Survey Conducted July-September 2016

Burt Lake Aquatic Plant Survey

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SUMMARY

Aquatic plants provide many benefits to aquatic ecosystems, but can become a recreational nuisance when growth is excessive. Heavy aquatic plant growth can occur naturally given the correct combination of environmental variables (e.g., light and nutrient availability), but is accelerated due to factors such as nutrient pollution or the introduction of non-native species. Burt Lake, a 17,436-acre lake in the Northern Lower Peninsula of Michigan, has played host to one particular invasive species – Eurasian watermilfoil (*Myriophyllum spicatum)* – for the better part of two decades. To better understand the current status of the infestation, and to gauge other plant growth across the lake, the Burt Lake Preservation Association (the Association) sponsored a comprehensive aquatic vegetation survey, conducted in 2016 by Tip of the Mitt Watershed Council (Watershed Council).

The survey was carried out in the summer and early fall of 2016. Watershed Council staff collected plant specimens, recorded abundance, and noted densities at 537 sites throughout Burt Lake. In addition, aquatic plant communities were delineated through interpolation or extrapolation of sample site data or directly in the field using GPS units.

The 2016 survey documented 38 different aquatic plant taxa. An average of 1.4 taxa per site were collected, with a maximum of 9 taxa were found at a site. Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), variable-leaf watermilfoil (*Myriophyllum heterophyllum*), and eelgrass (*Valisneria americana*) were the most commonly collected species. The submergent invasive plant, Eurasian watermilfoil, was documented at 20 sample sites during the survey.

Little to no vegetation was found in 87% of Burt Lake in 2016. Muskgrass was the dominant growth form in nearly 37% of the vegetated lake area, primarily spread throughout mid-depth ranges across the northern two thirds of the Lake. Variable-leaf watermilfoil was the second-most dominant, found in 21% of vegetated lake area, primarily in Bullhead and Maple Bays. Diverse, mixed submergent communities that generally included pondweed were found in the narrow ring of vegetation at the drop-off zone. Approximately 79% of the vegetated area contained light density plant growth, while only 4% had heavy-density growth. Most of this dense aquatic growth was found in Bullhead and Maple Bays, near the mouths of the Crooked and Maple Rivers.

The extensive and dense vegetation in the western bays of Burt Lake is attributed to shallow depths and nutrient inputs from inlet tributaries. Invasive zebra mussels and nutrient pollution from shoreline properties may also contribute to aquatic plant growth throughout Burt Lake.

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

The Association should share results from this survey to maximize benefits and assist in lake management efforts. Information and education efforts should be undertaken to promote an understanding of aquatic plant communities and the lake ecosystem among riparian property owners and other lake users, as well as encourage behaviors and practices that protect and improve lake water quality. Future surveys are recommended to collect the necessary data for determining trends over time, evaluating successes or failures of aquatic plant management projects, and documenting the locations and spread of non-native aquatic plant species.

INTRODUCTION

Background

Aquatic plant communities provide numerous benefits to lake ecosystems. Aquatic plants provide habitat, refuge, and act as a food source for a large variety of waterfowl, fish, aquatic insects, and other aquatic organisms (Valley et. al. 2004, Dibble et. al. 1996, Engel 1985). Like their terrestrial counterparts, aquatic plants provide primary production to the ecosystem and oxygen via photosynthesis. Aquatic plants utilize nutrients in the water and sediments that could otherwise be used by algae and potentially result in nuisance blooms. A number of aquatic plants, including bulrush, water lily, cattails, and pickerelweed help prevent shoreline erosion by absorbing wave energy and moderating currents (Madsen and Warncke 1983). In addition, soft sediments along the lake bottom are held in place by rooted aquatic plants (Engel 1985).

In spite of all the benefits associated with aquatic plants, some aquatic ecosystems suffer from overabundance, particularly where non-native nuisance species have been introduced. Excessive plant growth can create a recreational nuisance by making it difficult or undesirable to boat, fish, and swim. It also has the potential to cause aquatic ecosystem disruptions. In lakes plagued by nuisance plant growth, it sometimes becomes necessary to develop and implement programs to control excessive growth and non-native species.

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

Aquatic plant management is a critical component of lake management. In turn, aquatic vegetation surveys are necessary to effectively manage a lake's aquatic plant communities. Past vegetation surveys on Burt Lake include a 2003 survey of Poverty Bay, Maple Bay, and the mouth of the Crooked River conducted by the Watershed Council, as well as a 2011 survey of the Plymouth Beach Canal conducted by the University of Michigan Biological Station. Stocking of aquatic weevils (*Euhrychiopsis lecontei*) occurred in 2004 to control Eurasian watermilfoil discovered near King Road, which involved various localized vegetation surveys by the Watershed Council and the consulting company EnviroScience, Inc.

In 2016, the Association contracted with the Watershed Council to perform a comprehensive aquatic plant survey of Burt Lake. Survey field methods, data management procedures, project results, and discussion of results for the 2016 survey are contained in this report.

Study Area

Burt Lake is located in the northern tip of the Lower Peninsula of Michigan; in Burt and Tuscarora Townships of east-central Cheboygan County. Based on digitization of aerial orthophotography provided by Cheboygan County Equalization (2012), the shoreline of Burt Lake measures 35.07 miles and lake surface area totals 17,436 acres. Burt Lake is approximately 9.5 miles long and nearly 5 miles across at its widest point. A prominent lobe called Colonial Point extends out from the west shore toward the middle of the lake, to the south of which lie Maple, Bullhead, and Poverty Bays. In the northeast corner, Greenman Point extends southward, sheltering White Goose Bay to the east.

Bathymetry maps from the State of Michigan show the deepest area located directly out from Colonial Point with a maximum depth of 73 feet (Figure 1). Tip of the Mitt Watershed Council water quality monitoring data have confirmed this maximum depth. According to digitized bathymetry maps acquired from the Michigan Geographic Data Library, approximately 64% of the lake exceeds 20 feet of depth. Broad shallow plateaus are found on the west central side between Maple and Poverty Bays as well as in the north end of the lake.

Burt Lake is a drainage lake with water flowing into and out of the lake. The primary inlets include the Maple and Crooked Rivers to the west, the Sturgeon River in the southeast corner and Carp Creek in the north end. The only outlet is the Indian River in the southeast corner. Extensive wetland areas are located adjacent to the lake between Maple and Poverty Bays on the west-central shoreline and at the northern end of the lake.

Based on a watershed boundary map layer developed by Tip of the Mitt Watershed Council using GIS (Geographical Information System) data from the Michigan Geographical Data Library, the Burt Lake watershed encompasses approximately 371,173 acres of land and water. The watershed stretches from the City of Gaylord in the south to the Village of Levering to the north and contains a number of other regionally important water bodies including Crooked, Douglas, Larks, Munro, Pickerel, and Round Lakes (Figure 2).

