Walloon Lake Aquatic Vegetation Survey 2013

Tip of the Mitt Watershed Council

Survey performed and report written by Kevin L. Cronk and Daniel T. Myers

Table of Contents

List of Tables

List of Figures

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. Concerns regarding non-native (invasive) species and fish habitat prompted the Walloon Lake Association (Association) to sponsor a comprehensive aquatic plant survey in Walloon Lake.

During the summer and fall of 2013, Tip of the Mitt Watershed Council (TOMWC) conducted a plant survey in Walloon Lake, a 4,620-acre oligotrophic lake located in Emmet and Charlevoix Counties in the Northern Lower Peninsula of Michigan. TOMWC staff collected specimens and noted plant densities at 908 sites throughout Walloon Lake, documenting 32 different aquatic plant taxa during the survey. Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), and eel-grass (*Valisneria americana*) were the most commonly collected species and dominant at the greatest number of sample sites. Two invasive species, Eurasian watermilfoil (*Myriophyllum spicatum*) and purple loosestrife (*Lythrum salicaria)* were found during this survey. Eurasian watermilfoil is a plant of particular concern due to its ability to outcompete native vegetation and crowd waterways.

Aquatic plant communities were delineated directly in the field using a GPS (global positioning system) or indirectly through interpolation or extrapolation of sample site data. Plant community data showed that a majority of Walloon Lake (78%) contained no or little aquatic vegetation. Reflecting sample site results, muskgrass, slender naiad and pondweed commonly dominated the lake's aquatic plant communities.

The aquatic plant communities of Walloon Lake predominantly contained very light to light density growth (66% of the vegetated area). Relatively little heavy density growth was documented and very heavy growth was limited to 7 acres (0.6%). A few areas in Walloon Lake contained what is generally considered to be nuisance plant growth. Areas of dense vegetation (classified as very heavy) were found near mouths of Schoofs Creek and Fineout Creek, as well as throughout the Mud Lake Basin. Nutrient inputs from these creeks likely contribute to the

heavy plant growth near their mouths because streams typically contain higher levels of nutrients than lakes in this region. The small, sheltered, and shallow nature of the Mud Lake Basin likely contributes to the dense plant growth.

Invasive species and nutrient pollution may be contributing to aquatic plant growth throughout Walloon Lake. Invasive zebra mussels (*Dreissena polymorpha*) are present in Walloon Lake and potentially increase plant growth by altering the lake ecosystem. These filter feeding mussels clear the water column, allowing more light to reach aquatic plants, and concentrate nutrients on the lake bottom where they are favorable to plant growth. Human development of the landscape and activity in nearshore areas invariably leads to unnaturally elevated nutrient inputs into the lake, which contribute to aquatic plant growth.

The WLA should share results from this survey to maximize benefits and assist in lake management efforts. Shoreline areas should continue to be surveyed on a regular basis for evidence of nutrient pollution and any problem areas addressed to prevent or reduce nuisance aquatic plant growth. The Association should continue its efforts to control Eurasian watermilfoil in the lake. Additionally, the Association should regularly survey other lake areas for the presence of Eurasian watermilfoil and implement control measures as necessary.

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 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. Following the discovery of Eurasian watermilfoil by TOMWC staff in the Mud Lake Basin in 2005, the Association contracted with TOMWC to perform aquatic plant surveys and with EnviroScience, Inc. to stock weevils as a biological control measure. TOMWC staff mapped out Eurasian watermilfoil beds in the Mud Lake Basin in 2006 and again in 2007 to document the areal extent of the beds and evaluate the effectiveness of weevil treatment. Although the effectiveness of weevil treatment was not immediately apparent, TOMWC staff observed large reductions in the size of the Eurasian watermilfoil beds during subsequent years. There are no records of previous comprehensive aquatic plant surveys on Walloon Lake.

With the absence of continued treatment, Eurasian watermilfoil resurged and in 2013, the Association coordinated the installation of benthic barriers (i.e., mats on the lake bottom) and herbicide application. Benthic barriers were installed in two infestation locations in Bear Cove Marina in the West Arm of Walloon Lake. The Association contracted with Professional Lake Management to treat known infestations in the Mud Lake Basin with approved herbicides. In 2013, the Association also contracted with TOMWC to perform a comprehensive aquatic plant survey of Walloon Lake. Survey field methods, data management procedures, project results, and discussion of results are contained in this report.

Study Area

Walloon Lake is located in the northwest Lower Peninsula of Michigan; in Bear Creek and Resort Townships of Emmet County and Bay, Evangeline, and Melrose Townships of Charlevoix County. Based on digitization of aerial orthophotography from the Charlevoix and Emmet County Equalization Departments (2010 and 2012, respectively), the shoreline of Walloon Lake measures 30.9 miles and lake surface area totals 4,620 acres. Walloon Lake extends approximately 9.5 miles in a southeast to northwest direction and is generally less than one mile wide throughout its length. A number of prominent land points project out into the lake and define the boundaries of the lake's five distinct basins. The five basins in Walloon Lake include (from northwest to southeast): Mud Lake, the West Arm, the Wildwood Basin, the Foot Basin, and the North Arm (Figure 1).

Bathymetry maps from the Michigan Department of Natural Resources (MDNR 2013) show the deepest location to be near the center of the West Arm, with a maximum depth of 100 feet. Maximum depths in the other basins are as follows: 94' in the Foot Basin, 80' in the Wildwood Basin, 52' in the North Arm, and 14' in Mud Lake. Broad shallow areas are found between the various basins and throughout Mud Lake.

Walloon Lake is a drainage lake with water flowing into and out of the lake. The primary inlets include Schoof's Creek in the north end of the North Arm and South Arm Creek (AKA, Fineout Creek) in the south end of the Foot Basin. The only outlet is the Bear River, which flows out the east end of the Foot Basin at Walloon Lake Village. Extensive wetland areas are found in the lower ends of the Schoof's and South Arm Creeks' watersheds, as well as the perimeter of the Mud Lake basin.

Using elevation data acquired from the State of Michigan, TOMWC staff developed watershed boundary files for Walloon Lake in a GIS (Geographical Information System). Based on these data, the Walloon Lake watershed encompasses approximately 26,500 acres of land and water (Figure 1). Land cover statistics were generated for the watershed using remote sensing data from the Coastal Great Lakes Land Cover project (NOAA 2007). Based on 2006 data, the majority of the watershed's landcover is natural; consisting primarily of forest, wetlands, and grassland (Table 1). There is a moderate amount of agricultural landcover in the watershed (~22%), but little urban (~3.5%). Both agricultural and urban landcover increased by roughly one percent between 2000 and 2006.

Table 1. Walloon Lake watershed land-cover statistics.

Land Cover Type	Acres (2000)	Percent (2000)	Acres (2006)	Percent (2006)	Change, Acres (2000-2006)	Change, Percent (2000-2006)
Agriculture	5499.14	20.74	5835.38	21.99	336.24	1.25
Barren	34.71	0.13	47.73	0.18	13.01	0.05
Forested	10100.97	38.10	10468.19	39.46	367.21	1.35
Grassland	3162.54	11.93	1974.97	7.44	-1187.57	-4.49
Scrub/Shrub	521.03	1.97	619.82	2.34	98.79	0.37
Urban/residential	691.33	2.61	927.45	3.50	236.12	0.89
Wetland	1788.91	6.75	1958.49	7.38	169.58	0.63
Water	4711.44	17.77	4699.15	17.71	-12.29	-0.06
TOTAL	26510.07	100.00	26531.17	53062.35	NA	NA

The water quality of Walloon Lake has been monitored consistently for more than two decades through the TOMWC's Comprehensive Water Quality Monitoring program (CWQM) and Volunteer Lake Monitoring program (VLM). TOMWC databases contain VLM and CWQM data that date back to 1989 and 1992 respectively. Data collected through these programs indicate good water quality.

