Aquatic Vegetation Surveys 2013

on Lake Bellaire and Clam Lake

by 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 and have ecosystem impacts 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.

The Tip of the Mitt Watershed Council (TOMWC) received funding in 2013 from the Dole Family Foundation to perform comprehensive aquatic plant surveys for Bellaire and Clam Lakes (Antrim County, MI) to address concerns involving aquatic invasive species, aquatic plant management, and fish habitat. During the summer and fall of 2013, Tip of the Mitt Watershed Council staff collected specimens and documented plant densities at 420 sites throughout Bellaire and Clam Lakes; 241 sites in Bellaire and 170 in Clam. A total of 27 aquatic plant taxa were documented on Lake Belliare while 28 taxa were found on Clam Lake. Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), and eel-grass (*Valisneria americana*) were the most commonly collected species on Lake Bellaire. Variable-leaf watermilfoil (*Myriophyllum heterophyllum*), muskgrass, and eelgrass were the most commonly encountered species on Clam Lake. Only one invasive species, Eurasian watermilfoil (*Myriophyllum spicatum*) was found during this survey and at only one site in the Clam River.

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 Lake Bellaire (82%) contained little or no aquatic vegetation. Conversely, nearly 70% of Clam Lake contained aquatic vegetation. Reflecting sample site results, variable-leaf watermilfoil, muskgrass, eel-grass, and slender naiad commonly dominated the lakes' aquatic plant communities. Bulrush (*Schoenoplectus spp.*) also commonly dominated plant communities in both lakes. Over 30% of the vegetated area of Clam Lake was dominated by multiple species (i.e., a mix of four or more co-dominant species).

Similar to findings at sample sites, aquatic plant community mapping showed that Lake Bellaire predominantly contained light to moderate-density plant growth whereas the majority of Clam Lake had moderate to heavy-density growth. Approximately 77% of vegetated areas in Lake Bellaire had densities in the light, light-moderate, or moderate categories. Conversely, over 85% of plant communities in Clam Lake had densities in the moderate, moderate-heavy, or heavy categories. In Lake Bellaire, clusters of heavy-density macrophyte growth were found in the north tip of the northwest arm and along the north and northeast shore of the main basin. Heavy-density macrophyte growth was found to be pervasive in Clam Lake, occurring throughout much of the vegetated lake area.

The contrast in the extent and densities of macrophyte communities between the two lakes is attributed to the morphological characteristics of the lakes; Lake Bellaire has extensive deep areas that do not support macrophyte growth whereas the majority of Clam Lake is less than 20 feet deep and therefore, conducive to aquatic plant growth. Areas of heavy-density plant growth in Lake Bellaire occurred near stream inlets, which is typical because streams in this region generally contain higher nutrient concentrations than lakes. Although nutrient inputs from inlet streams such as the Grass River and Finch Creek likely influence plant growth in Clam Lake, the heavy-density growth found throughout the lake was attributed principally to extensive shallow areas. However, unnaturally elevated nutrient inputs from residential shoreline development could also be contributing to heavy-density plant growth in both lakes. In spite of differences in vegetated lake area and plant community densities, macrophyte species diversity was approximately the same in the two lakes.

Eurasian watermilfoil was only found in one site on the Clam River. It appears that Three Lakes Association's (TLA) control efforts have been successful in preventing the spread of this invasive species to other parts of Clam Lake, the Grass River, and Lake Bellaire.

Results from this survey should be shared to maximize benefits and assist in lake management efforts. Information and education outreach 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. Shoreline areas in Bellaire and Clam Lakes should be regularly surveyed for evidence of nutrient pollution and problematic areas addressed to protect against nuisance aquatic plant growth. Monitoring efforts for Eurasian watermilfoil and other invasive plant species should continue in these lakes, and control measures implemented as necessary. Aquatic vegetation surveys should be repeated on a regular basis to determine trends over time, evaluate successes or failures of aquatic plant management projects, and document 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.

Eurasian watermilfoil (*Myriophyllum spicatum*) is a non-native submergent macrophyte species that was found in Clam Lake. It is thought that Eurasian watermilfoil was introduced to the United States in the 1940’s, spreading throughout the country since then and now present in many Northern Michigan lakes. Although the exact date of introduction to Clam Lake is not known, the Three Lakes Association (TLA) has worked to control a persistent bed of this invasive species near Butch's Marina efforts since the 1990s. TLA has used benthic barriers, herbicides, and diver-assisted suction harvesting in their efforts to control it. Specimens collected from the marina in 2012 and sent to the Molecular Ecology / Thum Lab at Grand Valley State University for DNA testing were found to be a hybrid form of Eurasian watermilfoil. Control efforts have been successful in that this invasive species has not spread to other areas of Clam Lake. TLA plans to continue efforts into the future.

Aquatic plant management, both in terms of invasive and native species, is a critical component of lake management. Thus, an important first 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. In 2013, the Tip of the Mitt Watershed Council (TOMWC) received funding from the Dole Family Foundation to perform comprehensive aquatic plant surveys of Bellaire and Clam Lakes. The information gleaned from these surveys will assist TLA and other organizations in their efforts to maintain vibrant natural plant communities and control invasive species. Survey field methods, data management procedures, project results, and discussion of results are contained in this report.

Study area

Bellaire and Clam Lakes are located in southern Antrim County in the Northern Lower Peninsula of Michigan. They are part of the Elk River Chain of Lakes (ERCOL), which consists of over 50 miles of interconnected lakes and streams that drain into East Grand Traverse Bay at the Village of Elk Rapids. Lake Bellaire is located in Forest Home, Kearney, and Custer Townships, and Clam Lake is in Forest Home and Helena Townships.

Clam Lake lies to the southwest of Lake Bellaire and connected by the 2.5 mile-long Grass River. Lake Bellaire is widest near the middle and narrows into distinct arms on the north and south ends. Clam Lake is an elongate lake stretching from east to west. Based upon digitization of 2011 Bing imagery acquired from the State of Michigan (NAIP 2012), the Lake Bellaire shoreline measures 11.8 miles and the lake surface area totals 1,810 acres whereas Clam Lake has 9.3 miles of shoreline and 446 acres of surface area. Lake Bellaire measures approximately 3.8

miles from north to south at its widest point and 1.5 miles from east to west. From northeast to southwest, Clam Lake measures roughly 3.3 miles and has a maximum width of 0.4 miles.

The majority of Lake Bellaire is not suitable for macrophytes (i.e., higher aquatic plants) due to depth, whereas most of Clam Lake is shallow enough to support macrophyte growth. Bathymetry maps from the Michigan Department of Natural Resources Institute for Fisheries Research (MDNR 2013) indicate that the deepest point in Lake Bellaire, 95 feet, is located roughly in the center of the lake. Clam Lake's greatest depth, 27 feet, is located near the western end of the lake. The nearshore shallow areas of both lakes support communities of emergent vegetation.

Bellaire and Clam Lakes are connected drainage lakes of glacial origin. The retreating glaciers (~11,600 years ago) that covered Northern Michigan during the last ice age scoured deep valleys and created deep depressions that would fill in with water to become the Chain of Lakes. Tall moraines of course-textured glacial till were left behind, forming the hills of the region. After the glaciers retreated, the water level in the area was about 80 feet higher than it is today, making the Chain of Lakes a long, winding fiord connected to at-the-time Lake Algonquin (Fuller 2001).

The largest inlet streams on Lake Bellaire include the Intermediate River, which drains the Upper ERCOL, and Grass Creek. Both major inlets enter the lake on the north side. Lake Bellaire's only outlet is the Grass River, on the southeast shore of the lake, which in turn is the major inlet for Clam Lake. Clam Lake's other notable inlet is Finch Creek. Both inlets to Clam Lake are located at the eastern end of the lake. Clam Lake's only outlet, the Clam River, is located on the west end and flows approximately 1000' into Torch Lake.

Based on watershed delineations created by TOMWC staff in a GIS (Geographical Information System), the Lake Bellaire and Clam Lake Watershed encompasses approximately 127,213 acres, which includes all upstream lakes and streams in ERCOL (Figure 1). Land cover statistics for the watershed were generated using remotely sensed data from the Coastal Great Lakes Land Cover project (NOAA 2007). Based on the 2006 data, there is scattered agricultural landcover within the watershed (~15.5%) and little urban (~3.0%). The majority of the watershed's landcover is natural, consisting of forest, grasslands, scrub/shrub, and wetlands (Table 1). During the five-year period between 2001 and 2006, agricultural landcover decreased while urban landcover increased. However, the change during this period for these landcover types was only 1-2%.