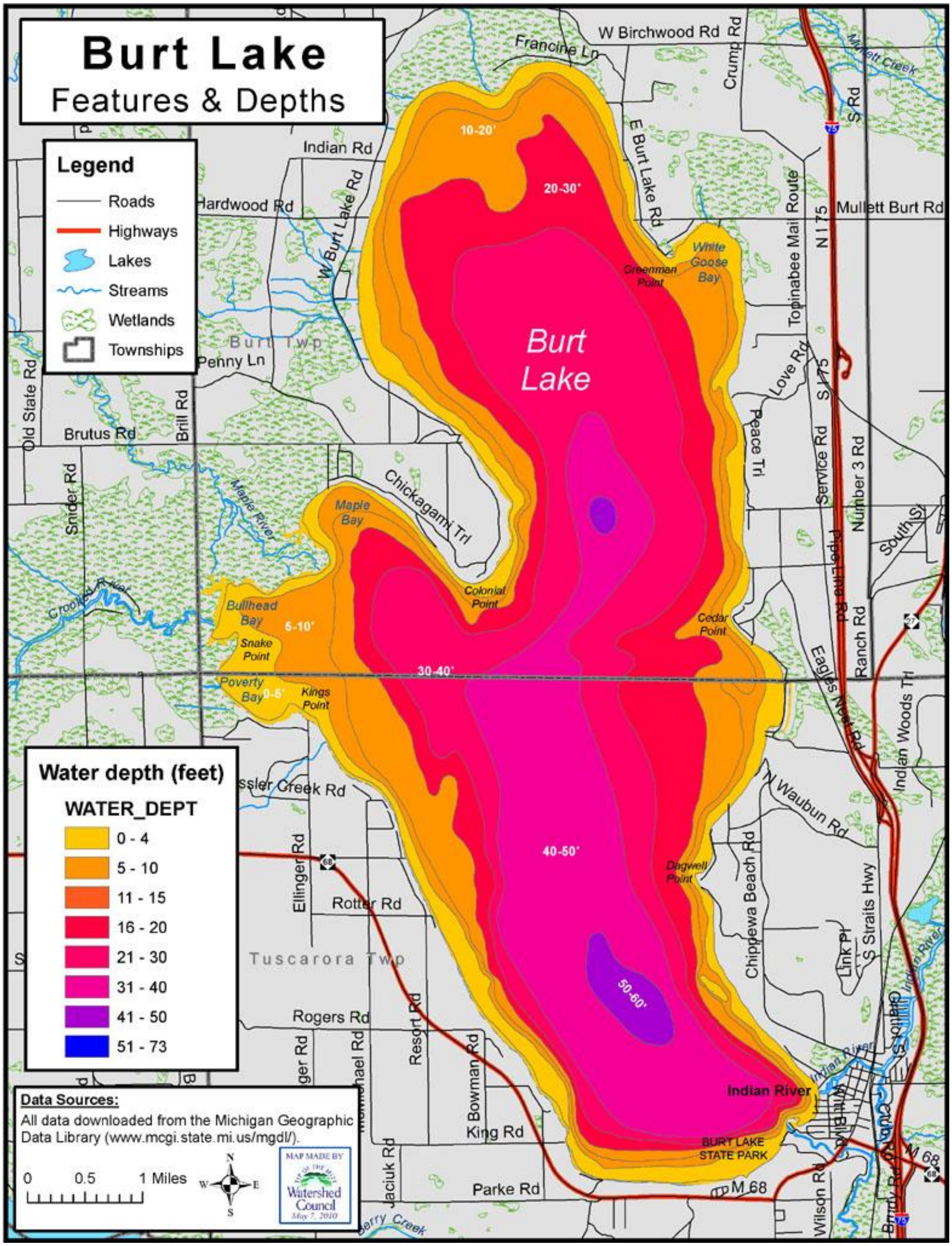


Figure 1. Burt Lake: features and bathymetry

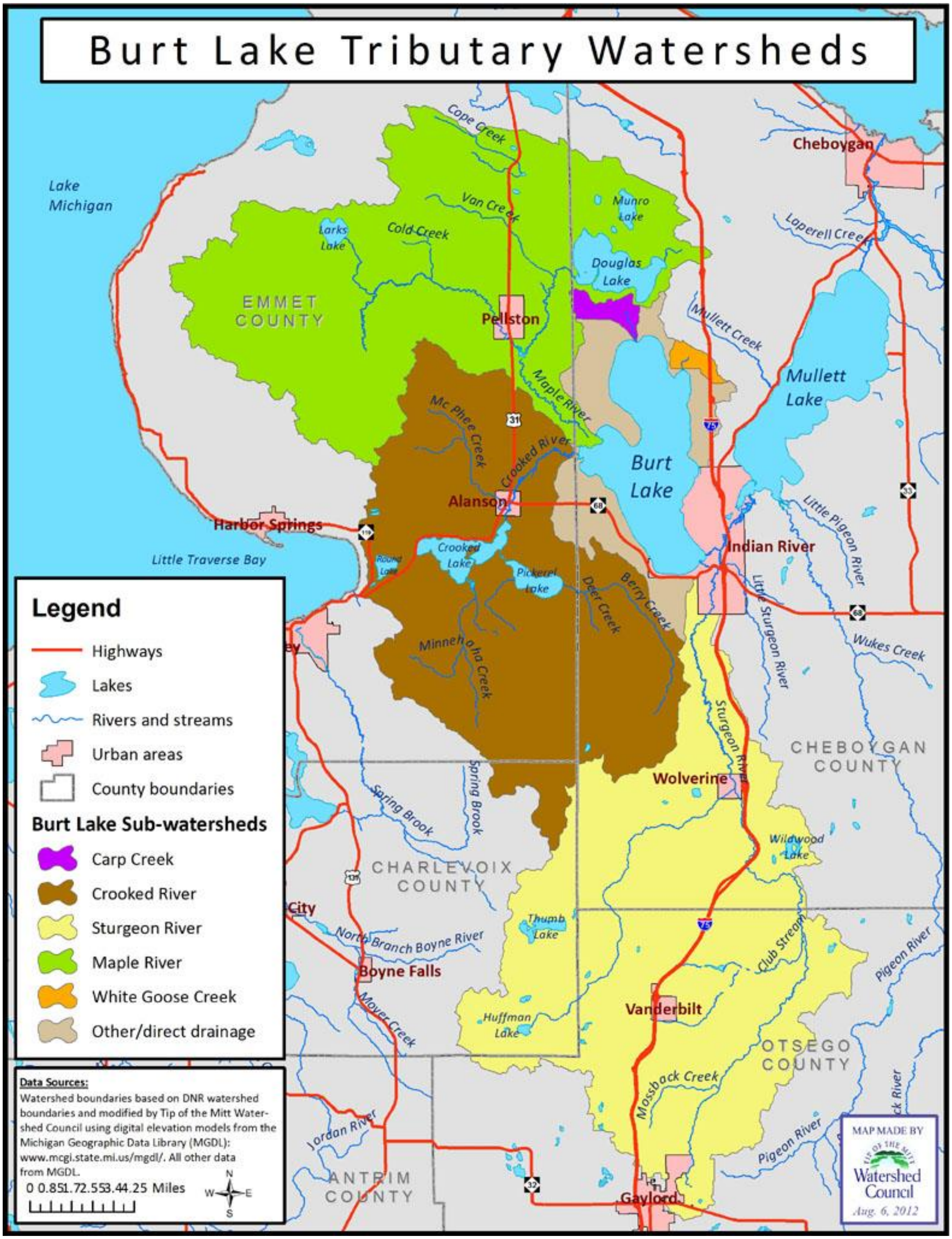


Figure 2: Watershed features and sub watersheds

Land cover statistics were generated for the watershed using remote sensing data from the NOAA Coastal Change Analysis Program (Table 1). Based on 2010 data, the majority of the watershed's landcover is natural; consisting primarily of forest and wetlands. There is relatively little agricultural landcover in the watershed (~9%) and even less urban (~3.7%). However, urban landcover has increased by approximately one percent, and agricultural landcover by .78% between 1985 and 2010.

Table 1. Burt Lake Watershed land-cover statistics

Land Cover Type	1985 Acres	1985 Percent	2010 Acreage	2010 Percent	1985-2010 Change (Acres)	1985-2010 Change (Percent)
Agriculture	30,746	8.28	33,648	9.07	0.62	0.78
Barren	464	0.12	727	0.20	-0.05	0.07
Forested	195,515	52.68	188,221	50.71	0.41	-1.97
Grassland	38,321	10.32	33,704	9.08	-5.90	-1.24
Scrub/shrub	13,198	3.56	18,637	5.02	1.89	1.47
Urban	10,479	2.82	13,855	3.73	1.23	0.91
Water	28,003	7.54	27,998	7.54	-0.08	0.00
Wetland	54,447	14.67	54,382	14.65	1.89	-0.02
Total	**371,173**	**100.00**	**371,173**	**100.00**	**N/A**	**N/A**

The water quality of Burt Lake has been monitored consistently for decades through the Watershed Council's Comprehensive Water Quality Monitoring (CWQM) and Volunteer Lake Monitoring (VLM) programs. Burt Lake water quality data date back to 1987 for the CWQM program and 1986 for the VLM program. Data from both programs indicate that water quality has been and remains high in Burt Lake.

Phosphorus is a nutrient that is necessary for a healthy aquatic ecosystem, but excess can lead to problematic algae and plant growth. Typically, large, deep, high-quality lakes of Northern Michigan like Burt have total phosphorus concentrations of less than 10 parts per billion (ppb). Total phosphorus concentrations measured as part of the CWQM program have rarely been above 10 ppb and, in fact, have gradually decreased from about 10 ppb in the late 1980s to less than 5 ppb in 2010 (Figure 3). This drop in phosphorus is largely attributed to invasive zebra mussels that have altered the natural nutrient cycle in Burt Lake by filter-feeding on plankton, though it may also be the result of decreased inputs from anthropogenic sources, such as malfunctioning septic systems or fertilizers.

In some situations, particularly where polluted runoff causes nuisance algae and plant growth, a decrease in chlorophyll-a concentrations can be desirable. Conversely, in nutrient-poor surface waters like Burt Lake, declining chlorophyll levels can be problematic, altering the natural food web and lake ecosystem by reducing primary productivity. The invasive zebra mussels (*Dreissena polymorpha*) present in Burt Lake are likely responsible for the increase in water clarity because they filter-feed on phytoplankton. However, there is evidence in recent data that chlorophyll-a concentrations may be rebounding (Figure 4).

Based on trophic status index data from the VLM program, Burt Lake borders between a mesotrophic system and oligotrophic, tending towards oligotrophic. (Figure 5). Oligotrophic lakes are typically large, deep, clear, and nutrient poor. In general, oligotrophic lakes contain high quality waters, but paradoxically have a lackluster fishery due to low biological productivity. Mesotrophic lakes are moderately productive. Low total phosphorus concentrations support the trophic status interpretation from the VLM program data. CWQM program data show that total phosphorus has decreased throughout the last 20 years and are now consistently below 10 micrograms per liter (μg/L), which is typical for oligotrophic lakes in Northern Michigan (Figure 6). The decrease is attributed to, at least in part, the introduction of zebra mussels. As zebra mussels filter phytoplankton from the water column, they also remove the phosphorus contained within the phytoplankton, which disrupts the natural nutrient cycle in the lake.