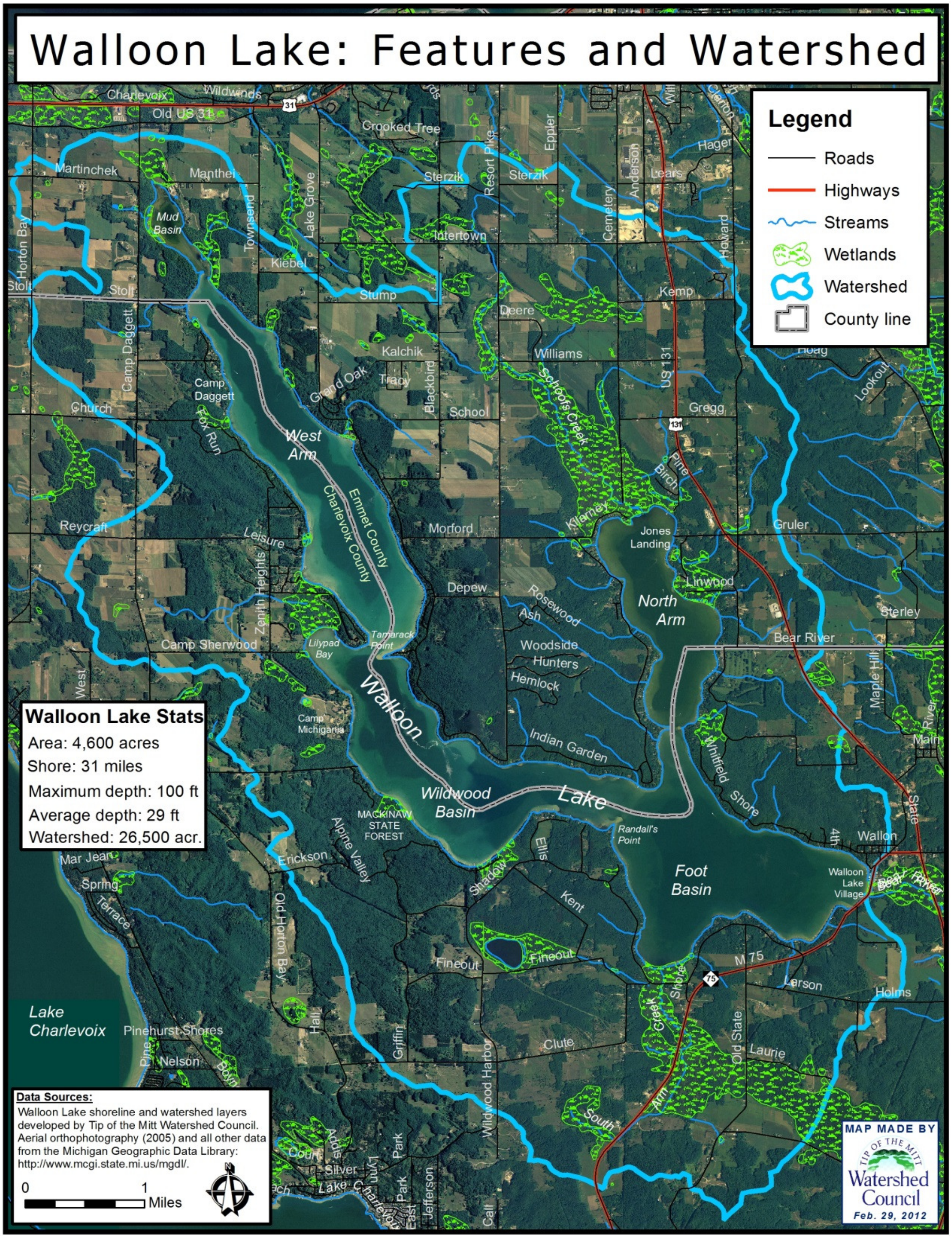

Figure 1. Walloon Lake: Features and Watershed.

Volunteer Lake Monitoring program data show that averaged Secchi disc depths on Walloon Lake have ranged from 7 to 23 feet (Figure 2). There seems to be a trend of increasing clarity over time. Water clarity is usually determined by two key factors: sediments and phytoplanktonic algae. Little sediment in the water is desirable, but too little algae can negatively impact the natural food web and lake ecosystem. A decrease in phytoplanktonic algae equates to a loss in primary productivity, which has cascading effects throughout the food chain. Invasive zebra mussels (*Dreissena polymorpha*), observed in Walloon Lake during the survey, filter-feed on phytoplanktonic algae, which typically results in greater water clarity. However, chlorophyll-a measurements, which provide an indication of algal biomass in the lakes, have not decreased as typically occurs when zebra mussels become established in a lake (Figure 3).

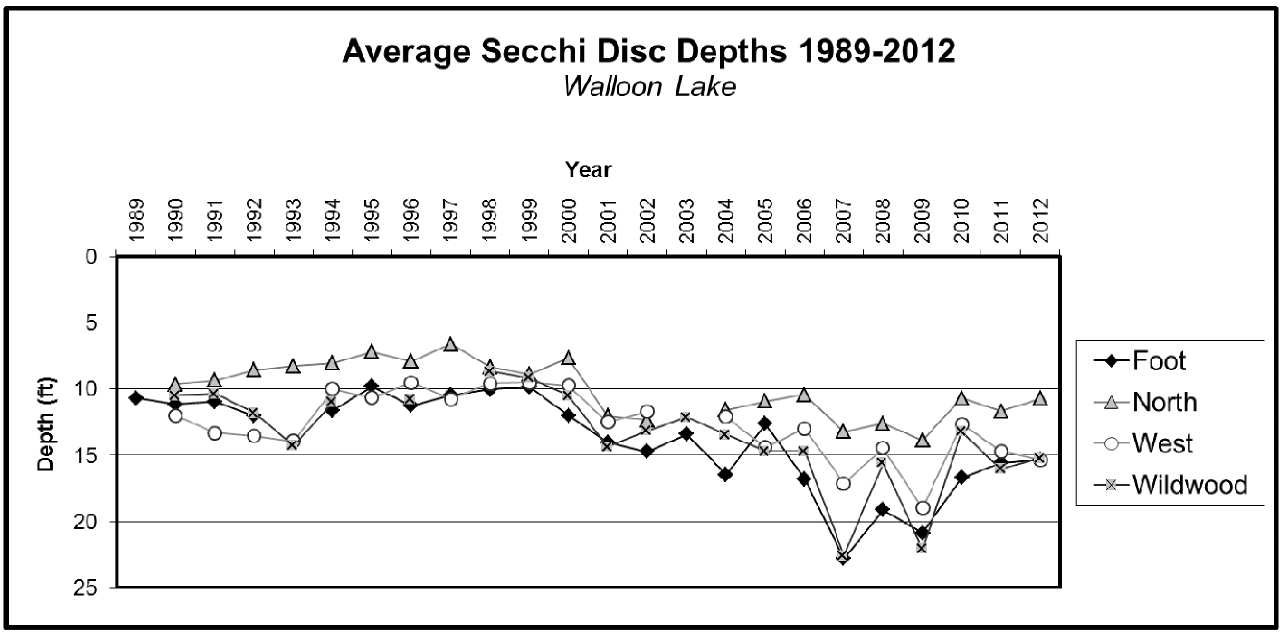

Figure 2. Secchi disc depth data from Walloon Lake (TOMWC 2013).

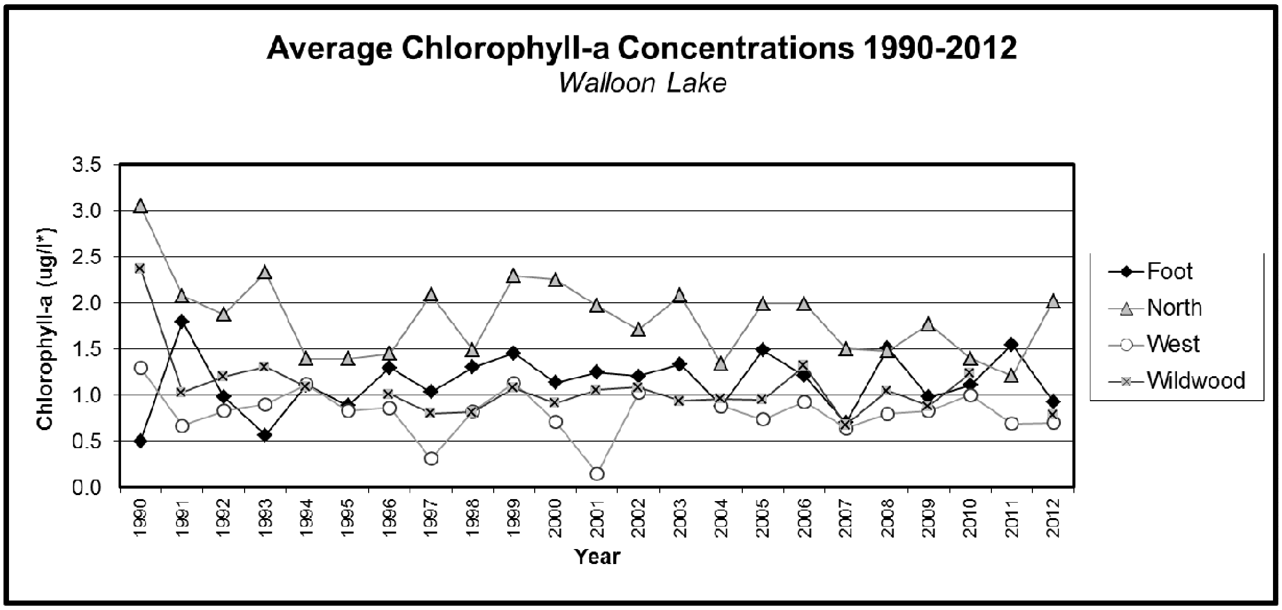

Figure 3. Chlorophyll-a data from Walloon Lake (TOMWC 2013).
**Chlorophyll-a is measured in ug/L, which is micrograms per liter or parts per billion.*

Based on trophic status index data from the VLM program, Walloon Lake borders between mesotrophy and oligotrophy, though it was consistently mesotrophic in the 1990s (Figure 4). Oligotrophic lakes are typically large, deep, clear, and nutrient poor. In general,