Table 1. Land-cover statistics from the Lake Bellaire and Clam Lake Watershed.

Land Cover Type	**Acres (2001)**	**Percent (2001)**	**Acres (2006)**	**Percent (2006)**	**Percent Change (2001-2006)**
Agriculture	29654	17.0	29637	15.5	-1.51
Barren	383	0.2	232	0.1	-0.10
Forested	78326	44.9	98033	51.3	6.34
Grassland	20299	11.6	13061	6.8	-4.81
Scrub/shrub	3220	1.9	3773	2.0	0.13
Urban	3313	1.9	5698	3.0	1.08
Water	24680	14.2	24618	12.9	-1.28
Wetland	14478	8.3	16165	8.5	0.15
TOTAL	174355	100.0	191217	100.0	NA

Invasive species and nutrient pollution can result in unnatural increases in the extent and/or density of macrophyte populations in lakes. Invasive zebra mussels (*Dreissena polymorpha*, present in both lakes) contribute to macrophyte growth in that they alter the lake ecosystem through their feeding habits and sheer numbers. The invasive mussels filter plankton from the water column, which allows sunlight to reach greater depths and therefore, expands habitat availability for macrophytes. Furthermore, nutrient availability for macrophytes increases as the zebra mussels excrete wastes on the lake bottom.

Nutrients are essential for an aquatic ecosystem, but excess can affect the lake ecosystem and potentially degrade water quality. Human development of the landscape and activity in nearshore areas invariably leads to unnaturally elevated nutrient inputs to lakes, which is termed nutrient pollution. The increased availability of nutrients resulting from nutrient pollution can accelerate aquatic plant growth.

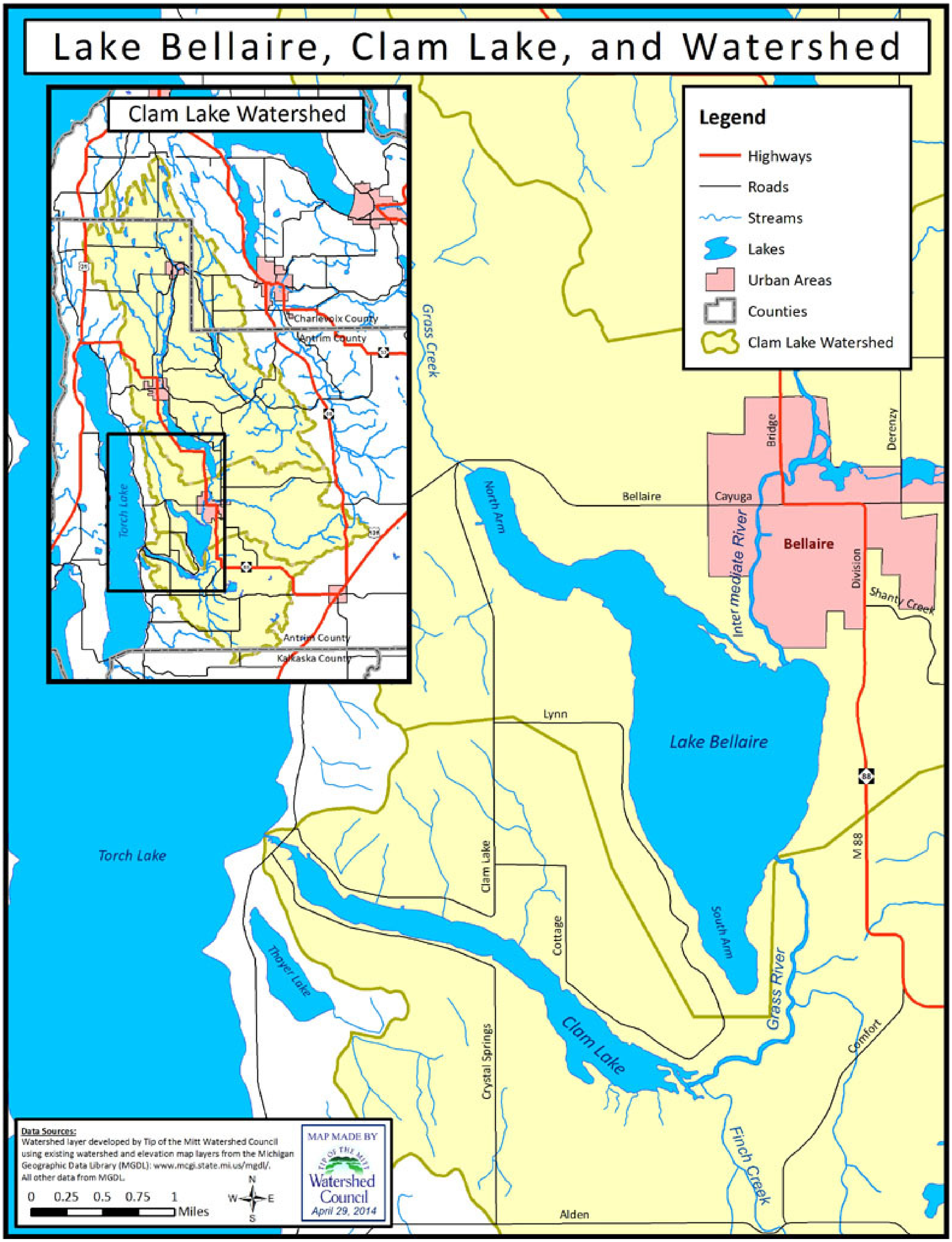

Figure 1. Map of Lake Bellaire, Clam Lake, and Watershed.

Volunteer water quality monitoring data from the TOMWC Volunteer Lake Monitoring (VLM) Program and Michigan Clean Water Corps' Cooperative Lakes Monitoring Program (CLMP) show some impacts from zebra mussels. Data show a trend of increasing water clarity over time (Figure 2), but no trends in terms of chlorophyll-a concentrations. Chlorophyll-a measurements provide an indication of algal biomass, which tends to decrease after zebra mussels become established in a lake (Figure 3).

Based on trophic status index data from the VLM and CLMP programs, both Bellaire and Clam Lakes border between mesotrophy and oligotrophy (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. Phosphorus data collected in the TOMWC Comprehensive Water Quality Monitoring program show a decrease in total phosphorus levels in Bellaire and Clam Lakes over the past two decades (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 lakes.