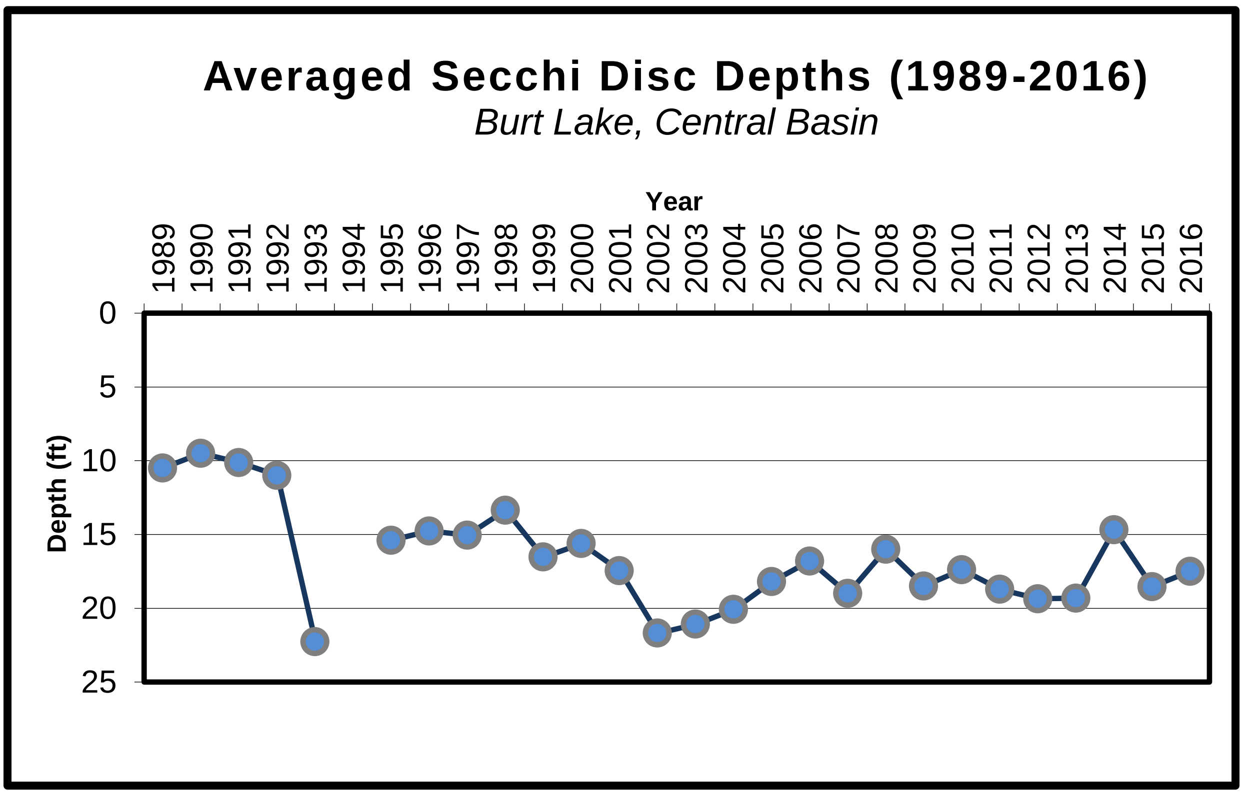


Figure 3. Secchi disc depth data from Burt Lake (TOMWC 2017)

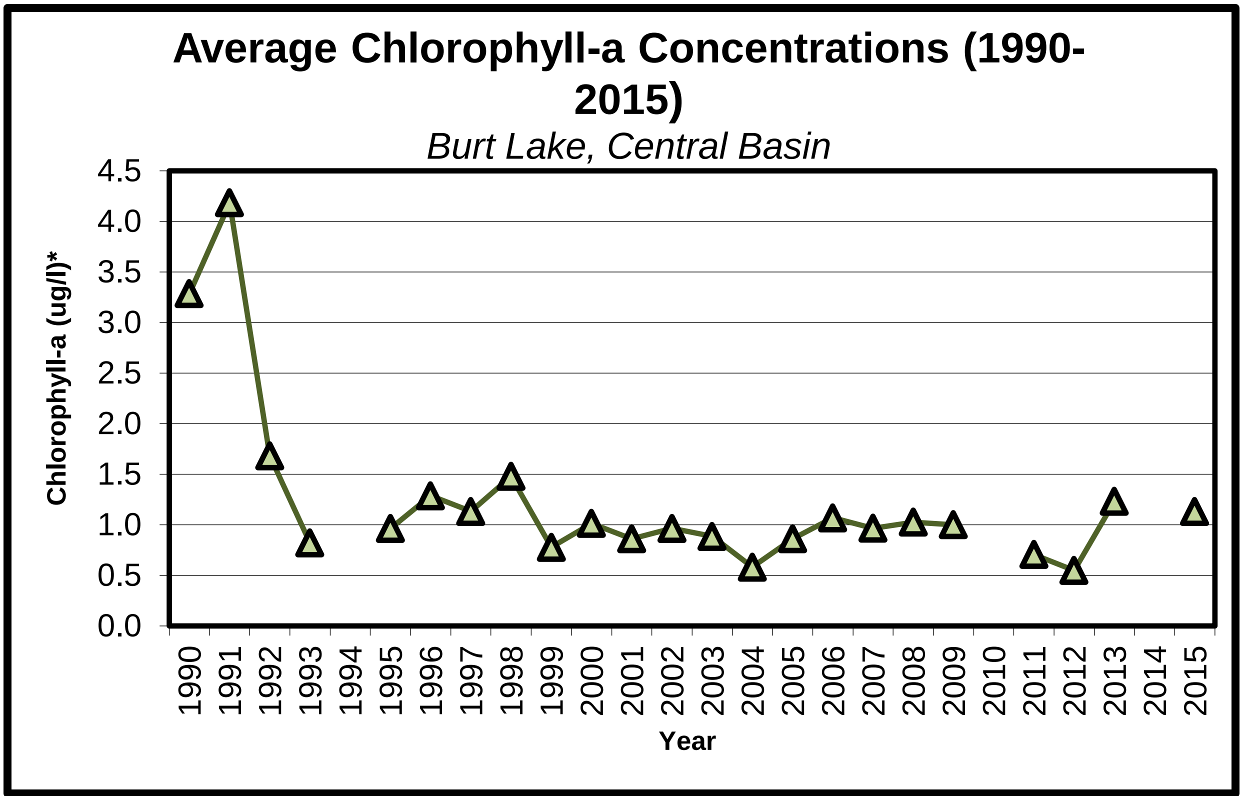


Figure 4. Chlorophyll-a data from Burt Lake (TOMWC 2016).

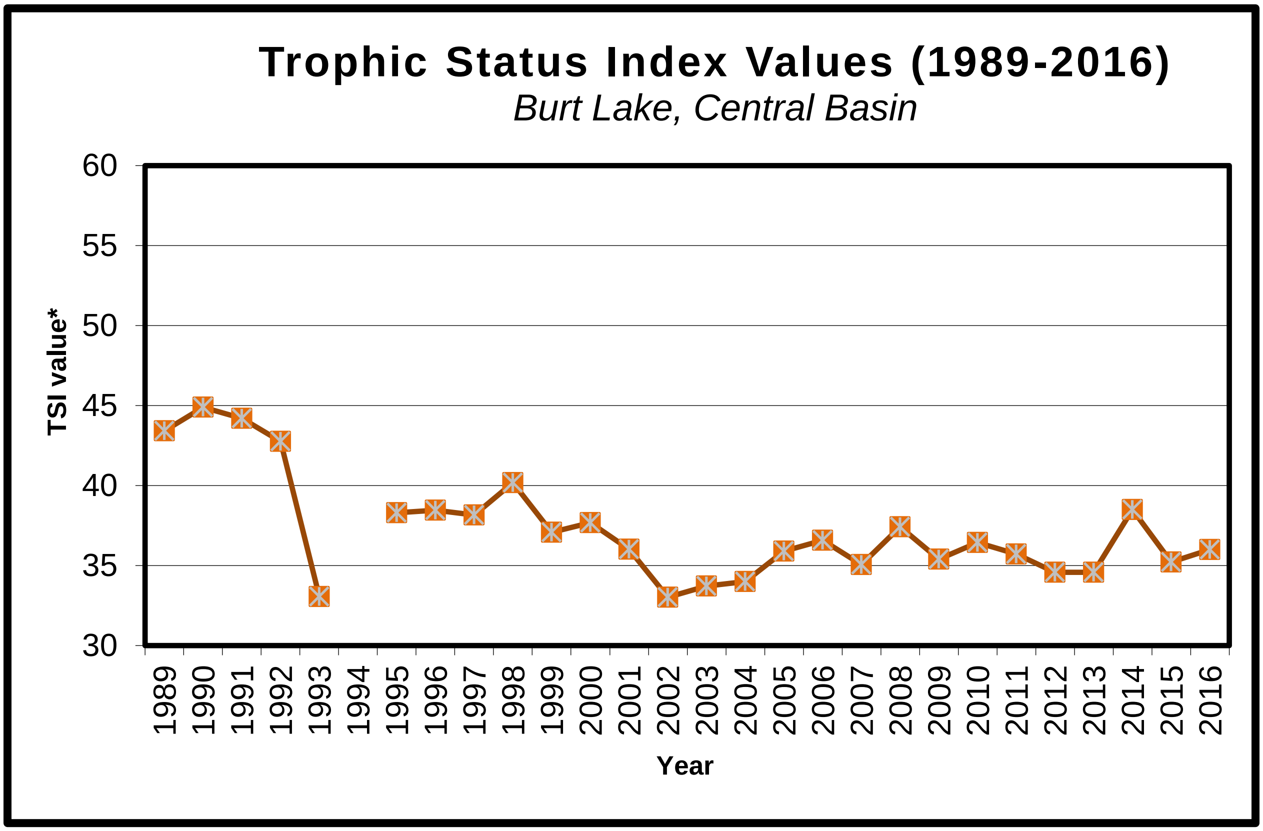
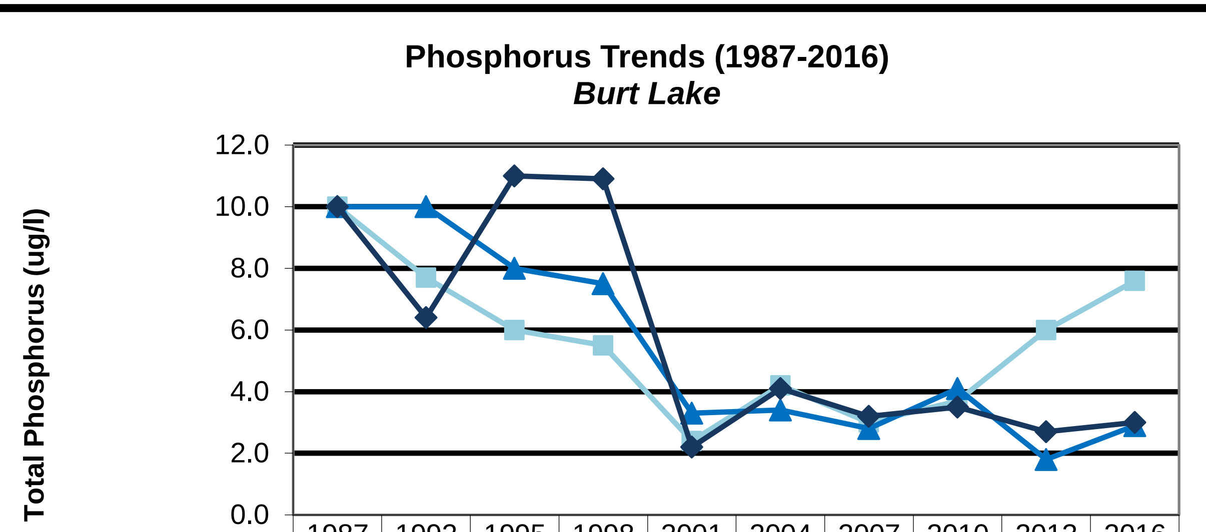


Figure 5. Trophic status index data from Burt Lake (TOMWC 2017).