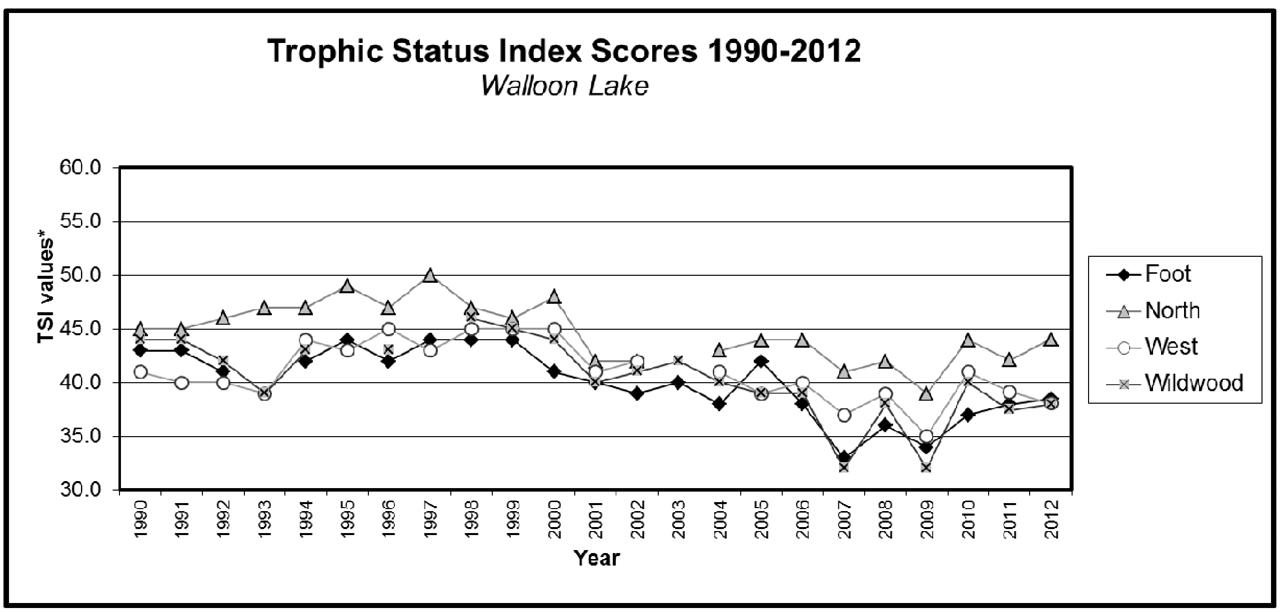

Figure 4. Trophic status index data from Walloon Lake (TOMWC 2013).
**Trophic Status Index values based on annual averaged Secchi disc depth data and represent the trophic status (biological productivity) of the lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive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

oligotrophic lakes contain high quality waters, but paradoxically have a lackluster fishery due to low biological productivity. Mesotrophic lakes are moderately productive. Total phosphorus data collected in the CWQM program show that levels have dropped considerably throughout the last 20 years and are generally found below 10 parts per billion (PPB), which is typical for high quality lakes of Northern Michigan (Figure 5). This decrease is probably due, at least in part, to the introduction of zebra mussels, which have filtered much of the algae out of the water column and disrupted the natural nutrient cycle in the lake.

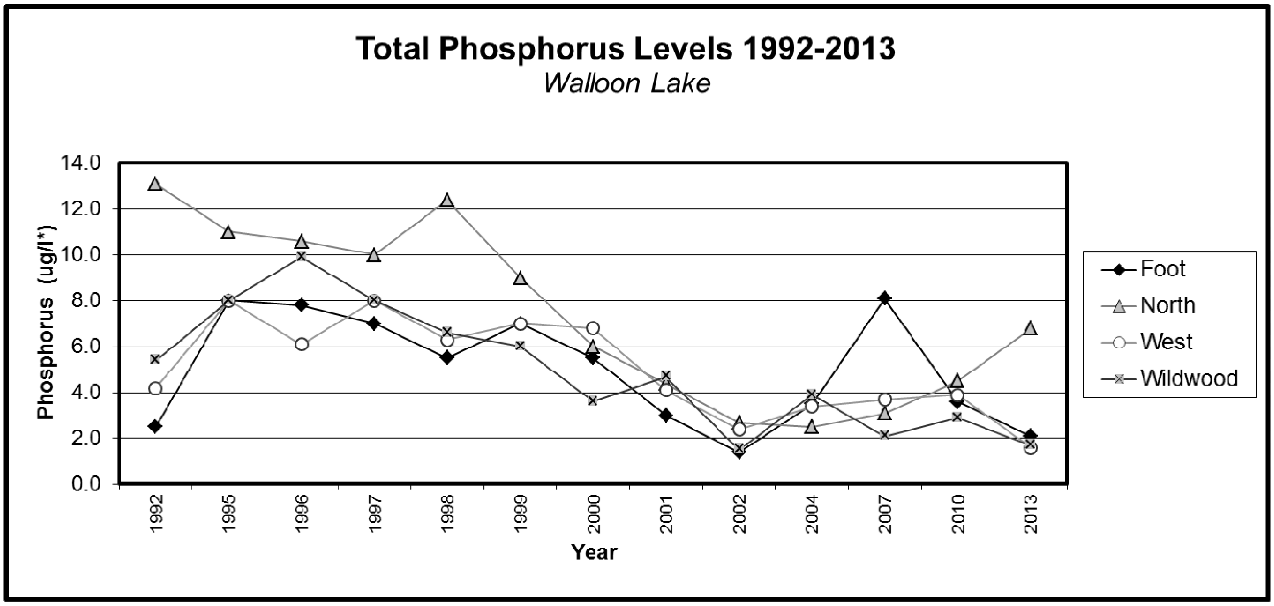

Figure 5. Total phosphorus trends in Walloon Lake 1992 to 2013 (TOMWC 2013).
**Total phosphorus is measured in ug/L, which is micrograms per liter or parts per billion.*

Fish surveys were conducted by the Michigan Department of Natural Resources in 1977, 1986, 1987, 1999, 2006 and 2007, and another is scheduled for 2015. These surveys show that Walloon Lake supports a variety of fish species typical for lakes of Northern Michigan. Fish species collected during the 2006 and 2007 surveys include black and brown bullhead, bluegill, white sucker, largemouth and smallmouth bass, northern pike, pumpkinseed, walleye, and yellow perch. Walloon Lake is one of seven area lakes that receive stocked Eagle Lake rainbow trout and Michigan steelhead from Thompson State Fish Hatchery (Nuhfer, 2007). Planted trout make up the vast majority of the trout fishery here, but one wild trout was collected in 2006.

METHODS

Aquatic plants were documented in all areas of Walloon Lake during August and September of 2013. Consistent with Michigan Department of Environmental Quality procedures, the aquatic plant communities of Walloon Lake 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 908 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. 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 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 in Walloon 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 Panasonic DMC-TS4 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 908 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 32 aquatic plant taxa were documented during the survey conducted on Walloon Lake. Additionally, five emergent taxa were noted in comments or mapped with GPS, but not represented in the spreadsheet columns: cattail (*Typha spp.*), sweet gale (*Myrica gale*), purple loosestrife (*Lythrum salicaria*), rushes (*Juncus spp.*), and three-square bulrush (*Schoenoplectus americanus*). Of the 908 locations sampled, aquatic plants were found at 574 sites (63%), while 334 sites (37%) had little or no vegetation (Figure 6). The number of aquatic plant taxa encountered at a site ranged from zero to 10 with an average of 1.8 taxa per sample site. Two invasive plant species were encountered during this survey: Eurasian watermilfoil and purple loosestrife.

Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), and variable-leaf pondweed (*Potamogeton gramineus*) were the most commonly encountered species; collected at approximately 88%, 74%, and 44% of vegetated sites respectively (Table 2). Four other taxa were collected at 25 sites or more and considered common: eel-grass (*Valisneria americana*), broad-leaved pondweed (*Potamogeton amplifolius*), bladderwort (*Utricularia vulgaris*), and floating-leaf pondweed (*Potamogeton natans*). Eleven plant taxa occurred uncommonly, which was defined as occurring at 6 to 24 sites, and the remaining nine taxa were rarely collected (occurring at 5 sites or less).

The plants most commonly collected were also those that dominated or co-dominated plant communities at the greatest number of sample sites. However, whereas slender naiad and muskgrass were collected at a similar number of sites (425 and 504, respectively), muskgrass was by far the most dominant, dominating plant communities at 399 sites (Table 3). Slender naiad and variable-leaf pondweed followed, dominating at 219 and 69 sites respectively.

Typical for lakes in this region, the pondweed family (*Potamogetonaceae)* was the most speciose (i.e., had the greatest number of species). A total of 10 pondweed species were documented in Walloon Lake during this survey.