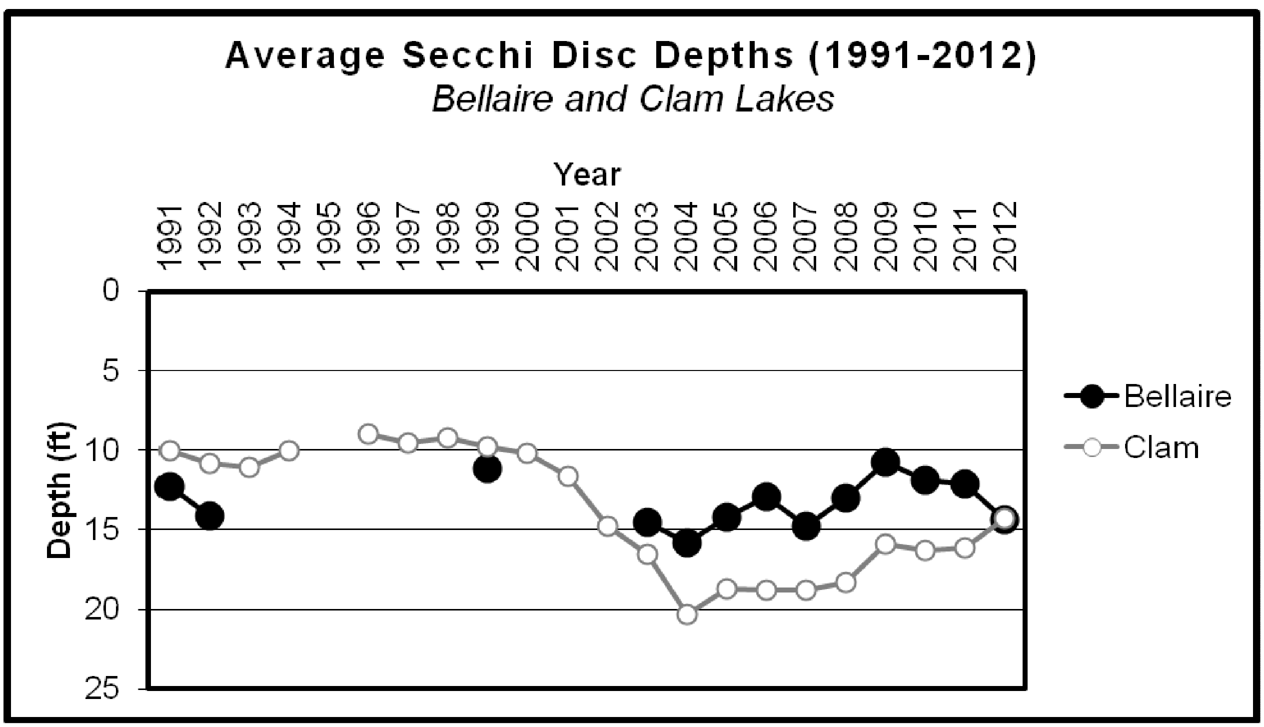

Figure 2. Water clarity trends for Bellaire and Clam Lakes

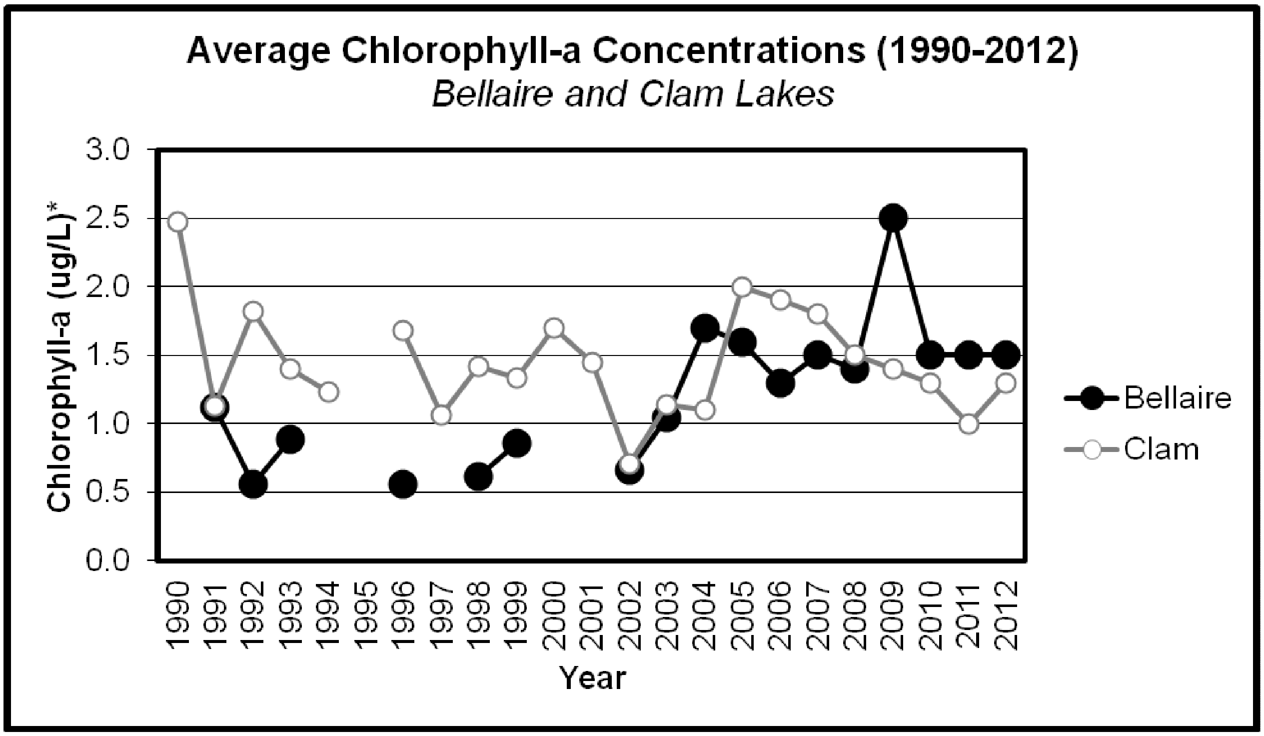

Figure 3. Chlorophyll-a data from Bellaire and Clam Lakes

**Chlorophyll-a is measured in ug/L, which is micrograms per liter or parts per billion.*

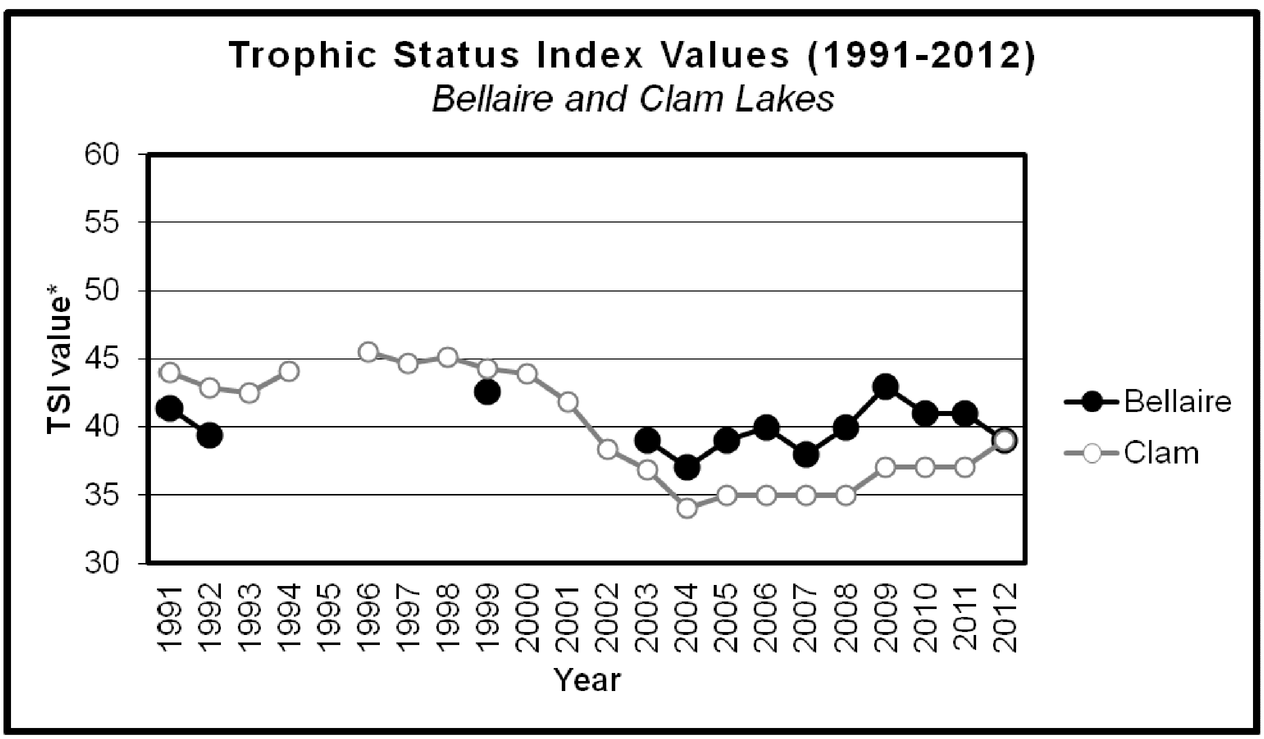

Figure 4. Trophic status trends for Bellaire and Clam Lakes.