**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).*



	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016
Surface	10.0	7.7	6.0	5.5	2.4	4.2	3.0	3.7	6	7.6
Middle	10.0	10.0	8.0	7.5	3.3	3.4	2.8	4.1	1.8	2.9
Bottom	10.0	6.4	11.0	10.9	2.2	4.1	3.2	3.5	2.7	3.0

Figure 6. Total phosphorus trends in Burt Lake 1987 to 2016 (TOMWC 2017).

METHODS

The aquatic plant communities of Burt Lake were sampled and mapped during the months of July through September, 2016. Survey methods used during the survey were developed by the Watershed Council, incorporating the experience and knowledge of Watershed Council surveyors, as well as elements of methods detailed in the Michigan Department of Environmental Quality's *Procedures for Aquatic Vegetation Surveys* (MDEQ, 2005). The methods were designed for comprehensive and detailed aquatic vegetation surveys that document aquatic plant species, community, and density information at specific sample sites while also mapping the areal extent and delineation of plant communities throughout the lake. Survey methods are described below and procedural details are in Appendix A.

Sampling

To document aquatic plant taxa, specimens were collected, identified, photographed and recorded on a standardized datasheet (Appendix B) at 537 sample sites throughout the lake. Sample site locations were not random, but rather selected with the intent of collecting representative information on all aquatic plant communities currently inhabiting the lake. Most sampling was conducted along transects across the lake that were spaced at regular intervals. In expansive, deep areas, transects began near the shoreline and continued linearly into deeper waters until plants were no longer found. The distance between sample points along transects varied depending upon plant community changes that were visible from the surface. In areas where plant communities were not visible, sample sites were selected based on interpretation of signals from the depth-finder or at regular intervals along the transect.

At each sample site, the boat was anchored, water depth noted, and GPS data recorded. Water depth was monitored using Hummingbird depth finders. Trimble 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, samples were taken by throwing and subsequently towing the rake in four directions at each site: towards shore, away from shore, and parallel with the shore in both directions. The approximate cardinal direction of each throw was used to document throw direction. Sometimes the exact direction of the throw would diverge from a cardinal direction due to natural or man-made features; in these cases, notes were taken for the updated direction. Sampling continued until the collector was satisfied that plant taxa present at the site were represented in the sample.

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 identification number assigned to that site. Taxon density was determined by the surveyor for each taxon at each toss and recorded as light (L), moderate (M), or heavy (H), but also included the sub-categories of very light (VL), light-moderate (LM), moderate-heavy (MH) and very heavy (VH). In general, the category “very heavy” was assigned when submergent 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 plant specimen could not be identified immediately, it was stored in a sealed bag and identified later with the aid of taxonomic keys, mounted herbarium specimens, and, if necessary, assistance from other aquatic plant experts. All taxa names, relative taxa densities, overall site density, and comments were recorded on the field datasheet. If no plants were encountered during sampling, “no vegetation” was recorded. Specimens representing each taxon found at the site were photographed.

To assist in mapping the aquatic vegetation in Burt Lake, additional photographs were taken to document emergent vegetation. At each sample site located within or adjacent to emergent vegetation, pictures were taken of surrounding areas. Pictures were taken with either a Ricoh G700SE or Nikon Coolpix AW110 digital GPS camera.

Community Mapping

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

A depth finder was also used to delineate plant communities, as signals show transitions between vegetated and non-vegetated areas, and between different growth forms of vegetation (Figure 7). By photographing these signals with a GPS camera, a record of local growth conditions is saved to aid in plant community delineation.

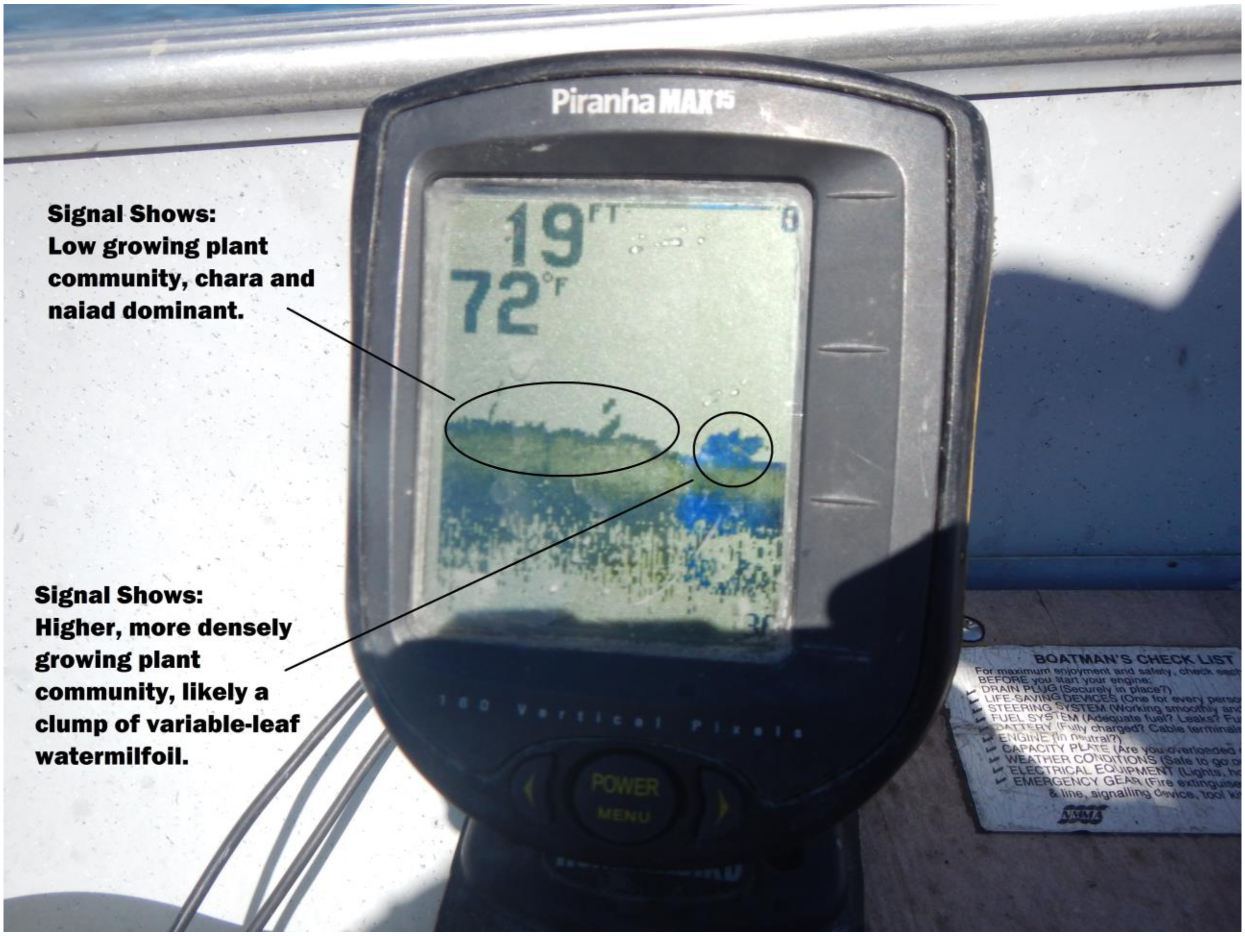


Figure 7. Example depth finder read out assists with plant community delineation

Distinct submerged aquatic plant beds and emergent vegetation were mapped with a GPS. Where feasible, the perimeter of submerged plant beds were followed as closely as possible in the boat and GPS data collected at major vertices to develop polygons representing distinct plant beds (Figure 8). Emergent plants growing directly along the shoreline were mapped directly on foot or at an offset distance that was recorded in the GPS unit. Plant specimens were not collected while mapping community lines with GPS. Occasionally wind, poor visibility, or other factors resulted in sinuous community lines which were noted in the GPS and later smoothed into more accurate, straight lines in a GIS.