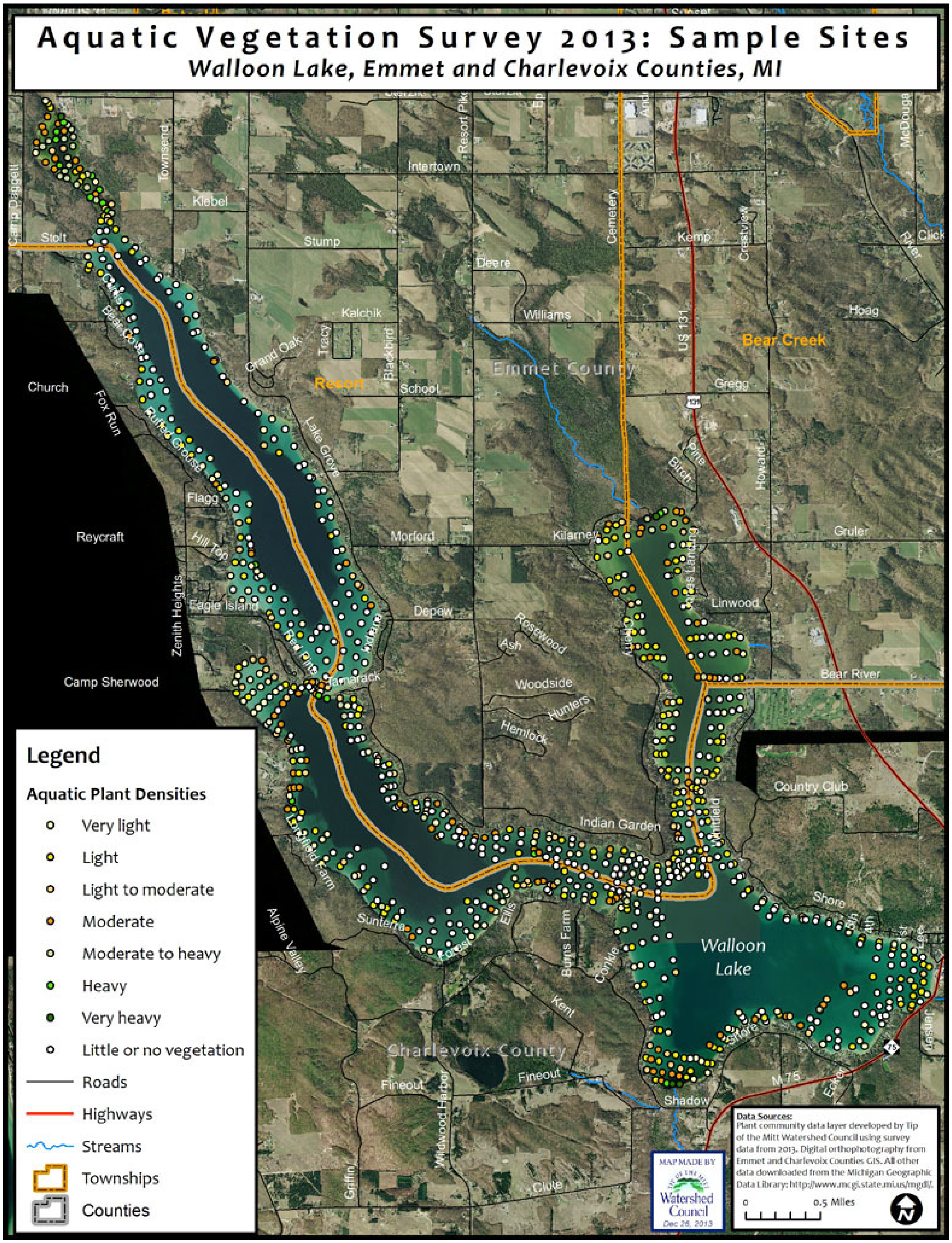

Figure 6. Sample sites for 2013 aquatic plant survey.

Table 2. Aquatic plant taxa occurrence at sample sites.

Genus and species	Common Name	Number of sites	Percent of sites*	Occurrence[†]
Chara spp.	Muskgrass	504	87.8	Very common
Najas flexilis	Slender naiad	425	74.0	Very common
Potamogeton gramineus	Variable-leaf pondweed	254	44.3	Very common
Vallisneria americana	Eel-grass	91	15.9	Common
Potamogeton amplifolius	Broad-leaved pondweed	75	13.1	Common
Utricularia vulgaris	Bladderwort	65	11.3	Common
Potamogeton natans	Floating-leaf pondweed	39	6.8	Common
Potamogeton zosteriformis	Flat-stem pondweed	24	4.2	Uncommon
Potamogeton strictifolius	Narrow-leaf pondweed	23	4.0	Uncommon
Stuckenia pectinata	Sago pondweed	23	4.0	Uncommon
Potamogeton praelongus	Whitestem pondweed	10	1.7	Uncommon
Myriophyllum sibiricum	Common watermilfoil	8	1.4	Uncommon
Sagittaria spp.	Arum	8	1.4	Uncommon
Elodea canadensis	Elodea	7	1.2	Uncommon
Myriophyllum spicatum	Eurasian watermilfoil	7	1.2	Uncommon
Potamogeton illinoensis	Illinois pondweed	7	1.2	Uncommon
Schoenoplectus spp.	Bulrush	7	1.2	Uncommon
Ceratophyllum demersum	Coontail	6	1.0	Uncommon
Nuphar variegata	Yellow pond-lily	5	0.9	Rare
Myriophyllum heterophyllum	Variable-leaf watermilfoil	4	0.7	Rare
Stuckenia filiformis	Fineleaf pondweed	4	0.7	Rare
Potamogeton spp.	Pondweed (species unknown)	3	0.5	Rare
Utricularia resupinata	Lavender bladderwort	3	0.5	Rare
Nymphaea odorata	White pond-lily	2	0.3	Rare
Megalodonta beckii	Water marigold	1	0.2	Rare
Potamogeton friesii	Fries' pondweed	1	0.2	Rare
Sparganium spp.	Burr reed	1	0.2	Rare

**Percent of sites based on only those sites with vegetation (=574).*

[†]*Occurrence categories determined by TOMWC staff based on natural breaks: 1-5 = rare, 6-24 = uncommon, 25-100 = common, and 100+ = bountiful.*

The distribution of aquatic plant community densities at sample sites leaned toward light-density growth (Table 4). Approximately 46% of sample sites had aquatic plant community densities that fell into the light categories (VL, L, and LM). Moderate growth was documented at 11% of sites and heavy-density growth (MH, H, and VH) accounted for 7%. The remaining sites (37%) had little or no vegetation. Clusters of heavy-density growth were typically found near stream inlets, such as Schoof's and Fineout Creeks, and throughout the Mud Lake Basin.

Table 3. Aquatic plant taxa dominance at sample sites.

Aquatic Plant Species	Common Name	Number of sites where dominant*	Percent of sites where dominant*
Chara spp.	Muskgrass	399	69.5
Najas flexilis	Slender naiad	219	38.2
Potamogeton gramineus	Variable-leaf pondweed	69	12.0
Vallisneria americana	Eel-grass	28	4.9
Potamogeton amplifolius	Broad-leaved pondweed	19	3.3
Potamogeton zosteriformis	Flat-stem pondweed	9	1.6
Stuckenia pectinata	Sago pondweed	7	1.2
Utricularia vulgaris	Bladderwort	5	0.9
Potamogeton natans	Floating-leaf pondweed	4	0.7
Myriophyllum heterophyllum	Variable-leaf watermilfoil	3	0.5
Schoenoplectus spp.	Bulrush	3	0.5
Myriophyllum spicatum	Eurasian watermilfoil	2	0.3
Nuphar variegata	Yellow pond-lily	2	0.3
Utricularia resupinata	Lavender bladderwort	2	0.3
Ceratophyllum demersum	Coontail	1	0.2
Megalodonta (Bidens) beckii	Water marigold	1	0.2
Myriophyllum sibiricum	Common watermilfoil	1	0.2
Potamogeton illinoensis	Illinois pondweed	1	0.2
Potamogeton praelongus	Whitestem pondweed	1	0.2
Potamogeton strictifolius	Narrow-leaf pondweed	1	0.2
Sagittaria spp.	Arum	1	0.2
Stuckenia filiformis	Fine-leaf pondweed	1	0.2

**Number or percent of vegetated sites where taxon was dominant or co-dominant.*

Table 4. Aquatic plant densities at sample sites.

Density Category	Number of sites	Percentage of sites
No vegetation	334	36.8
Very Light	166	18.3
Light	180	19.8
Light to Moderate	68	7.5
Moderate	99	10.9
Moderate to Heavy	40	4.4
Heavy	17	1.9
Very Heavy	4	0.4
TOTAL	908	100.0

Plant communities

Aquatic plant community mapping revealed that 3582 of the 4620 acres (~78%) of Walloon Lake contained little or no aquatic vegetation (Table 5). Plant communities dominated by a mix of muskgrass, naiad, and pondweed were found to be the most common and extensive, covering 886 acres of Walloon Lake (Table 5). Communities dominated by muskgrass followed at 50 acres, then bulrush at 30 and eelgrass at 23.

Table 5. Dominant aquatic plant communities: acres and percent.