**TSI values indicate the trophic status of lake: 0-38 = oligotrophic (low productive system), 39-49 = mesotrophic (moderately productive system), and 50+ = eutrophic (highly productive system).These TSI values were calculated from water transparency.*

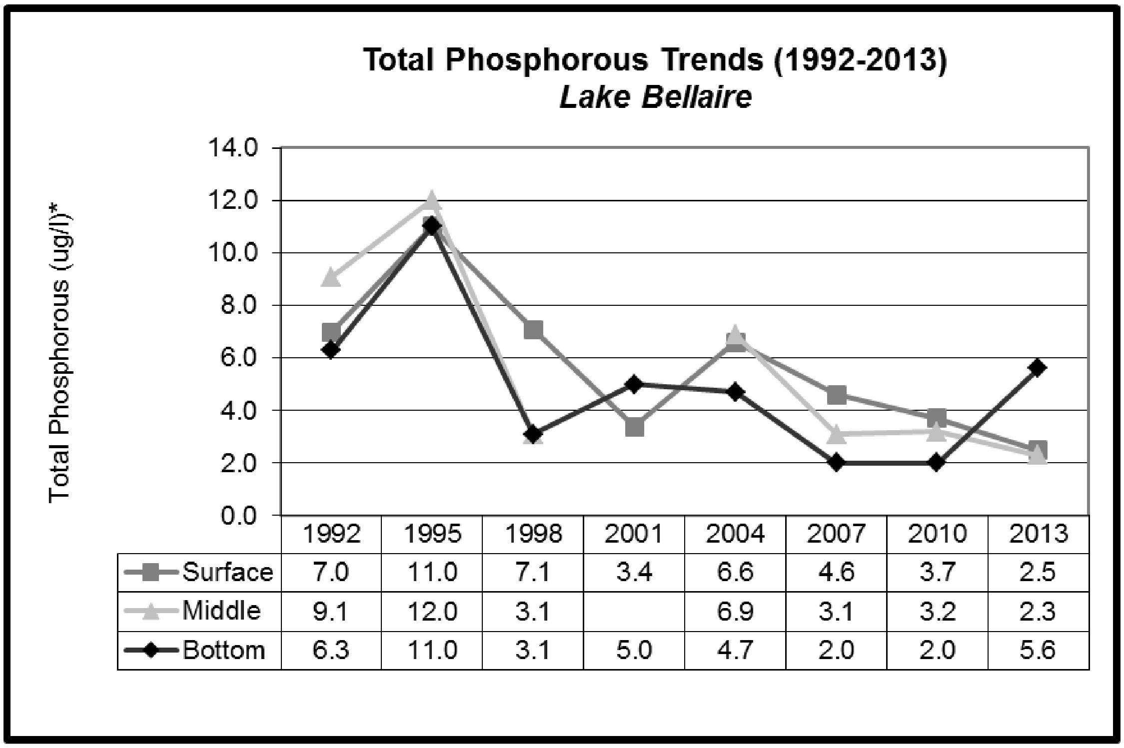

Figure 5. Total phosphorus trends from Bellaire and Clam Lakes.

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

Surveys by the Michigan Department of Natural Resources (MDNR) show that Clam and Bellaire Lakes support a mix of fish species typical for lakes of Northern Michigan. Fish species collected during a 2012 survey of Bellaire Lake include brown trout, emerald shiner, logperch, northern pike, smallmouth bass, rainbow smelt, walleye, and yellow perch (Hettinger 2012). Additional fish collected during a 2005 survey include black crappie, bluntnose minnows, brown bullhead, Iowa darter, lake whitefish, and sculpin.

METHODS

Field data for the Bellaire and Clam Lakes aquatic plant survey were collected in September and early October of 2013. Aquatic plants were documented in all lake areas. Similar to Michigan Department of Environmental Quality procedures, the aquatic plant communities of Clam and Bellaire Lakes 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.

Documenting aquatic plants at sample sites

Specimens were collected, identified, photographed and recorded in a notebook at 420 sample sites throughout the lakes to document aquatic plant taxa (241 sites on Lake Bellaire, 179 sites on Clam 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 sample lines that crossed the lake at regular intervals. In expansive, deep areas, sample lines began near the shoreline and continued straight out toward deeper waters until plants were no longer found. The distance between sample points along sample lines 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 sample line.

At each sample site, the boat was anchored, water depth noted, and GPS data recorded. Water depth was monitored using Hummingbird depth finders. The location of each sampling station was recorded using a Trimble GeoExplorer3 GPS unit with a reported accuracy of 1-3 meters or a Trimble Juno SB unit with ESRI ArcPad software.

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 all 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 plastic 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 Lake Bellaire, 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 digital GPS camera or Panasonic DMC-TS4 digital GPS camera.

Mapping aquatic plant communities

Plant communities can be delineated simply by interpolating or extrapolating between sample points, but the accuracy of such delineations can be 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, details observed about aquatic plant communities at or near the 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. Plant specimens were not collected while mapping community lines with GPS.

Emergent plant beds were mapped in Lake Bellaire only. Some emergent plant beds near the shoreline were mapped at an offset distance that was recorded in the GPS unit.

In spite of sampling at 420 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 was not post-processed, but transferred directly to a computer in ESRI shapefile format. Two GIS data layers were developed using the field GPS data collected from each unit; a point layer using the GPS data collected at sample sites and a polygon layer using a combination of information collected at sample site points and during plant community mapping. All GIS work was performed using ESRI GIS software: ArcMap 10.2 and ArcCatalog 10.2.

Digital photographs taken with the Ricoh G700SE GPS camera were processed and developed into a GIS data layer using GPS-Photo Link, Version 4.0. Photographs were rotated and light levels adjusted as necessary. The date, time, and location (latitude and longitude in the WGS84 datum) were included when processing the photographs and appear on the “tagged” digital photographic files. Using GPS-Photo Link, an ESRI shapefile was created to display locations of all photographs taken with the Ricoh camera. Photographs from the Panasonic camera were processed with the Geo Tagged Photos to Points tool in ESRI ArcGIS to create a shapefile displaying the locations of where photographs were taken in the field.

Data collected at sample sites and written in the field notebook were 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. Data recorded in the spreadsheet was saved as an .xlsx file and added as a table to a GIS. The table was joined to the sample site GIS point data layer, and then exported to a new GIS point data layer containing all attribute information collected in the field for 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 for sample sites also provided information about plant communities. After developing polygons, area statistics for specific plant communities and associated densities were calculated.

The final products include field data in a tabular format, photographs of plant specimens collected at each site, GIS data layers, descriptive statistics generated from tabular and GIS data, and presentation-quality maps. The maps depict sample site locations, plant community densities at sample sites, dominant plant communities, and plant community densities.

RESULTS

Sample site results

A total of 27 aquatic macrophyte taxa were documented during the survey conducted on Lake Bellaire, which includes three emergent taxa noted in comments or mapped with GPS, but not listed in the databases: Phragmites (*Phragmites australis*), bur-reed (*Sparganium spp.*), and lake iris (*Iris spp.*). On Clam Lake, 28 macrophyte taxa were documented. The number of aquatic plant taxa encountered at a site on both lakes ranged from zero to 10 with an average of 2.9 taxa per sample site on Lake Bellaire and 4.1 taxa per site on Clam Lake.

Slender naiad (*Najas flexilis*), muskgrass (*Chara spp.*), and eel-grass (*Valisneria americana*) were the most commonly encountered species on Lake Bellaire; collected at approximately 68%, 65%, and 46% of sites respectively (Table 2). Variable-leaf watermilfoil (*Myriophyllum*

Table 2. Aquatic plant taxa occurrence at sample sites on Lake Bellaire.

Genus and species	Common Name	Number of sites	Percent of sites
Najas flexilis	Slender naiad	164	68.05
Chara spp.	Muskgrass	157	65.15
Vallisneria americana	Eel-grass	110	45.64
Potamogeton gramineus	Variable-leaf pondweed	67	27.80
Myriophyllum heterophyllum	Variable-leaf watermilfoil	65	26.97
Potamogeton amplifolius	Broad-leaved pondweed	21	8.71
Potamogeton zosteriformis	Flat-stem pondweed	18	7.47
Potamogeton praelongus	Whitestem pondweed	16	6.64
Stuckenia pectinata	Sago pondweed	16	6.64
Heteranthera dubia	Water stargrass	8	3.32
Elodea canadensis	Elodea	7	2.90
Schoenoplectus spp.	Bullrush	6	2.49
Potamogeton natans	Floating-leaf pondweed	5	2.07
Nuphar variegata	Yellow pond-lily	4	1.66
Nymphaea odorata	White pond-lily	4	1.66
Potamogeton richardsonii	Richardsons' pondweed	4	1.66
Potamogeton strictifolius	Narrow-leaf pondweed	3	1.24
Carex spp.	Sedge	2	0.83
Myrica gale	Sweet gale	2	0.83
Sagittaria spp.	Arum	2	0.83
Typha latifolia	Cattail	2	0.83
Megalodonta beckii	Water marigold	1	0.41
Myriophyllum sibiricum	Common watermilfoil	1	0.41
Potentilla	Cinqufoil	1	0.41
Ranunculus spp.	Water crow-foot	1	0.41

heterophyllum), muskgrass, and eelgrass were the most commonly encountered species on Clam Lake; collected at approximately 60%, 56%, and 54% of sites respectively (Table 3).