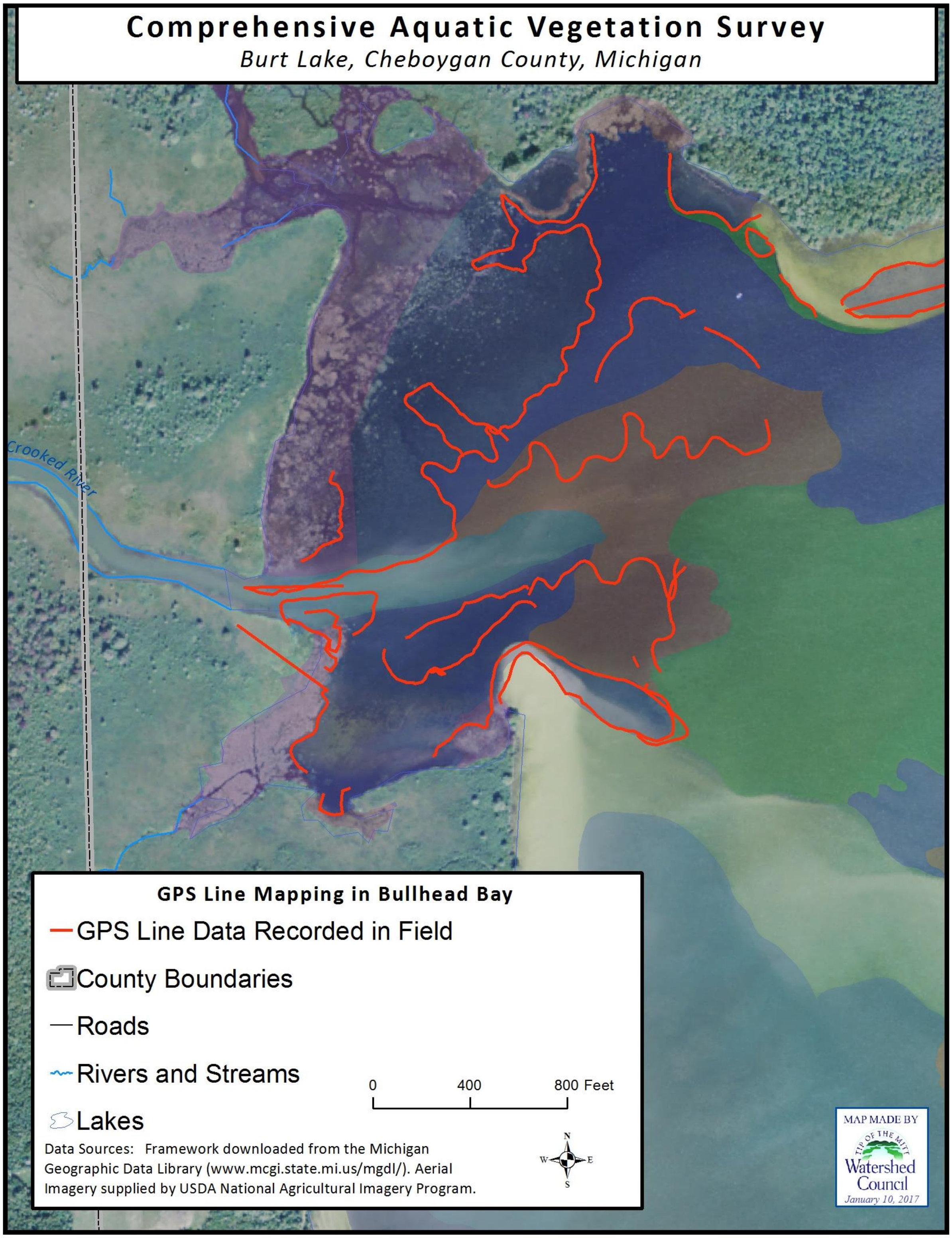


Figure 8. Example GPS data taken while afield in Bullhead Bay

Upon several occasions, plant community mapping was impeded by poor visibility, whether from wave turbulence, turbidity, or simply water depth and attenuation of sunlight. While these methods employ multiple tools to ensure mapping is as complete as possible, it is not possible to observe every individual plant within the lake, and omissions may have occurred.

Data Processing and Map Development

GPS data from the Trimble Juno SB units were transferred to a computer in an ESRI shapefile format. GIS data layers developed using the GPS data consisted of point layers representing sample sites and polygon layers representing plant communities. All GIS work was performed using Environmental Systems Research Institute's (ESRI) GIS software: ArcMap 10.4.

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

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

To further aid in plant community delineation, aerial imagery of Burt Lake was gathered from all possible sources. These sources include the USDA's National Agriculture Imagery Program, State of Michigan's public domain imagery, and Cheboygan County's GIS/Equalization Department imagery. The quality of imagery obtainable varies greatly by light and weather conditions at the time of fly-over. During optimal conditions, it is possible to observe plant communities at a depths of roughly 10 to 15 feet. Sample points overlaid with aerial images are used to general a "spectral signature" for plant community types based on samples collected in the field. The outlines of similar-looking vegetation in the image are followed when delineating plant communities (Figure 9).

After developing polygons, area statistics for specific plant communities and associated densities were calculated. Final products include both maps and statistics generated from digital map layers. Presentation-quality maps were developed to depict sample site locations, plant community densities at sample sites, dominant plant communities, and plant community densities. In addition, the sample site ESRI shapefiles allow GIS users to view all tabular data associated with the site. KML (keyhole markup language) data files of vegetation communities are also available for use with Google Earth® software, viewable on desktop or mobile platforms.

Figure 9. The King Road infestation of Eurasian watermilfoil, visible in aerial imagery

RESULTS

<u>Sample Sites</u>

Approximately 77% of sample sites were located in the primary growth zone of Burt Lake, between 5 and 20 feet deep.(Figure 10). A total of 38 aquatic plant taxa were documented during the survey conducted on Burt Lake; 27 taxa were documented at sample sites and 11 additional taxa were noted during community mapping. The additional taxa include: cattail (*Typha spp.*), sweet gale (*Myrica gale*), North American common reed (*Phragmites australis americanus*), pickerelweed (*Pontedaria cordata*), yellow pondlily (*Nuphar varigata*), white pondlily (*Nymphea odorata*), hardstem bulrush (*Schoenoplectus acutus*), softstem bulrush (*Schoenoplectus tabernaemontani*), sedge (*carex spp.*), duckweed (*lemna spp.*), and three-square bulrush (*Schoenoplectus americanus*). The number of aquatic plant taxa encountered at a sample site ranged from zero to nine with an average of 1.4 taxa per site. One invasive plant species was encountered during this survey, Eurasian watermilfoil (*Myriophyllum spicatum*), and was found at 20 sites throughout the southern portion of Burt Lake.

Muskgrass (*Chara spp.*), slender naiad (*Najas flexilis*), variable-leaf watermilfoil (*Myriophyllum* heterophyllum), and eelgrass (*Valisneria americana*) were the most frequently collected species, documented at approximately 83%, 41%, 38%, and 20% of vegetated sites, respectively (Table 2). Other taxa that were commonly found include flat-stem pondweed (*Potamogeton zosteriformis*), bladderwort (*Utricularia vulgaris*), large-leaf pondweed (*Potamogeton amplifolius), and* waterweed (*Elodea canadensis*). These species were collected at 17%, 10%, 8%, and 8% of vegetated sites respectively. The pondweed family (*Potamogetonaceae)* was the most speciose with a total of 10 pondweed species documented during the Burt Lake survey.

