Populate the new attribute columns based on comments from the GPS field line data. The dominant communities and respective densities of the remaining unclassified areas must be determined by interpolating or extrapolating from the sample site data layer and using any other information that can be gleaned from the other point and line data collected in the field. The GPS photographs can also be referenced to assist with community mapping by using the hyperlink tool and clicking on features in the GIS photograph point file. Once all lake areas in the communities shapefile have been categorized and attribute columns populated, create a new field called “Acres” and right click on attribute column to calculate geometry as “Acres US”.

10. <u>Data Summarization.</u> Summarize dominant community data by right clicking on the “Dominant” attribute column heading and selecting “Summarize”. Select a field to summarize = “Dominant”, choose summary statistics for the output table = “acres”, check the “sum” box, specify output table: choose location on server and title file appropriately, and click “okay”. This same procedure can be performed for other attributes in both the sample site and communities GIS data layers as needed.
11. <u>Map Development.</u> After completing both sample site and communities GIS data layers, display maps can be developed in a GIS. Suggested maps include: sample sites map displaying density results, communities map with dominant communities, communities map with community densities, and map with results from both sample site and community layers (Appendix C). Optionally, tables from data summarization can be included on the maps.