Dominant Community Type	Lake Surface Area (acres)	Lake Surface Area (percent)
Little or no vegetation	3581.59	77.527
Muskgrass, Naiad, and Pondweed	885.63	19.170
Muskgrass	49.68	1.075
Bulrush	29.76	0.644
Eelgrass	22.56	0.488
Multiple Species	15.10	0.327
Bulrush and Lily Pads	9.40	0.203
Lily Pads	6.73	0.146
Pondweed	6.09	0.132
Bladderwort	4.16	0.090
Watermilfoil	3.69	0.080
Cattail	2.62	0.057
Cattail and Lily Pads	1.25	0.027
Lily Pads, Muskgrass, and Naiad	1.22	0.026
Rushes	0.16	0.003
Bulrush and Purple Loosestrife	0.08	0.002
Muskgrass and Watermilfoil	0.04	0.001
Purple Loosestrife	0.03	0.001
TOTAL	4619.79	100.000

Vegetated areas were divided into broad categories of emergent vegetation (bulrush, cattails, pond-lilies, etc.) and submergent vegetation (muskgrass, pondweed, naiad, etc.). Submergent plants were found to be the only form of aquatic vegetation at over 95% of the 1038 acres of vegetated area in Walloon Lake (Table 6). Approximately 5% of the vegetated area was dominated by emergent vegetation. The majority of emergent vegetation occurred along the shallow edges of the lake, though it extended out toward the middle of the Mud Lake Basin due to shallow depths prevalent throughout much of the basin (Figures 7, 8, 9, 10, 11).

Table 6. Emergent versus submergent vegetation statistics.

Lake and Vegetation	Lake Surface Area (acres)	Lake Surface Area (Percent)
Walloon Lake	4619.8	100.0
Little or no vegetation	3581.6	77.5
Lake area with aquatic vegetation:	1038.2	22.5
a. Emergent vegetation dominant*	50.0	4.8
b. Submergent vegetation dominant*	987.0	95.1
c. Mixed emergent and submergent*	1.2	0.1

*Refers to percent of surface area with aquatic vegetation (i.e., 1038 acres).

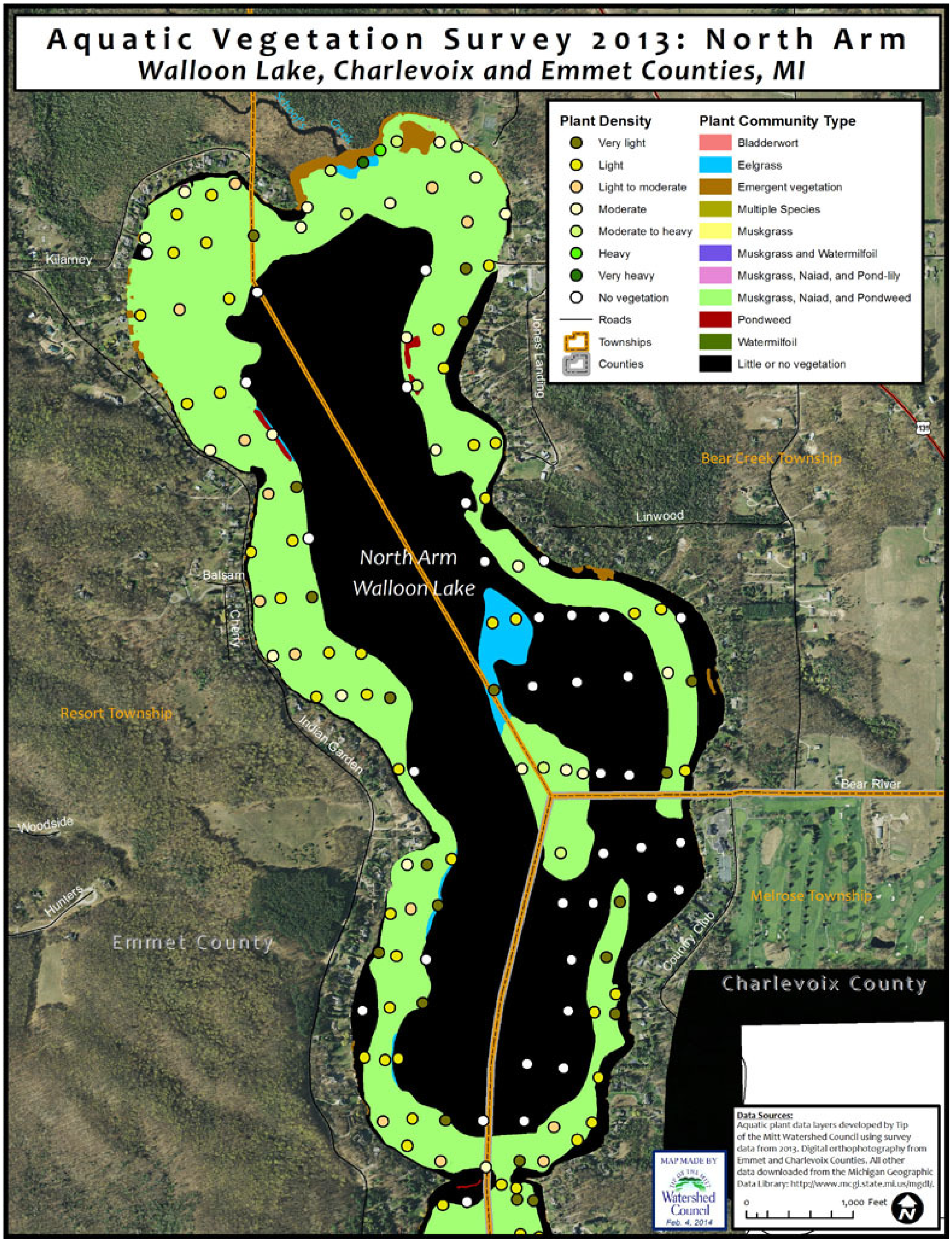

Figure 7. Aquatic plant communities in the North Arm.

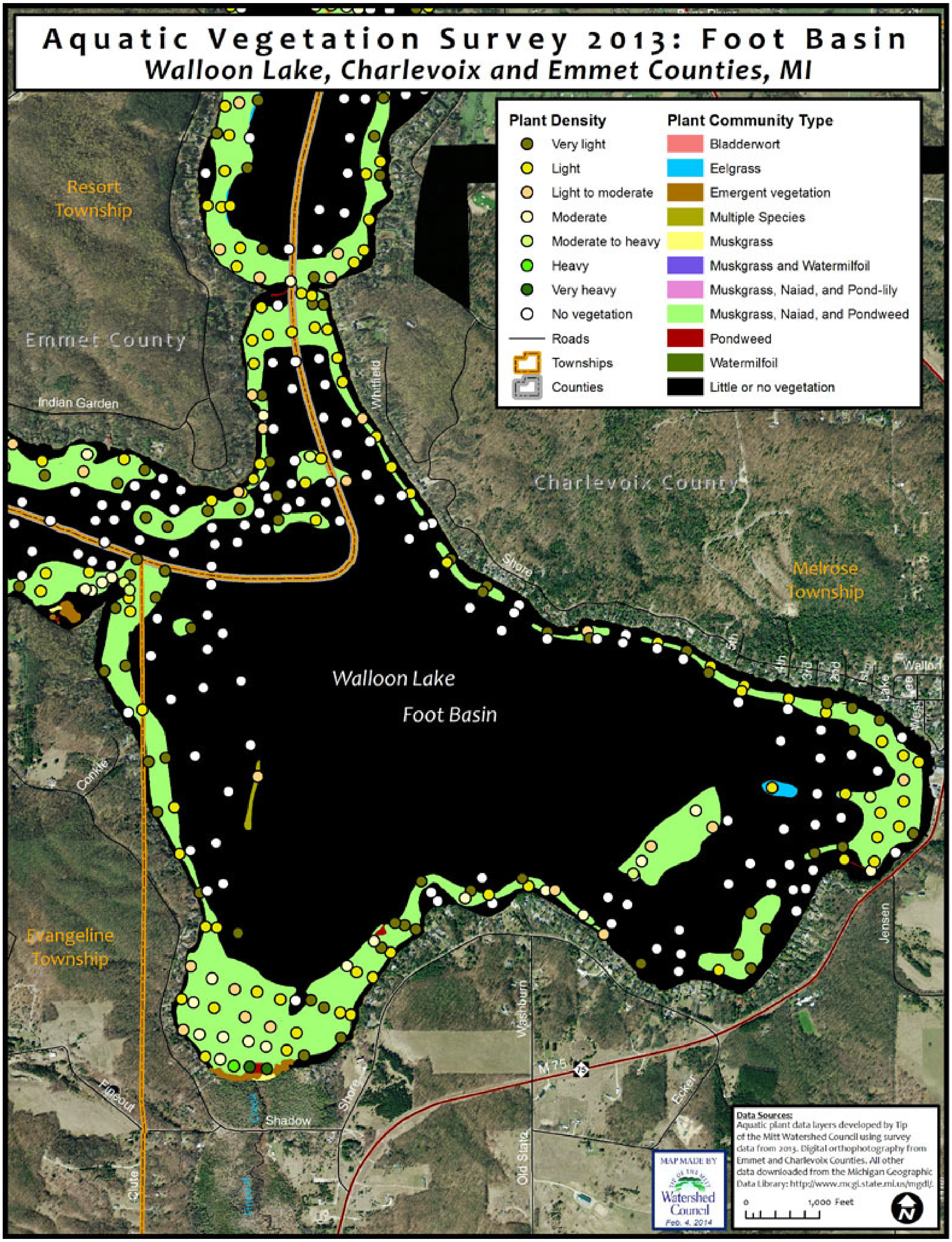

Figure 8. Aquatic plant communities in the Foot Basin.