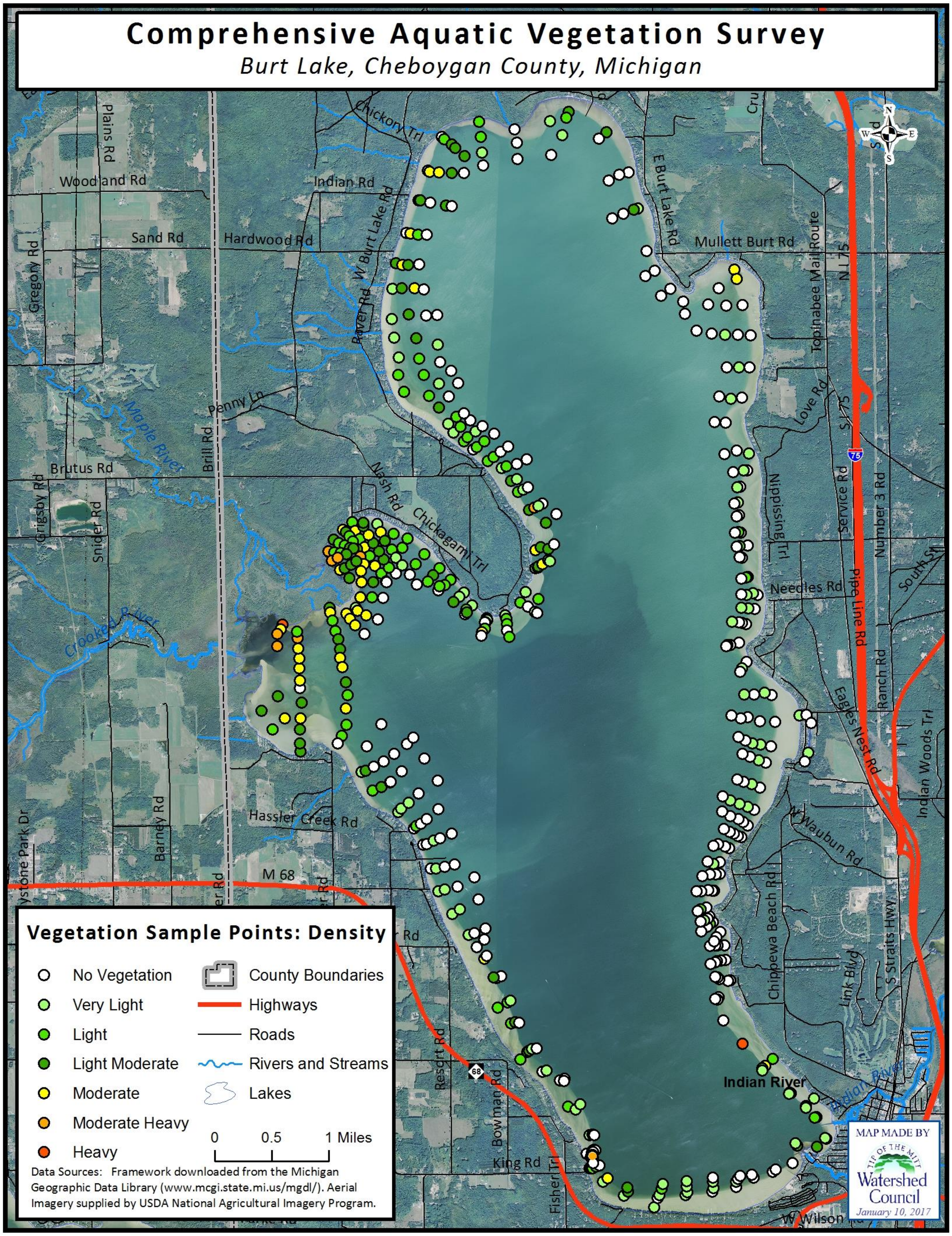


Figure 10. Sample sites for the 2016 Burt Lake Aquatic Plant Survey

Table 2. Aquatic plant taxa occurrence at sample sites

Scientific Name	Common Name	Total # of Sites	Total % Sites*
Chara spp.	Muskgrass	247	83.4
Najas flexilis	Slender Naiad	120	40.5
Myriophyllum heterophyllum	Variable-leaf Watermilfoil	113	38.2
Valisneria americana	Eelgrass	59	19.9
Potamogeton zosteriformis	Flat-stem Pondweed	50	16.9
Utricularia vulgaris	Bladderwort	29	9.8
Potamogeton amplifolius	Broad-leaf Pondweed	24	8.1
Elodea canadensis	Waterweed	24	8.1
Myriophyllum spicatum	Eurasian Watermilfoil	20	6.8
Stuckenia pectinata	Sago Pondweed	17	5.7
Najas guadalupensis	Naiad (species unknown)	16	5.4
Heteranthera dubia	Water Stargrass	14	4.7
Potamogeton xhaynesii	Haynes Pondweed	8	2.7
Potamogeton pusillus	Small Pondweed	5	1.7
Potamogeton strictifolius	Narrow-leaf Pondweed	5	1.7
Potamogeton gramineus	Variable-leaf Pondweed	4	1.4
Potamogeton natans	Floating-leaf Pondweed	4	1.4
Schoenoplectus subterminalis	Swaying Bulrush	4	1.4
Potamogeton richardsonii	Richardson's Pondweed	4	1.4
Potamogeton friesii	Fries' Pondweed	3	1.0
Potamogeton praelongus	White-stem Pondweed	2	0.7
Myriophyllum sibiricum	Northern Watermilfoil	2	0.7
Bidens (syn. Megalodonta) beckii	Water Marigold	1	0.3
Sagittaria cuneata	Arrowhead	1	0.3
Utricularia resupinata	Lavender Bladderwort	1	0.3
Stuckenia filiformis	Fine-leaf Pondweed	1	0.3
Iris spp.	Iris	1	0.3

**Percent of sites based on only those sites with vegetation (=296).*

The distribution of plant community densities at sample sites leaned toward light-density or no growth (Table 3). Approximately 45% of sample sites had aquatic plant community densities that fell into the light categories (very light, light, and light to moderate), whereas heavy-density growth was limited to one site. There were no sites with very heavy growth. The majority of sites with moderate to heavy-density growth were found in Maple and Bullhead bays, where large expanses of shallow water enable plant growth.

Table 3. Aquatic plant densities at sample sites

Density Category	Number of Sites	Percentage of Sites
Little/no vegetation	241	44.9
Very Light	98	18.2
Light	81	15.1
Light to Moderate	64	11.9
Moderate	42	7.8
Moderate to Heavy	10	1.9
Heavy	1	0.2
Very Heavy	0	0.0
TOTAL	537	100

Plant Communities

Aquatic plant community mapping showed that 15144 of the 17,436 acres (87%) of Burt Lake contained little or no aquatic vegetation. Of the 2292 acres with vegetation, approximately 94% consisted of submergent plant species (Table 4). Two submergent species, muskgrass and variable-leaf watermilfoil, were the dominant plants in nearly 57% of the vegetated lake area (Table 5). Over one half of the vegetated area in Burt Lake contained very light- to light-density plant growth while moderate-heavy to heavy growth covered less than 5% (Table 6).

Table 4. Generalized aquatic vegetation statistics

Lake and Vegetation	Lake Area (acres)	Lake Area (percent)
Burt Lake surface area	17,436	100.0
Little or no vegetation	15,143	86.8
Lake area with aquatic vegetation:	2,292	13.2
a. Emergent species dominant*	111	4.9
b. Submergent species dominant*	2166	94.4
c. Floating-leaf species dominant*	15	0.7

**Refers to percent of surface area with aquatic vegetation (i.e., 2292 acres).*

Table 5. Dominant aquatic plant community statistics

Dominant Community Type	Vegetated Lake Area (acres)	Vegetated Lake Area (percent)
Chara	837.72	36.54%
Watermilfoil	486.20	21.21%
Naiad and chara	428.97	18.71%
Pondweed	163.25	7.12%
Bladderwort	136.96	5.97%
Multiple species	81.22	3.54%
Bulrush	79.62	3.47%
Mixed Emergents	31.39	1.37%
Water Lily	14.95	0.65%
Eelgrass	12.12	0.53%
Eurasian watermilfoil	9.42	0.41%
Arrowhead	6.70	0.29%
Elodea	3.18	0.14%
Native Phragmites	0.38	0.02%
Floating Leaf Pondweed	0.25	0.01%
TOTAL	2292.33	100.00%

Table 6. Density statistics for aquatic plant communities

Density Category	Lake Area (acres)*	Lake Area (percent)*
Very Light	709.73	30.97
Light	500.17	21.82
Light to Moderate	601.74	26.25
Moderate	387.58	16.91
Moderate to Heavy	85.07	3.71
Heavy	7.66	0.33
Very Heavy	0.38	0.02
TOTAL	2292.33	100.0

**Refers to percent of surface area with aquatic vegetation (i.e., 2292 acres).*

Near-shore shoals, areas of shallow water extending up to 1000 feet from land's edge, rarely contained vegetation. The drop off zone, where depths quickly increase from five to roughly 15 feet generally contained larger-growing plants such as pondweed or watermilfoil. The majority of emergent vegetation occurred along the shallow edges of the lake, extending further from shore in the western bays due to shallow depths. Extensive chara-dominated communities occurred throughout the northern portions of Burt Lake, often deeper than the drop off.