Table 3. Aquatic plant taxa occurrence at sample sites on Clam Lake.

Genus and species	**Common Name**	**Number of sites**	**Percent of sites**
Myriophyllum heterophyllum	Variable-leaf watermilfoil	107	59.78
Chara spp.	Muskgrass	101	56.42
Vallisneria americana	Eel-grass	97	54.19
Najas flexilis	Slender naiad	93	51.96
Schoenoplectus subterminalis	Swaying bullrush	58	32.40
Potamogeton amplifolius	Broad-leaved pondweed	53	29.61
Potamogeton zosteriformis	Flat-stem pondweed	50	27.93
Utricularia vulgaris	Bladderwort	44	24.58
Potamogeton gramineus	Variable-leaf pondweed	42	23.46
Elodea canadensis	Elodea	22	12.29
Ceratophyllum demersum	Coontail	13	7.26
Stuckenia pectinata	Sago pondweed	10	5.59
Heteranthera dubia	Water stargrass	8	4.47
Myriophyllum sibiricum	Common watermilfoil	8	4.47
Stuckenia filiformis	Thread-leaf pondweed	6	3.35
Bidens (Megalodonta) beckii	Water marigold	3	1.68
Potamogeton richardsonii	Richardsons' pondweed	3	1.68
Potamogeton strictifolius	Narrow-leaf pondweed	3	1.68
Potamogeton natans	Floating-leaf pondweed	2	1.12
Potamogeton praelongus	Whitestem pondweed	2	1.12
Myriophyllum spicatum	Eurasian watermilfoil	1	0.56
Ranunculus spp.	Water crow-foot	1	0.56
Sagittaria spp.	Arum	1	0.56
Sparganium spp.	Bur-reed	1	0.56

In general, the plants most commonly collected were also those that dominated or co-dominated plant communities at the greatest number of sample sites (Tables 4 and 5). The exception was swaying bulrush (*Schoenoplectus subterminalis*), which dominated communities at 24% of sites on Clam Lake. Typical for lakes in this region, the pondweed family (*Potamogetonaceae)* was the most speciose (i.e., had the greatest number of species), with a total of 12 pondweed species were documented in Bellaire and Clam Lakes during this survey. Only one invasive plant species was encountered during this survey and at only one site on Clam Lake: Eurasian watermilfoil.

Table 4. Aquatic plant dominance at sample sites on Lake Bellaire.

Aquatic Plant Species	Common Name	Number of Sites*	Percent of sites*
Najas flexilis	Slender naiad	116	48.13
Chara spp.	Muskgrass	99	41.08
Vallisneria americana	Eel-grass	75	31.12
Potamogeton gramineus	Variable-leaf pondweed	25	10.37
Myriophyllum heterophyllum	Variable-leaf watermilfoil	17	7.05
Stuckenia pectinata	Sago pondweed	6	2.49
Nymphaea odorata	White water lily	4	1.66
Potamogeton zosteriformis	Flat-stem pondweed	4	1.66
Schoenoplectus spp.	Bullrush	4	1.66
Potamogeton amplifolius	Broad-leaved pondweed	3	1.24
Potamogeton natans	Floating-leaf pondweed	3	1.24
Carex spp.	Sedge	2	0.83
Heteranthera dubia	Water stargrass	2	0.83
Elodea spp.	Elodea	1	0.41
Myrica gale	Sweet gale	1	0.41
Nuphar variegata	Yellow pond lily	1	0.41
Potamogeton praelongus	White-stem pondweed	1	0.41
Potamogeton strictifolius	Narrow-leaf pondweed	1	0.41
Typha latifolia	Cattail	1	0.41

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

Table 5. Aquatic plant dominance at sample sites on Clam Lake.

Aquatic Plant Species	Common Name	Number of Sites*	Percent of sites*
Myriophyllum heterophyllum	Variable-leaf watermilfoil	56	31.3
Chara spp.	Muskgrass	49	27.4
Schoenoplectus subterminalis	Swaying bullrush	42	23.5
Vallisneria americana	Eel-grass	24	13.4
Najas flexilis	Slender naiad	21	11.7
Potamogeton zosteriformis	Flat-stem pondweed	8	4.5
Elodea canadensis	Elodea	7	3.9
Ceratophyllum demersum	Coontail	6	3.4
Potamogeton amplifolius	Broad-leaved pondweed	3	1.7
Potamogeton gramineus	Variable-leaf pondweed	2	1.1
Heteranthera dubia	Water stargrass	1	0.6
Myriophyllum sibiricum	Common watermilfoil	1	0.6
Potamogeton richardsonii	Richardsons' pondweed	1	0.6
Sparganium spp.	Bur-reed	1	0.6
Stuckenia pectinata	Sago pondweed	1	0.6

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

The distribution in overall growth densities of aquatic macrophytes at sample sites on Lake Bellaire leaned toward light-density growth. The overall plant density at over 80% of sites on

Lake Bellaire was in the light or moderate categories. Conversely heavy-density growth was common at sample sites on Clam Lake (Table 6). Approximately 88% of sample sites on Clam Lake had community growth densities that fell into the moderate to heavy categories.

Table 6. The overall growth density of aquatic macrophytes at sample sites.

Density Category	Number of Sites* (Lake Bellaire)	Percent of Sites* (Lake Bellaire)	Number of Sites* (Clam Lake)	Percent of Sites* (Clam Lake)
Very Light	30	13.95	6	3.41
Light	50	23.26	9	5.11
Light to Moderate	33	15.35	6	3.41
Moderate	60	27.91	40	22.73
Moderate to Heavy	24	11.16	39	22.16
Heavy	17	7.91	76	43.18
Very Heavy	1	0.47	0	0.00
TOTAL	215	100.00	176	100.00

**Only for sites where macrophytes were found.*

Plant community mapping results

Aquatic plant community mapping revealed that 1489 of the 1810 acres (~82%) of Lake Bellaire contained little or no aquatic vegetation (Figure 6). Conversely, only 31% of Clam Lake did not have vegetation (Figure 7). In Lake Bellaire, 69% of the vegetated lake area was classified as submergent vegetation (e.g., muskgrass, naiad, watermilfoil etc.) while 31% was emergent vegetation (e.g., bulrush, cattails, pond-lilies, etc.). Emergent plants were not mapped in Clam Lake.

In Lake Bellaire, bulrush-dominated plant communities were the most extensive, covering 28% of the vegetated lake area, followed by mixed muskgrass and naiad at 21% (Table 7). A mix of muskgrass and naiad as co-dominants accounted for 22% of the vegetated area of Lake Bellaire, followed by solely naiad-dominated communities at 14%. Over 30% of the vegetated area of Clam Lake was dominated by multiple species (i.e., a mix of four or more co-dominant species) and nearly 20% was dominated by a mix of muskgrass, naiad, and pondweed (Table 8).

Reflecting data from sample sites, aquatic plant community mapping showed that Lake Bellaire predominantly contained light to moderate-density plant growth whereas the majority of Clam Lake had moderate to heavy-density growth. Approximately 77% of vegetated areas in Lake

Bellaire had densities in the light, light-moderate, or moderate categories (Table 9). Conversely, over 85% of plant communities in Clam Lake had densities in the moderate, moderate-heavy, or heavy categories (Table 9). In Lake Bellaire, clusters of heavy-density macrophyte growth were found in the north tip of the northwest arm and along the north and northeast shore of the main basin (Figure 8). Heavy-density macrophyte growth was found to be pervasive in Clam Lake, occurring throughout much of the vegetated lake area (Figure 9).