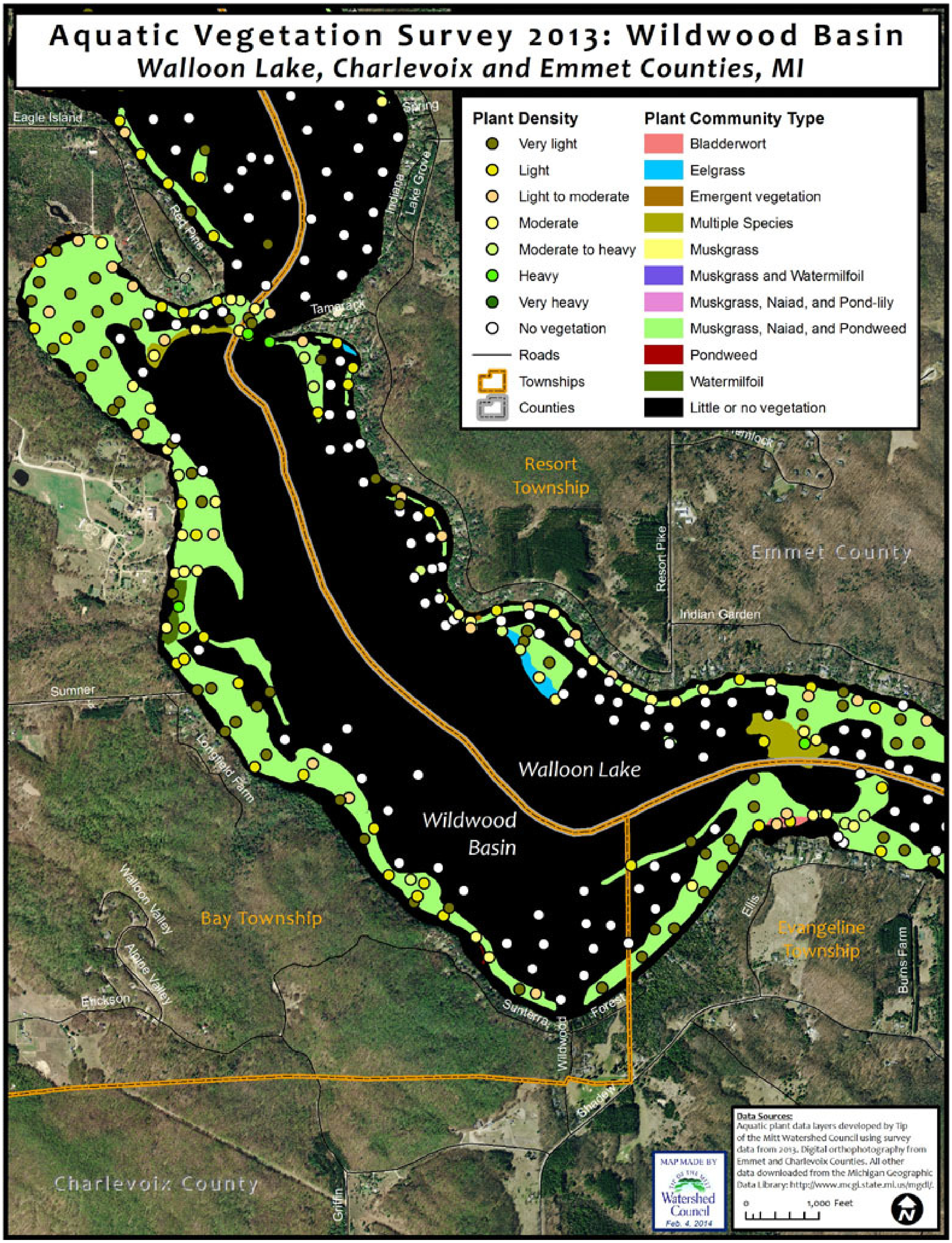

Figure 9. Aquatic plant communities in the Wildwood Basin.

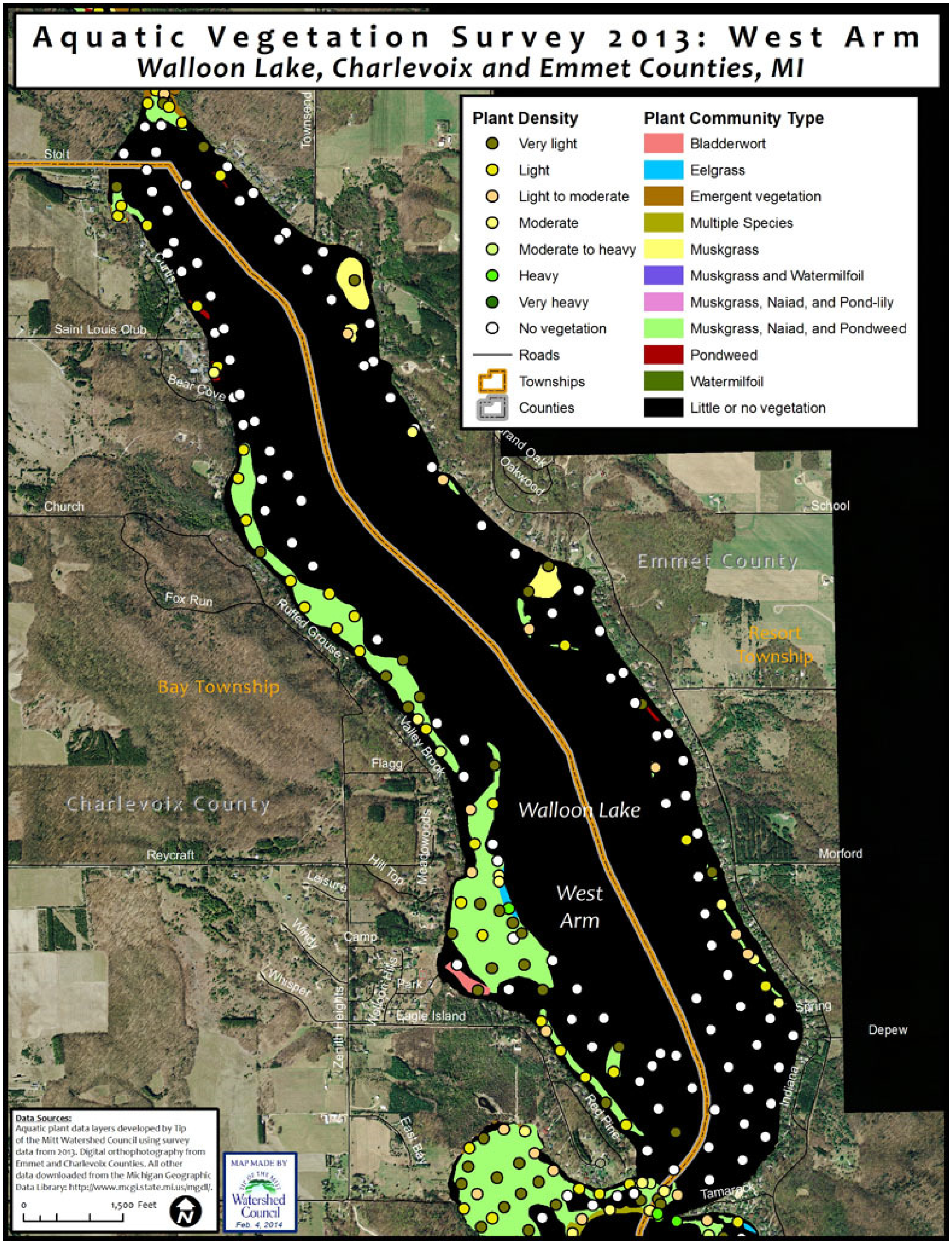

Figure 10. Aquatic plant communities in the West Arm.