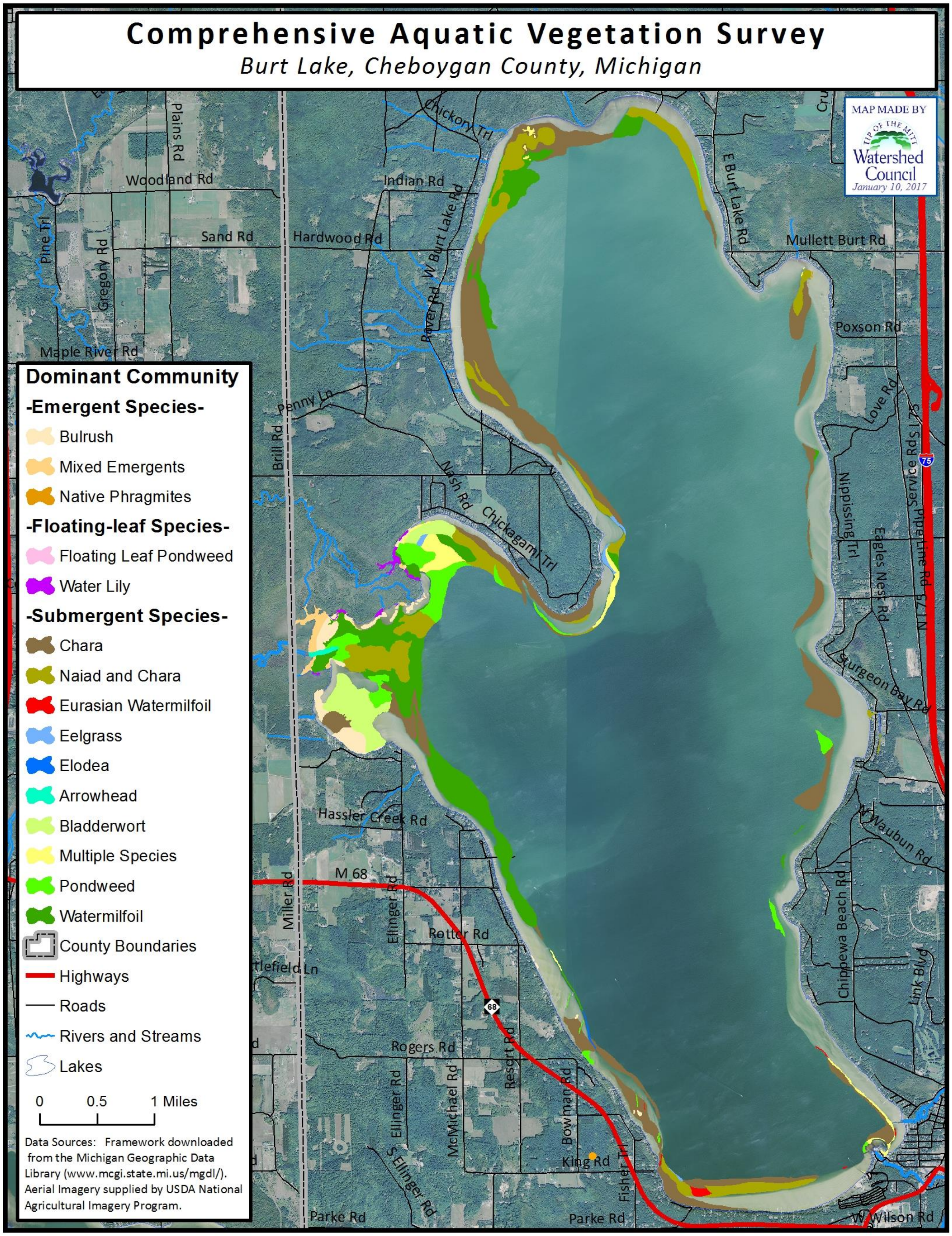


Figure 11. Aquatic plant communities in Burt Lake

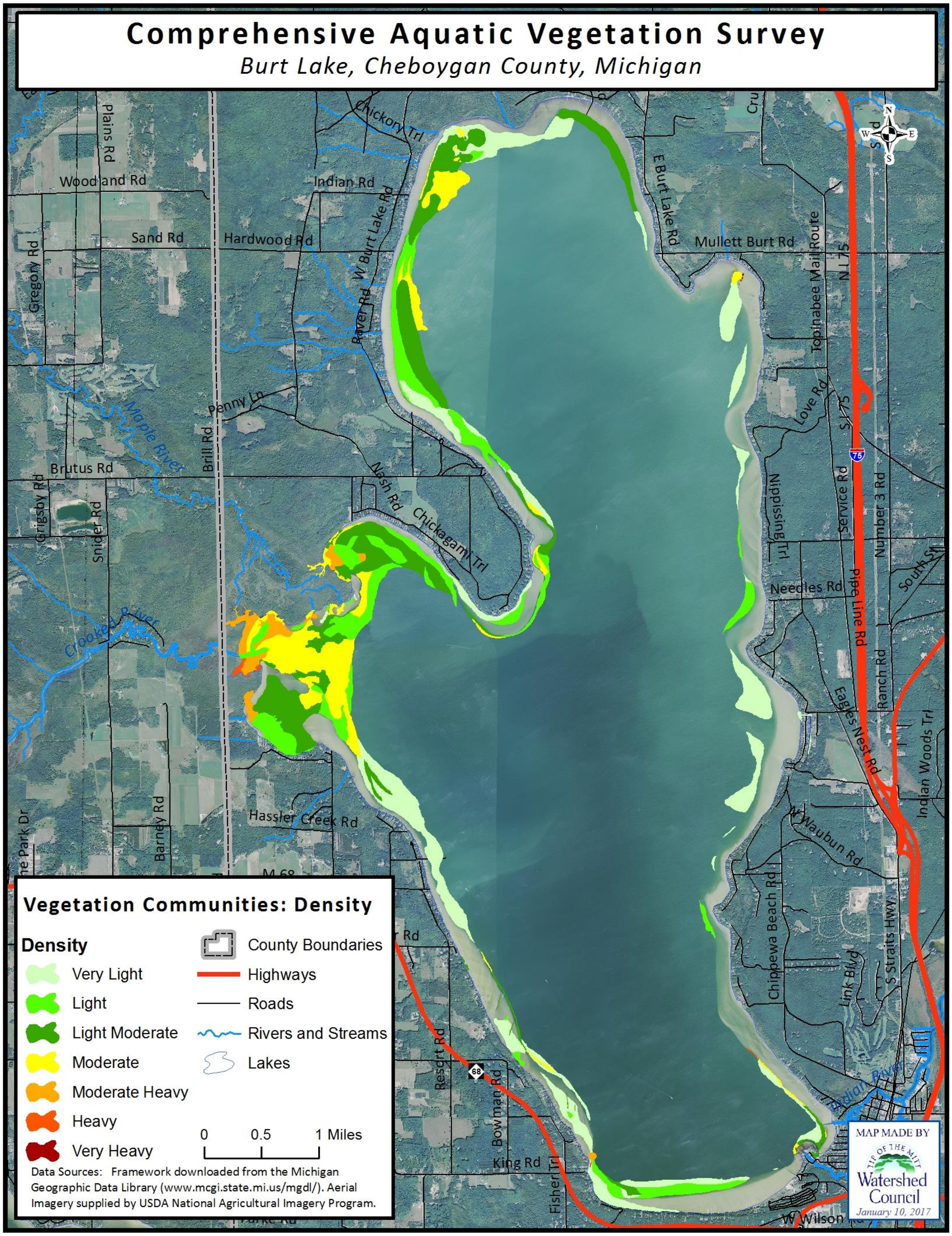


Figure 12. Aquatic plant densities in Burt Lake

Eurasian watermilfoil was found in multiple locations in the southern portion of Burt Lake (Figure 13). A previously identified infestation (discovered in the early 2000's) was mapped and found to have grown only slightly in size, to an area of 0.64 acres. The infestation is oriented north-south, along the drop off just north of King Road. Eurasian watermilfoil was found to be well established in two other locations, exhibiting dense monoculture growth. The larger of the two, at 0.88 acres, was found along the drop off on the southeast side of the lake, in the area between Hillside Avenue and Wright Road. A 0.44 acre infestation was found near Indian River, about 400 feet out from the end of Mack Avenue.

Large areas of moderate plant diversity throughout southern portions of Burt Lake contained Eurasian watermilfoil as a component of the plant community, often documented as light or moderate densities in samples. Native species such as variable-leaf watermilfoil, pondweed, and elodea were often found growing alongside the invasive plant. These areas total 21.4 acres in size.

A singular plant of Eurasian watermilfoil was observed growing in shallow water at the Maple Bay boat lunch as Watershed Council staff prepared for survey activities. The plant was retrieved with a sampling device in order to confirm its identity. No other Eurasian watermilfoil plants remained in the area after removal of the first plant, confirmed by a ~20 minute visual search of plant communities within the vicinity of the initial discovery. No community or sample point data was established for this occurrence, but follow up actions are recommended.

Samples sites in Burt Lake often exhibited low diversity (average of 1.4 species per sample site), but some localized areas had much higher diversity, commonly reaching eight species per sample site (Figure 14). These areas were often found in sheltered bays such as Bullhead and Maple Bays on the west side of the lake.

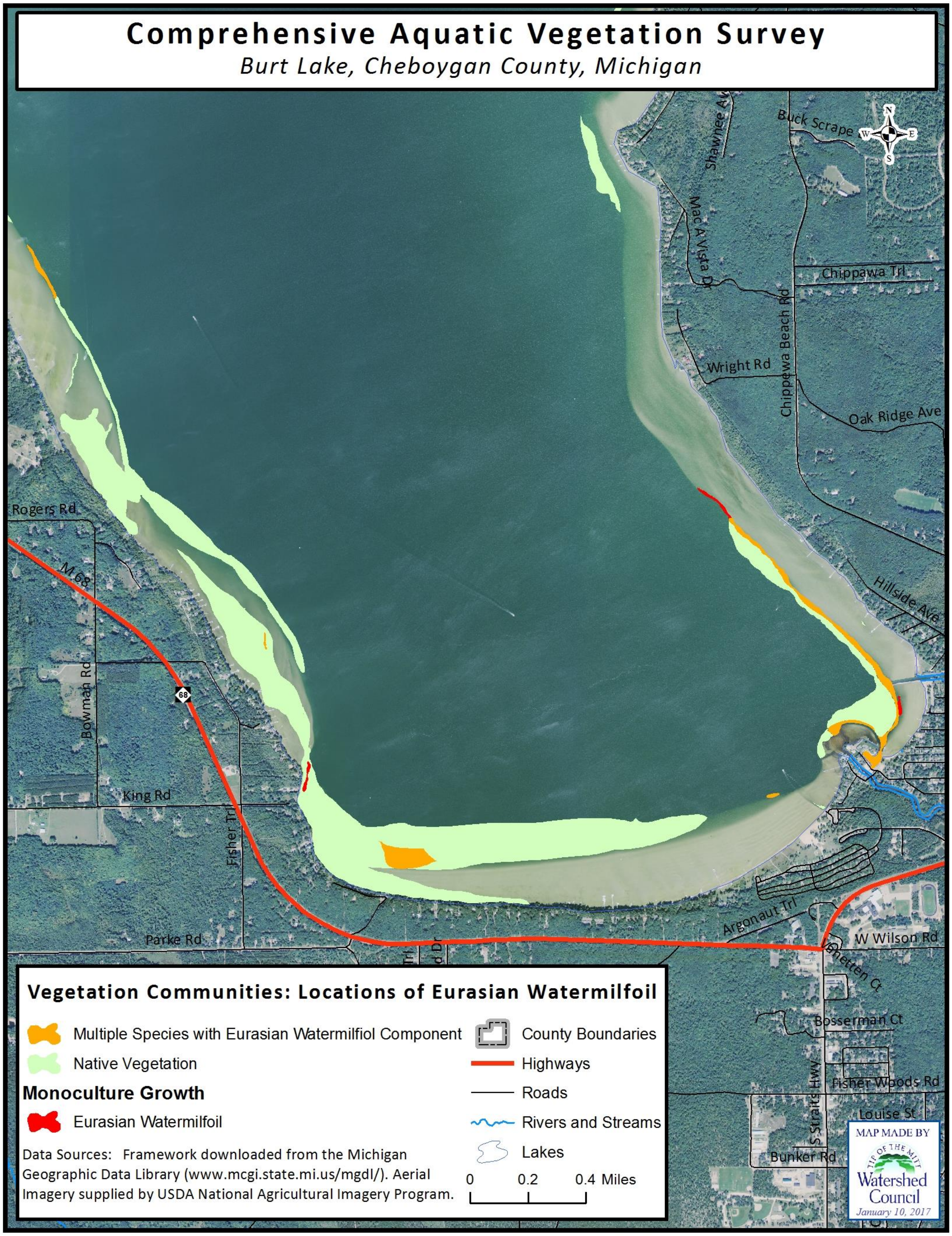


Figure 13. Invasive Eurasian watermilfoil locations throughout southern Burt Lake