Table 7. Dominant aquatic plant community types in Lake Bellaire.

Dominant Community	**Area (acres)**	**Percent***
Bulrush	88.804	27.621
Muskgrass and Naiad	69.656	21.665
Naiad	46.034	14.318
Eelgrass	32.138	9.996
Muskgrass, Naiad, and Pondweed	17.620	5.480
Muskgrass	14.533	4.520
Muskgrass, Naiad, and Eelgrass	8.866	2.758
Eelgrass and Watermilfoil	8.091	2.517
Pond-lily	7.620	2.370
Pondweed	7.098	2.208
Naiad and Watermilfoil	4.001	1.244
Muskgrass and Eelgrass	3.272	1.018
Eelgrass and Pondweed	2.978	0.926
Naiad and Pondweed	1.432	0.445
Eelgrass, Pondweed, and Watermilfoil	1.413	0.439
Naiad and Eelgrass	1.389	0.432
Floating-leaf Pondweed	1.156	0.360
Muskgrass and Pondweed	1.049	0.326
Lake Iris	0.989	0.308
Multiple Species	0.846	0.263
Phragmites	0.588	0.183
Muskgrass and Pond-lily	0.481	0.150
Elodea and Pondweed	0.403	0.125
Cattail	0.311	0.097
Bur-reed	0.184	0.057
Water stargrass	0.141	0.044
Sedges	0.131	0.041
Lake Iris and Pond-lily	0.105	0.033
Pondweed and Pond-lily	0.099	0.031
Eelgrass, Naiad, and Pondweed	0.078	0.024
Arrowhead	0.004	0.001
TOTAL	321.51	100.000

**Percent of the vegetated lake area (i.e., 322 acres).*

Table 8. Aquatic plant community types in Clam Lake.

Dominant Community	Area (acres)	Percent*
Multiple Species	137.41	45.15
Muskgrass, Naiad, and Pondweed	83.11	27.31
Swaying Bulrush	20.08	6.60
Watermilfoil and Emergent Bulrush	16.87	5.54
Swaying Bulrush and Naiad	15.20	4.99
Bladderwort, Eelgrass, and Watermilfoil	8.10	2.66
Muskgrass and Watermilfoil	8.06	2.65
Watermilfoil	6.04	1.98
Muskgrass	5.77	1.90
Elodea and Pondweed	1.43	0.47
Eelgrass, Muskgrass, and Water Stargrass	1.03	0.34
Pondweed	0.67	0.22
Muskgrass and Eelgrass	0.58	0.19
TOTAL	304.35	100.00

**Percent of the vegetated lake area (i.e., 304 acres).*

Table 9. Aquatic plant community density statistics for Lake Bellaire and Clam.

Density Category	Acreage (Lake Bellaire)	Percent (Lake Bellaire)	Acreage (Clam Lake)	Percent (Clam Lake)
Very Light	23.81	7.41	14.09	4.63
Light	103.65	32.25	29.56	9.71
Light to Moderate	37.93	11.80	0.17	0.05
Moderate	83.31	25.92	57.68	18.95
Moderate to Heavy	37.07	11.53	41.81	13.74
Heavy	33.70	10.48	161.04	52.91
Very Heavy	1.97	0.61	0.00	0.00
TOTAL	321.43	100.00	304.35	100.00

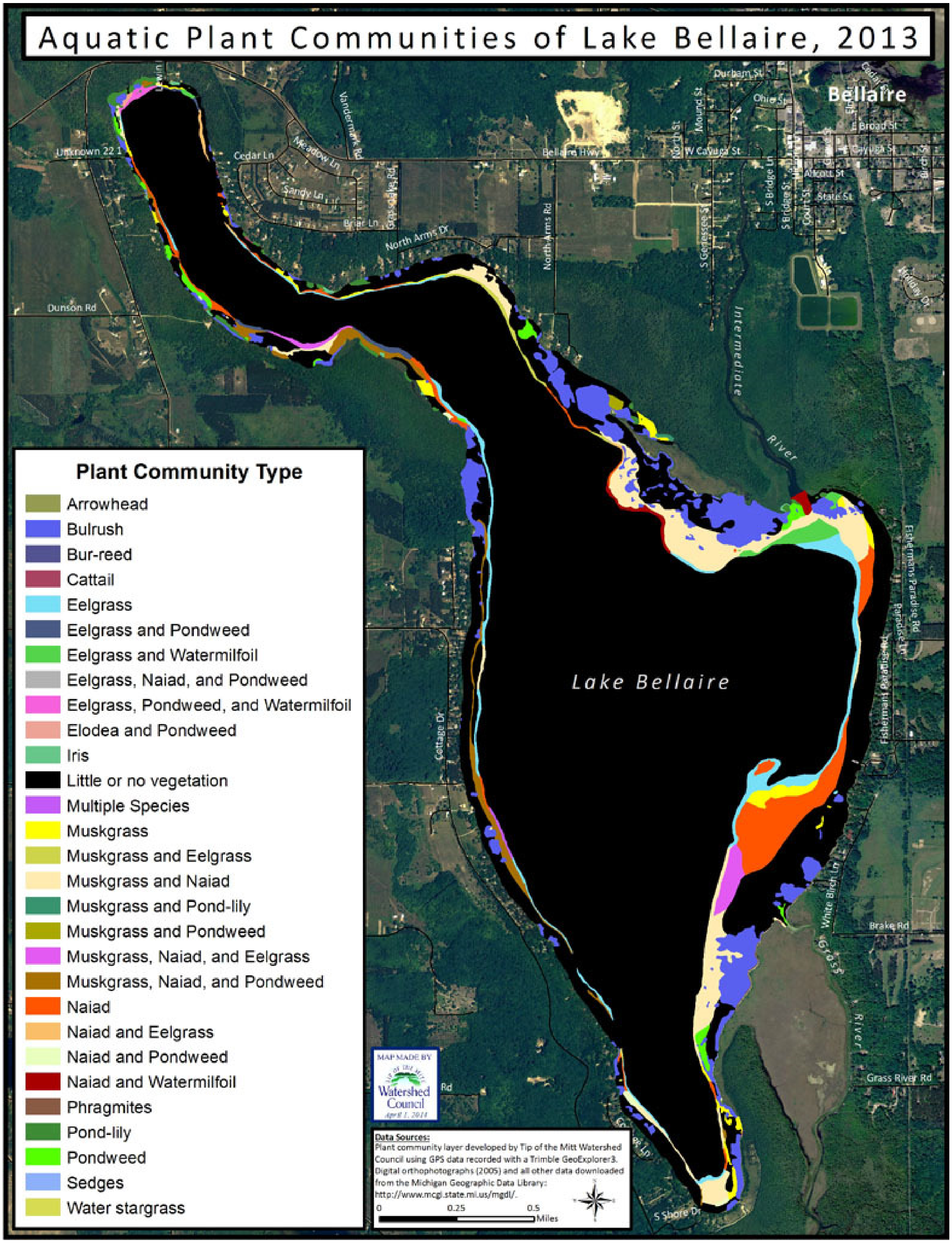

Figure 6. Aquatic plant community types in Lake Bellaire.