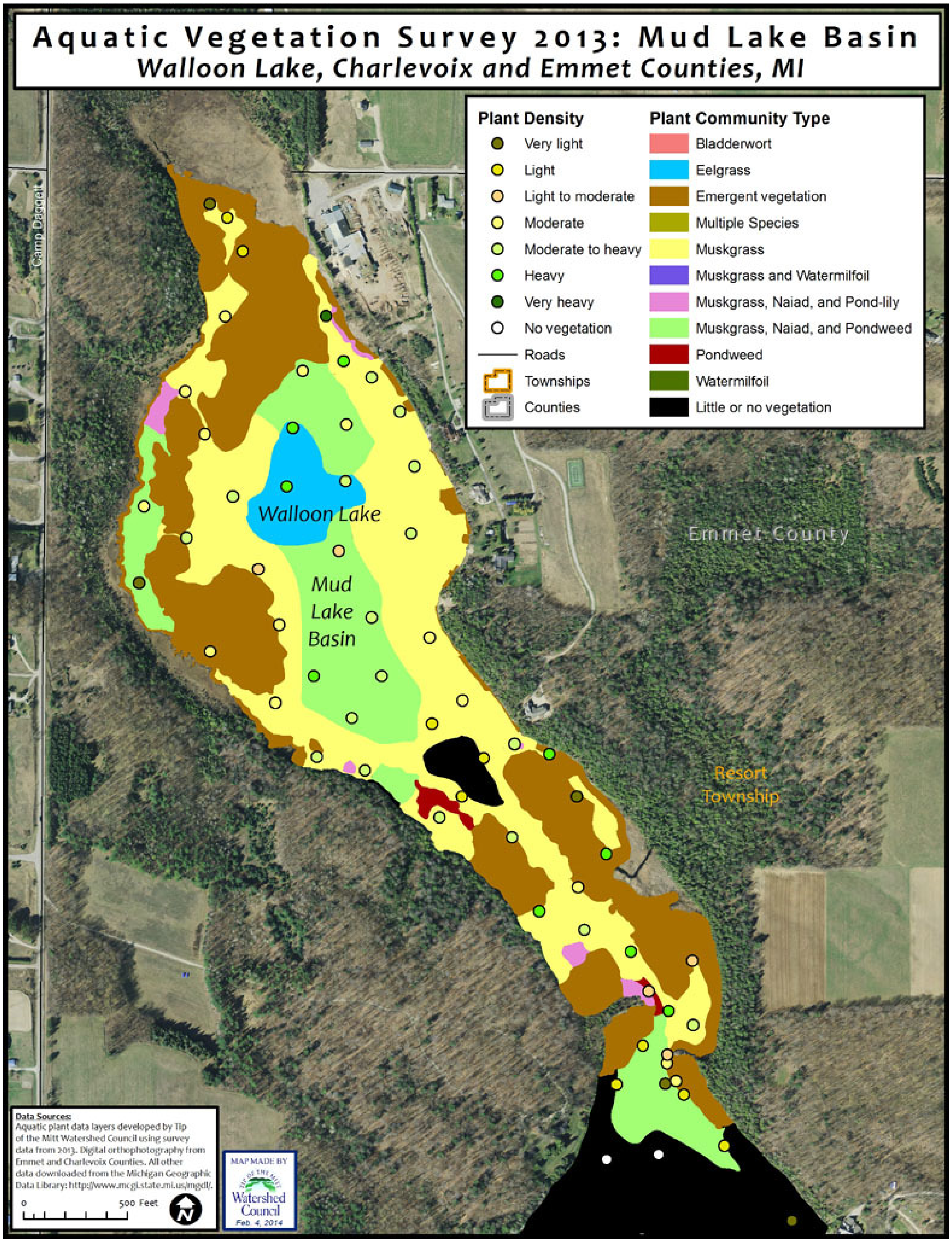

Figure 11. Aquatic plant communities in the Mud Lake Basin.

Over 65% of the vegetated areas of Walloon Lake contained very light to light density plant growth (Table 7). Moderate growth, ranging from light-moderate and moderate-heavy, accounted for 32%, while heavy and very heavy growth combined covered less than 3% of vegetated areas. Very heavy growth was found near the mouths of Schoof's Creek and Fineout Creek, as well as throughout the Mud Lake Basin (Figure 12).

Table 7. Density statistics for aquatic plant communities.

Density Category	Lake Surface Area (acres)	Lake Surface Area (percent)*
Very Light	323.4	31.2
Light	357.2	34.4
Light to Moderate	70.4	6.8
Moderate	158.4	15.3
Moderate to Heavy	100.6	9.7
Heavy	21.7	2.1
Very Heavy	6.5	0.6
TOTAL	1038.2	100.0

*Refers to percent of surface area with aquatic vegetation (i.e., 1038 acres).

Eurasian watermilfoil was documented in five locations throughout Walloon Lake: Camp Michigania (<0.01 acres, light), on the south side of the east point between the West and Wildwood Basins (<0.01 acres, heavy), the northeast side of the Mud Lake Basin (0.75 acres, light), the entrance to the Mud Lake Basin (0.33 acres, light), and at Bear Cove Marina (<0.01 acres, very light). Very little was found at Camp Michigania and but a single stem found at Bear Cove Marina. The combined acreage of Eurasian watermilfoil beds was approximately 1.1 acres (Figure 13).

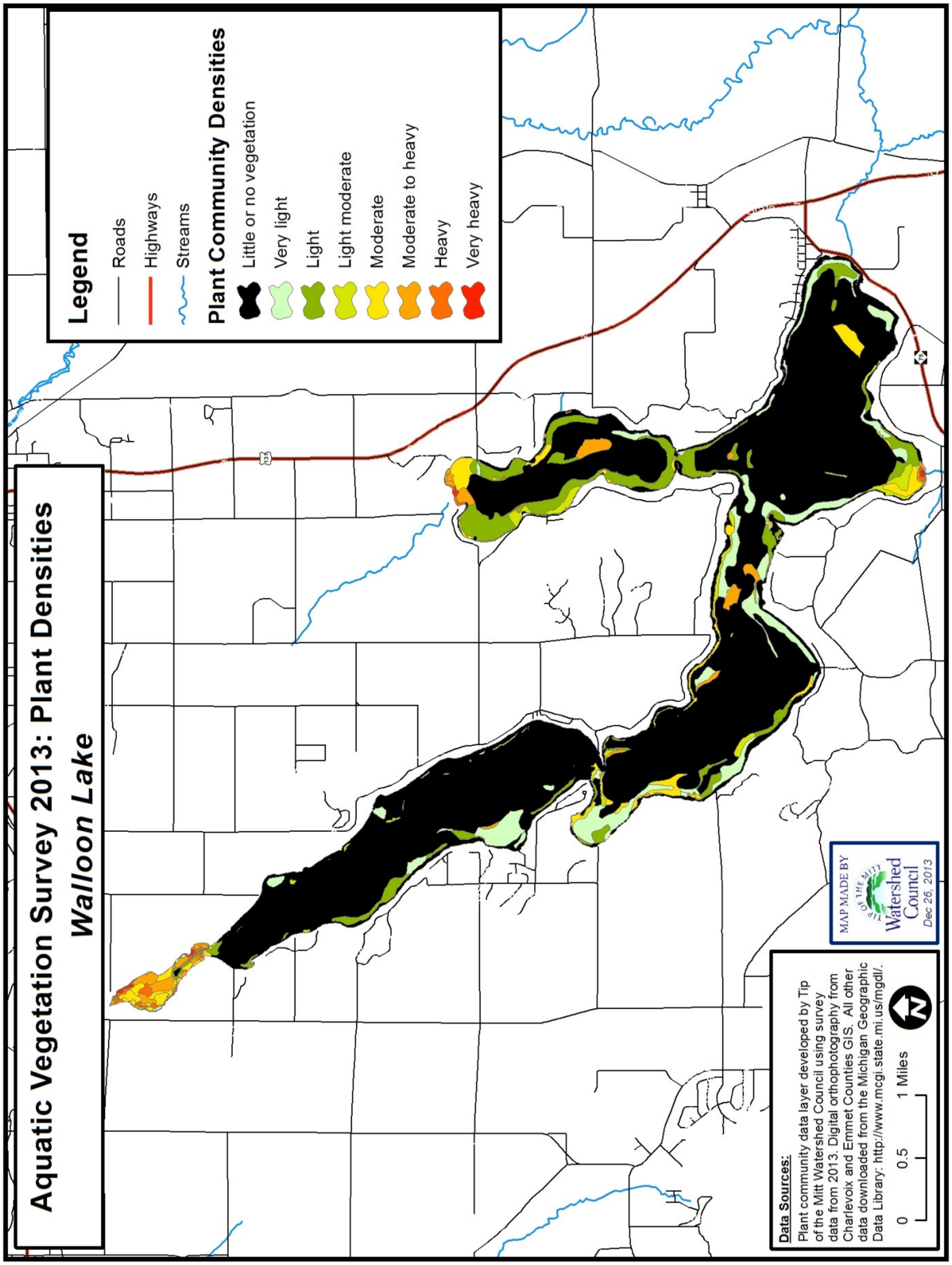

Figure 12. Aquatic plant densities in Walloon Lake.

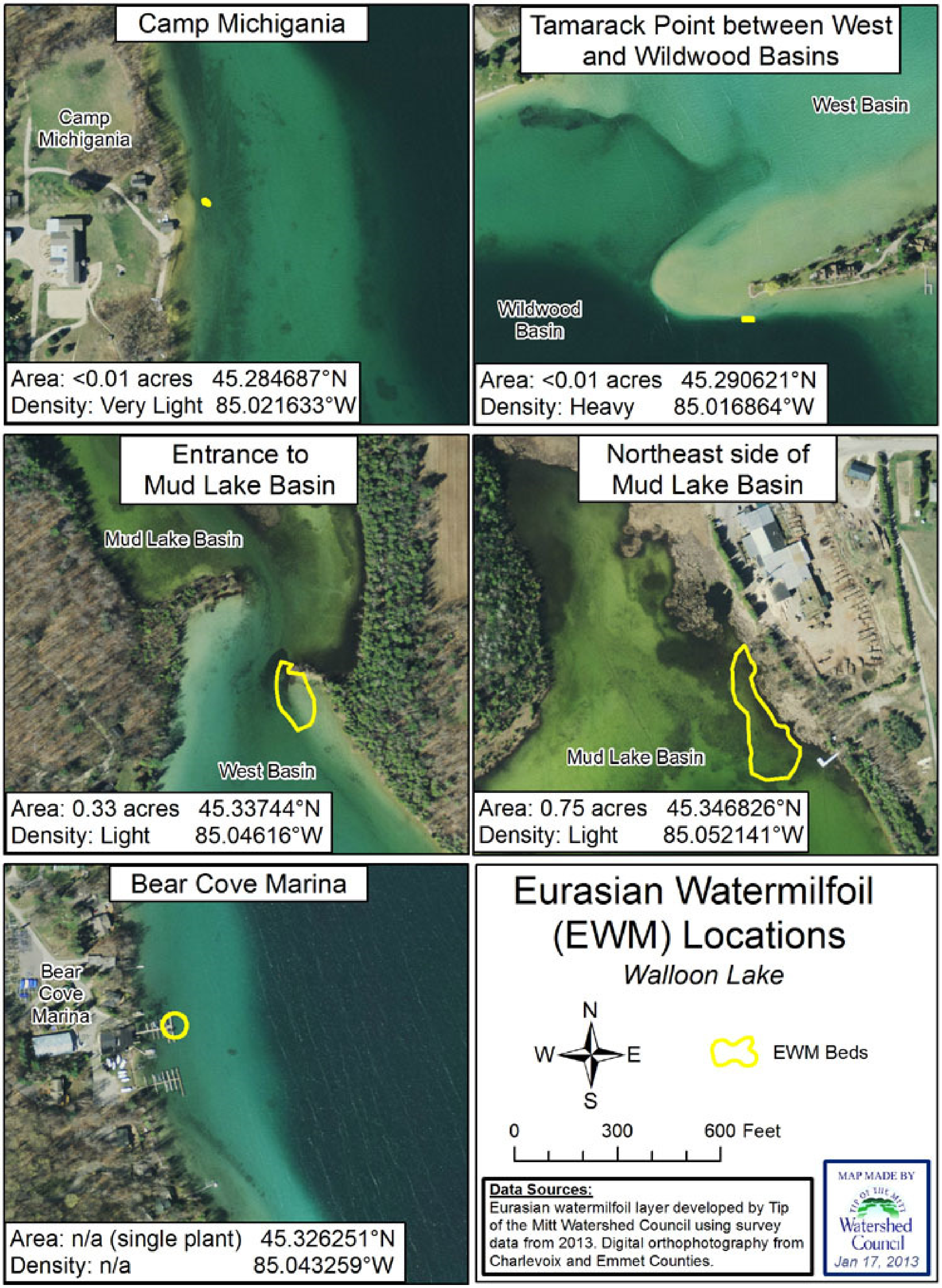

Figure 13. Eurasian watermilfoil locations in Walloon Lake.

DISCUSSION

Survey results revealed that large areas of Walloon Lake contain little or no vegetation, but that a diverse assemblage of native plant species exists in the lake. In terms of lake surface area, about 78% of the lake contains little or no vegetation. A total of 32 aquatic plant taxa were documented during the survey. Plant diversity in Walloon Lake is a little above average compared with data from other lakes surveyed in the area (Table 8). However, the averaged diversity across all sample sites in Walloon Lake (1.8 taxa/site) was among the lowest.

Table 8. Aquatic plant survey statistics from area lakes.

Lake name*	Acreage	Maximum depth (ft)	Percent with vegetation	Percent with heavy vegetation†	Number of total taxa	Number of taxa/site
Black	10,133	50	13%	25%	32	3.7
Crooked/Pickerel	3,447	70	46%	11%	31	2.4
Long	398	61	24%	11%	26	2.8
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	45%	22%	30	3.7

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

Generally, water depth and prevailing winds are key determinants of vegetated versus non-vegetated lake areas, which to some extent are apparent in Walloon Lake. In other lakes surveyed by TOMWC, it has been found that aquatic plants are usually limited to 20 feet of depth and less; the same was found for Walloon Lake (Figure 7). As evidenced in aquatic plant surveys on other lakes, prevailing winds in this region 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), especially in areas that are highly exposed. This pattern was especially apparent around points in Walloon Lake. Vegetated areas along the eastern shores as well as areas of little or no vegetation spread throughout Walloon Lake points out that other factors beyond depth and prevailing winds contribute to vegetated lake areas, such as substrate types, nutrient availability, water clarity, and water currents.

Most of the vegetated areas in Walloon Lake contain very light to light density plant growth (>65%), while less than one percent was considered to be nuisance (very heavy) plant growth (Table 7). The heavy vegetation found near the mouths of Schoof's Creek and Fineout Creek is typical for lakes in this region. Streams have relatively high nutrient concentrations as compared to lakes, which stimulates aquatic plant growth in the vicinity of where the stream flows into the lake. The small size, shallow depths, and wind-sheltered nature of the Mud Lake Basin are factors that could explain the dense aquatic vegetation found in the basin. However, nutrient pollution in the creeks' watersheds or along the developed shoreline of the Mud Lake Basin could also be contributing to the heavy plant growth. A recent study shows evidence of nutrient pollution occurring in the Schoof's Creek watershed (TOMWC 2013).

Due to a lack of historical data, it was not possible to examine trends or changes in the composition or extent of aquatic plants in Walloon Lake. Factors that typically cause changes in aquatic plant growth include increased nutrient availability, the introduction of non-native species, and plant management efforts. Nutrient inputs from cultural (human) sources such as fertilizers, septic leachate, and stormwater have increased over time in many lakes. However, data from TOMWC monitoring programs do not show increases in nutrient concentrations in the open water of Walloon Lake (Figure 5). Changes to natural lake ecosystems brought on by zebra mussels often lead to increased aquatic macrophyte biomass (Higgins and Vander Zanden 2010). The increased water clarity evident in water quality data from Walloon Lake likely results from zebra mussels feeding on plankton, which increases both nutrient and habitat availability for higher aquatic plants (Figure 2). Recent nuisance plant control efforts by the Association have resulted in a reduction of heavy Eurasian watermilfoil growth in some areas.

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. 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. 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. Numerous shoreline surveys have been conducted on Walloon over the past three decades. It is recommended that the Association continue to sponsor shoreline surveys once every 3-5 years to document conditions and address any problem areas. In addition, 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.

4. Continue efforts to control Eurasian watermilfoil in the lake. Eurasian watermilfoil, an invasive species, was documented at five sites during this survey. Due to the plant's history of outcompeting native vegetation and crowding waterways in other lakes, the Association should continue its Eurasian watermilfoil control efforts. Early detection and rapid response are recommended as this approach is the most effective, least costly, and does less 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 Eurasian watermilfoil and implement control measures as necessary to prevent the spread of this invasive species. The Association has employed various treatment options including herbicides, benthic mats, and biological control. Weevils stocked in 2005 and 2006 in the Mud Lake Basin effectively controlled the Eurasian watermilfoil growth for several years, but were not restocked and thus, their effectiveness declined. Although recent herbicide treatments and installation of benthic mats appear to have been effective, the Association should consider stocking more weevils because it is the most environmentally-safe method for controlling Eurasian watermilfoil, and can have long-term 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 Walloon Lake. To effectively manage the aquatic plant community of Walloon 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.

LITERATURE AND DATA REFERENCED

Emmet County Equalization/GIS Department. 2012. Digital Orthophotography. Petoskey, MI. http://www.emmetcounty.org/equalizationgis-56/.

Charlevoix County GIS Office. 2010. Digital Orthophotography. Charlevoix, MI. http://www.charlevoixcounty.org/gis.asp.

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

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

Higgins, S. N. and M. J. Vander Zanden. 2010. What a difference a species makes: a meta-analysis of dreissenid mussel impact on freshwater ecosystems. Madison, WI.

Korth, P. A. et al. 2007. *Aquatic Plant Management in Wisconsin.* University of Wisconsin Extension. Stevens Point, WI. http://www.uwsp.edu/cnr/uwexlakes/ecology/APMguide.asp

Michigan Department of Environmental Quality. 2012. Management of Aquatic Plants. Lansing, MI. http://www.michigan.gov/documents/deq/wrd-anc-AquaticPlantMgmt_408522_7.pdf

Michigan Department of Environmental Quality. 2005. Procedures for Aquatic Vegetation Surveys. Lansing, MI. http://www.deq.state.mi.us/documents/deq-wd-illm-surveyprocedure.pdf.

Michigan Department of Information Technology, Center for Geographic Information. 2013. Michigan Geographic Data Library. Lansing, MI. http://www.mcgi.state.mi.us/mgdl/

Michigan Department of Natural Resources. 2013. Inland Lake Maps. Lansing, MI. http://www.michigan.gov/dnr/0,4570,7-153-10364_52261-67498--,00.html.

National Oceanic and Atmospheric Administration, Coastal Services Center. 2007. Coastal Great Lakes Land Cover Project. Charleston, SC. http://www.csc.noaa.gov/crs/lca/greatlakes.html

Nuhfer, A. 2007. Fisheries Technical Report. Michigan Department of Natural Resources. Hunt Creek Fisheries Research Station, MI.

Tip of the Mitt Watershed Council (TOMWC). 2013. Comprehensive Water Quality Monitoring Program. Petoskey, MI. http://www.watershedcouncil.org/

Tip of the Mitt Watershed Council (TOMWC). 2013. Volunteer Lake Monitoring Program. Petoskey, MI. http://www.watershedcouncil.org/

Tip of the Mitt Watershed Council (TOMWC). 2013. Fineout and Schoof's Creek Monitoring Study 2013. Petoskey, MI. http://www.watershedcouncil.org/