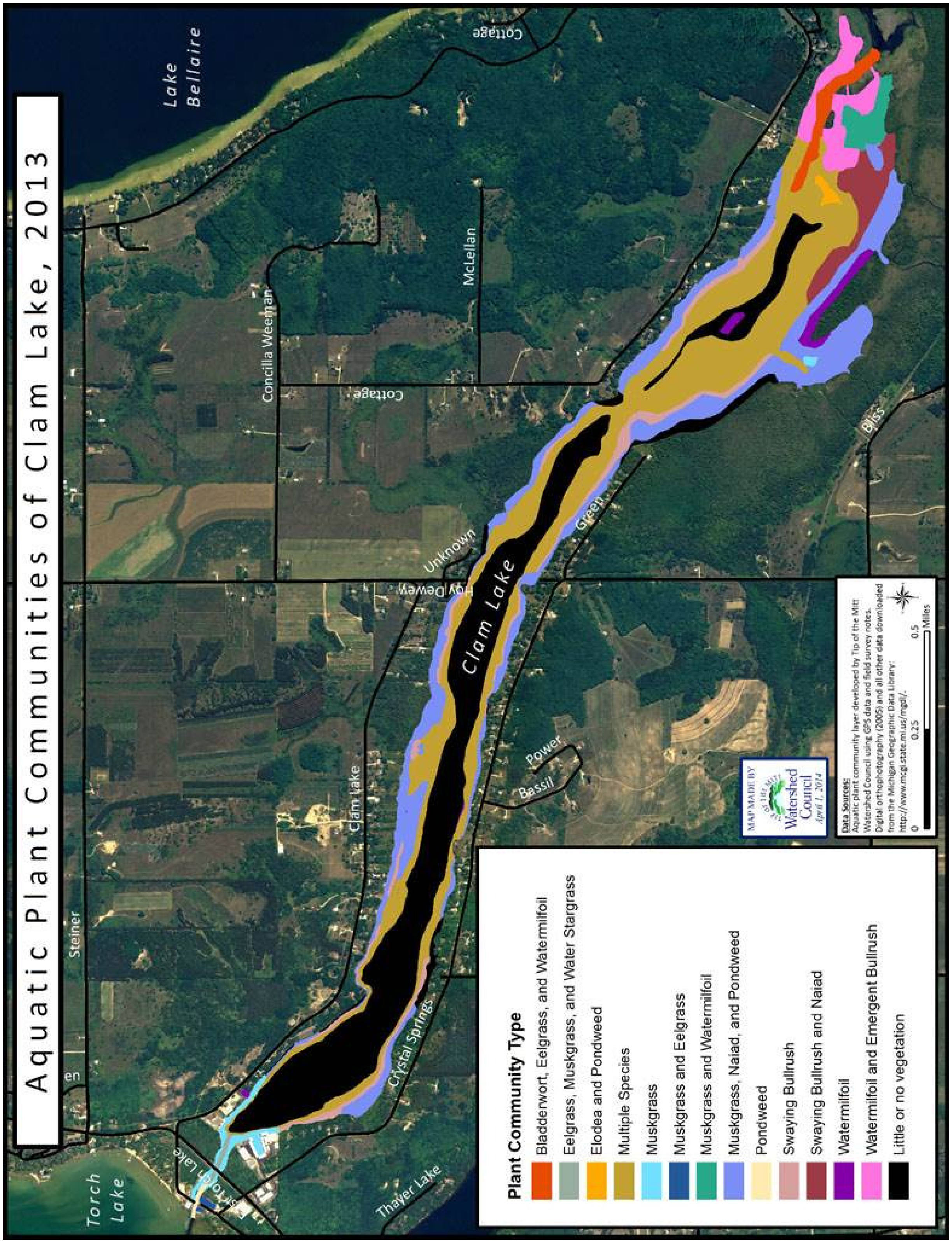

Figure 7. Aquatic plant community types in Clam Lake.

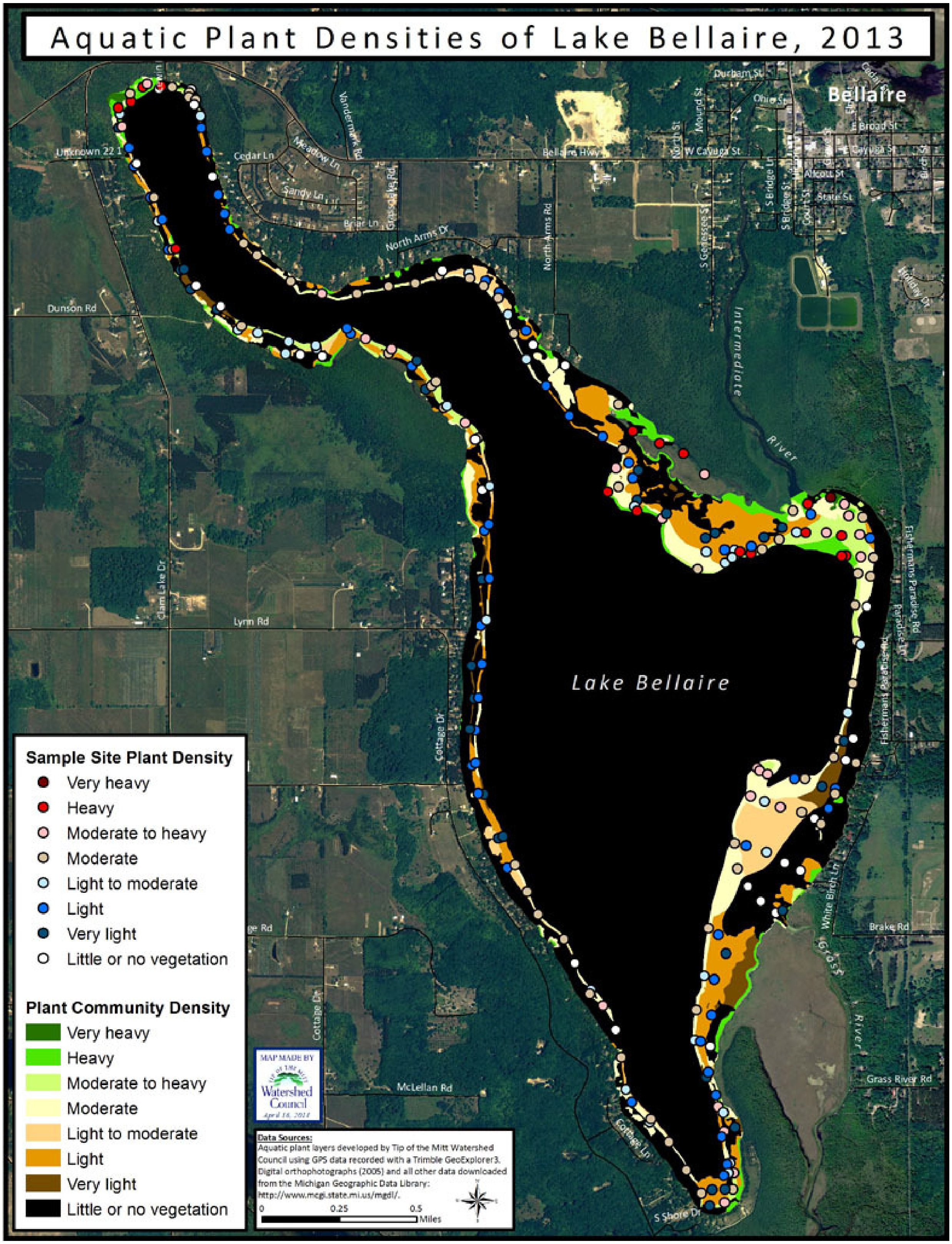

Figure 8. Aquatic macrophyte densities in Lake Bellaire.

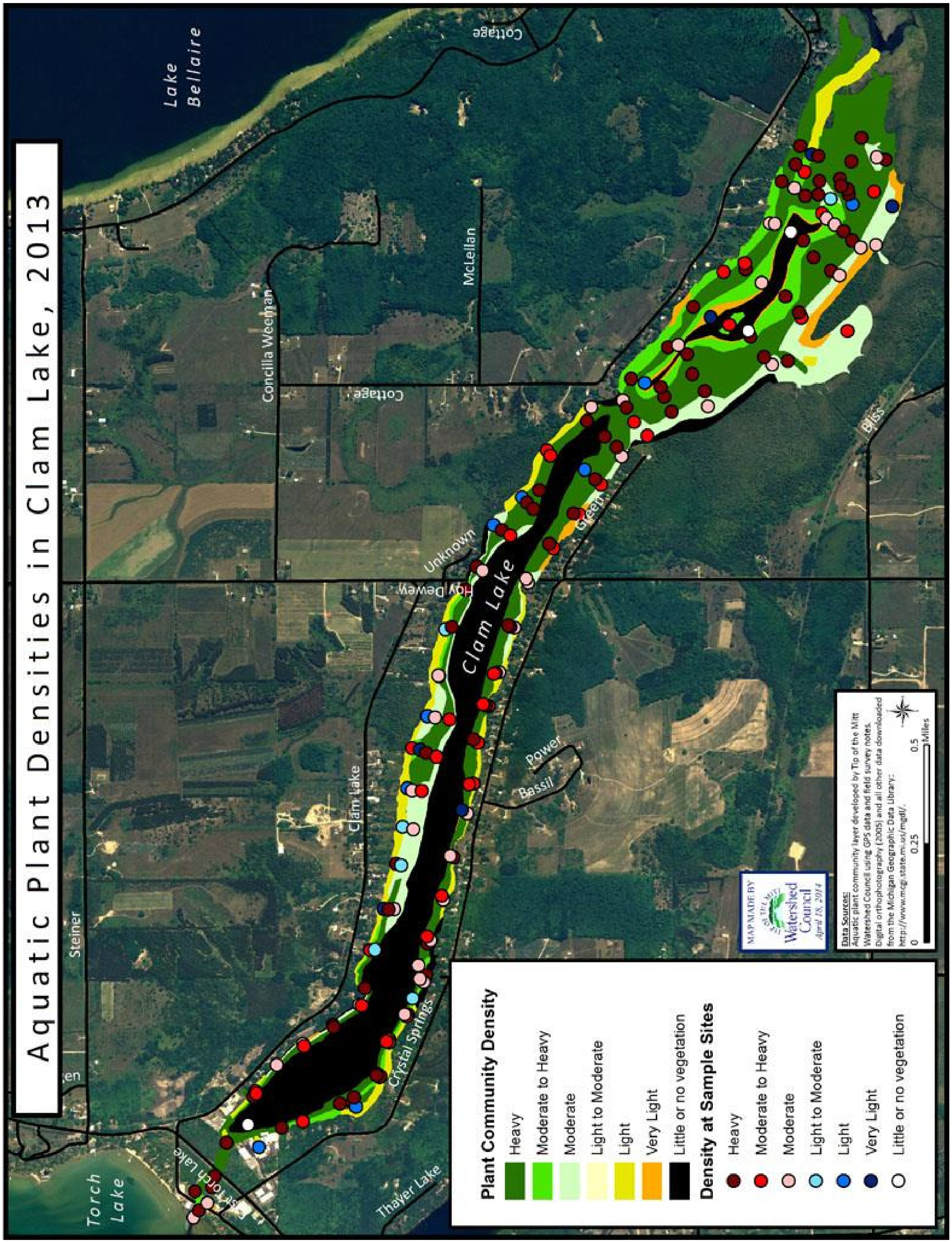

Figure 9. Aquatic macrophyte densities in Clam Lake.

DISCUSSION

Survey results showed that Lake Bellaire contained relatively little and light macrophyte growth compared to the extensive and heavy-density growth found in Clam Lake. Compared with other lakes surveyed by the Watershed Council, heavy-density plant growth at sample sites in Lake Bellaire was far below the average, while well above the average in Clam Lake (Table 10). This contrast in the macrophyte communities is attributed to the morphological characteristics of the two lakes; Lake Bellaire has extensive deep areas that do not support macrophyte growth whereas the majority of Clam Lake is less than 20 feet deep and therefore, conducive to aquatic plant growth.

Inlet rivers and creeks provide an explanation for the areas of heavy-density plant growth found in Lake Bellaire. In Northern Michigan, rivers and creeks typically contain higher nutrient concentrations than lakes, which results in heavy-density plant growth in lake areas near stream inlets. The heavy-density plant growth areas found on the north end of Lake Bellaire were likely influenced by the proximate Intermediate River and Grass Creek inlets. Although nutrient inputs from inlet streams such as the Grass River and Finch Creek likely influence plant growth in Clam Lake, the heavy-density growth found throughout the lake was attributed principally to extensive shallow areas. However, unnaturally elevated nutrient inputs from residential shoreline development could also be contributing to heavy-density plant growth in both lakes.

In spite of differences in vegetated lake area and plant community densities, macrophyte species diversity was approximately the same in the two lakes. A total of 27 aquatic plant taxa were documented in Lake Bellaire and 28 taxa in Clam Lake, which were just under the average for aquatic plant diversity found in all lakes surveyed by the Watershed Council (Table 10). The averaged diversity across all sample sites in Clam Lake was just over the average and that of Lake Bellaire below the average.

Table 10. Aquatic plant survey statistics from area lakes.

Lake name*	Acreage	Maximum depth (ft)	Lake area with vegetation	Sites with dense vegetation[†]	Number of total taxa	Number of taxa per site
Adams	43	18	99%	66%	27	4.9
Bellaire	1810	95	18%	8%	27	2.9
Black	10,133	50	13%	25%	32	3.7
Clam	446	27	69%	43%	28	4.1
Crooked/Pickerel	3,447	70	46%	11%	31	2.4
Long	398	61	29%	11%	30	3.9
Douglas	3,780	80	47%	15%	30	5.3
Millecoquin	1,116	12	95%	61%	20	6.0
Mullett	17,205	144	19%	13%	42	3.1
Paradise	1,947	17	58%	28%	24	5.0
Walloon	4,620	100	22%	3%	32	1.8
Wycamp	689	7	83%	24%	35	4.9
AVERAGE	NA	NA	50%	26%	30	4.0

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

Eurasian watermilfoil was only found in one site on the Clam River. It appears that the TLA's control efforts have been successful in preventing the spread of this invasive species to other parts of Clam Lake, the Grass River, and Lake Bellaire.

Due to a lack of historical data, being that this was the first comprehensive aquatic plant survey to be performed on Lake Bellaire and Clam Lake, it was not possible to examine trends or changes in the aquatic plant communities. Factors that typically cause changes in plant growth include aquatic plant management efforts, increased nutrient availability, and ecosystem changes caused by non-native species. Nutrient inputs from cultural (human) sources, such as fertilizers, septic leachate, and stormwater may have increased over time, though data from Tip of the Mitt Watershed Council monitoring programs do not show increases in nutrient concentrations in open water. Zebra mussels, which are present in both lakes, might be causing changes that have resulted in increased aquatic plant growth. Increased water clarity evident in the data from Clam Lake is probably a result of zebra mussels feeding on phytoplankton (i.e., algae), which would increase both nutrient and habitat availability for higher aquatic plants.

Recommendations

1. Share the results of this survey. Widely disperse the results of this study to get a maximum return on the investment. Sharing the results with lake association members, non-member lake users, government officials, and others will inform the public about problems occurring in the lake and progress of the efforts at aquatic plant and lake management. An informed public will be more supportive of any 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. Development an aquatic plant management plan enhances 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 develop such a plan, including *Management of Aquatic Plants* by Michigan DEQ (MDEQ 2012), *Aquatic Plant Management in Wisconsin* by University of Wisconsin Extension (Korth 2007), and *A Citizen's Manual for Developing Integrated Aquatic Vegetation Management Plans* by the Washington State Department of Ecology (Gibbons 1994).

3. Investigate potential nutrient pollution issues. Nutrient pollution can lead to excessive plant growth and should be controlled wherever and whenever possible. A shoreline survey provides 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. The last record in TOMWC records of a shoreline survey conducted on Bellaire and Clam Lakes with nutrient pollution as a focus occurred in 1998. Therefore, it is recommended that another shoreline survey be conducted to document current conditions and address any problem areas. In the meantime, positive steps toward controlling nutrient pollution can be made 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 (with rain gardens, grassy swales, retention ponds, or other methods for treating the stormwater).

4. Continue monitoring for aquatic invasive species and implementing control measures. Eurasian watermilfoil was only found in one site on the Clam River. It appears that TLA's control efforts have been successful in preventing the spread of this invasive species to other parts of Clam Lake, the Grass River, and Lake Bellaire. Visit locations of known infestations frequently to assess control efforts and perform follow-up treatment when needed. Additionally, regularly survey other lake areas for the presence of Eurasian watermilfoil and other aquatic invasive species, and implement control measures as necessary to prevent the spread of these invasive species.

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 an invasive species has been found, most of the vegetated lake area contains a vibrant, healthy aquatic plant population. With regards to plant management and control options, lake associations should strive to protect the diverse assemblage of plants present in the lakes, which are critical for sustaining a healthy fishery and maintaining a healthy aquatic ecosystem.

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 Bellaire and Clam Lakes. To effectively manage the aquatic plant community of Bellaire and Clam Lakes, periodically sponsor or conducte aquatic plant surveys. 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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