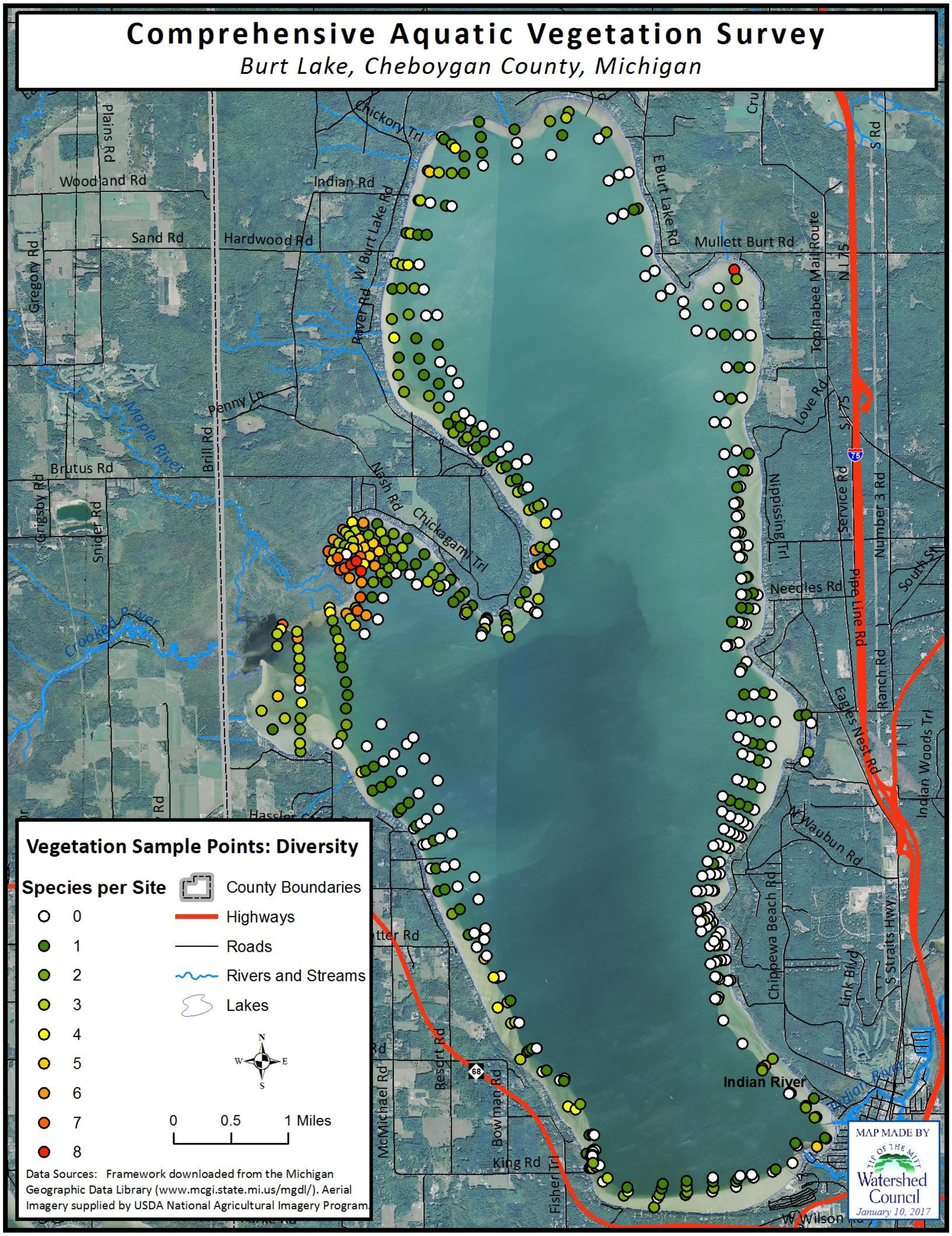


Figure 14. Plant diversity at sample sites in Burt Lake

DISCUSSION

Plant diversity in Burt Lake was above average compared with data from other lakes surveyed in the area (Table 7). The percentage of sample sites with dense aquatic vegetation in Burt Lake was far below average for Northern Michigan lakes. The majority of highly-diverse plant communities occurred near the mouths of tributaries, namely near the mouth of the Maple River. This is thought to result from a combination of factors including suitable depths and substrate for plant growth, but also nutrient inputs from the Maple River and the diverse, natural shoreline habitat found here. A highly diverse plant community provides numerous benefits to the aquatic ecosystem, including increased forage for aquatic and semi-aquatic species, variability in habitat for aquatic species including fish, and increased resistance to invasion by invasive species. A low-diversity condition throughout other areas of Burt Lake does not necessarily indicate environmental degradation, but rather conditions typical for large, oligotrophic lakes.

Table 7. Aquatic vegetation survey statistics from Northern Michigan Lakes

Lake Name	Survey Year	Lake Size (acres)	Max Depth (ft)	Total Taxa In Lake	Taxa Average Per Site	Vegetated Lake Area	Densely Vegetated Sites†
Adams	2010	43	18	27	4.9	99%	66%
Bellaire	2013	1810	95	27	2.9	18%	8%
Black	2014	10,133	50	38	3.9	18%	15%
Clam	2013	446	27	28	4.1	69%	43%
Burt	2016	17436	73	38	1.4	13%	<1%
Crooked	2008	2,351	50	28	2.8	56%	13%
Hanley	2014	89	27	29	6.3	94%	34%
Intermediate	2014	1,570	70	30	2.7	23%	1%
Long	2013	398	61	30	3.9	29%	11%
Douglas	2012	3,780	80	30	5.3	47%	15%
Millecoquin	2005	1,116	12	20	6.0	95%	61%
Mullett	2007	17,205	144	42	3.1	19%	13%
Paradise	2008	1,947	17	24	5.0	58%	28%
Pickerel	2008	1,083	70	20	1.5	24%	5%
Walloon	2013	4,620	100	32	1.8	22%	3%
Wycamp	2006	689	7	35	4.9	83%	24%
AVERAGE	NA	NA	NA	29	3.9	50%	23%

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

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

Substrate types available for aquatic plants to take root in also determine the distribution of aquatic plants. Marl substrate, typical of Northern Michigan lakes, is less conducive to vegetation growth than other substrate types. No plant growth was found throughout the broad plateaus east of Bullhead and Maple Bays, despite depths of 10 – 20 feet, well within the photic zone. The lack of vegetation in this area is best explained by substrate conditions unsuitable for plant growth. The majority of benthic life in this area consists of zebra or quagga mussels and algae, shown on a typical rake tow from this area (Figure 15). Sediment contributions from rivers and streams can provide more nutrient-heavy organic substrate that encourage aquatic plant growth and alter natural growth regimes. Shoreline erosion can also cause this condition.

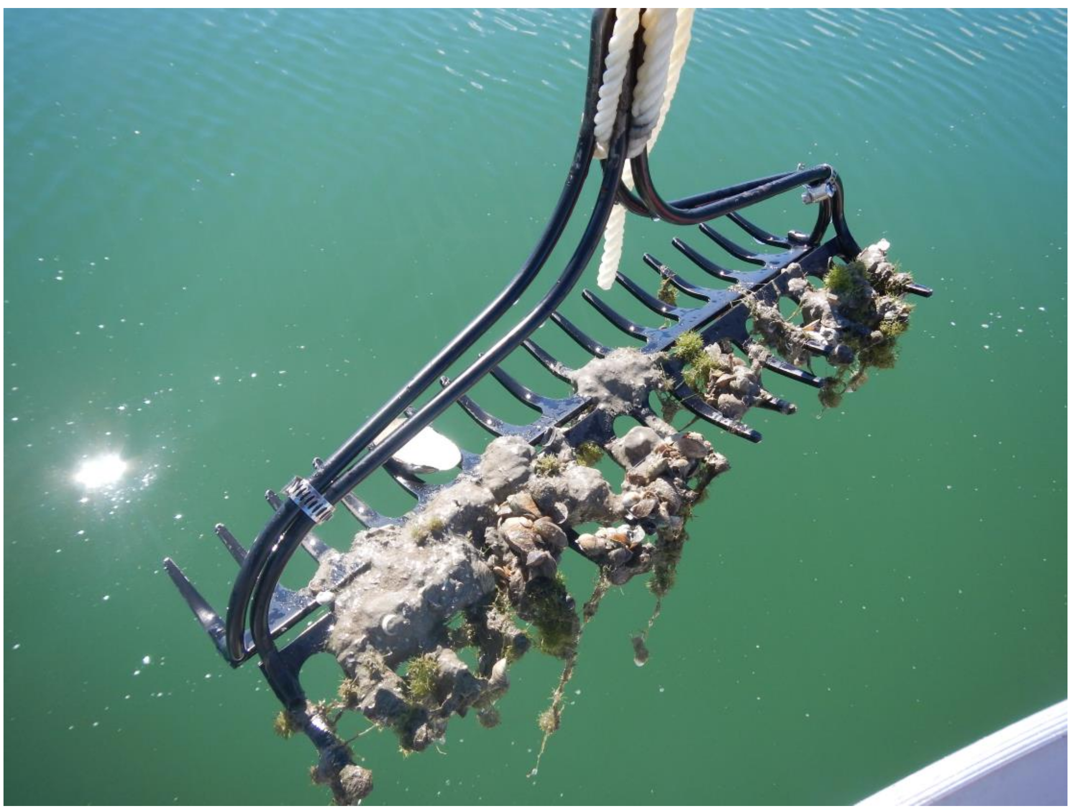


Figure 15. A rake tow reveals marl substrate that supports little aquatic plant growth

Plymouth Beach Canal contained few aquatic plants, compared to the 2011 survey conducted by the University of Michigan Biological Station. In the 2011 survey, heavy plant growth and the invasive species curly-leaf pondweed (*Potamogeton crispus)* were documented in the canal. No curly-leaf pondweed was documented during the 2016 survey. Conversations with riparian residents indicated that this area was recently treated with herbicide, explaining the lack of aquatic vegetation. Heavy filamentous algae covered most samples (Figure 16). In the absence of aquatic vegetation, algae grows heavier due to decreased competition for sunlight and nutrients. This condition is often exacerbated by herbicide treatments as nutrients are liberated from decaying vegetation.

Figure 16. Heavy algae found throughout Plymouth Beach Canal after herbicide treatments

While many Northern Michigan lakes are experiencing problems with Eurasian *Phragmites (Phragmites australis*), Burt Lake was not found to have this invasive reed during the 2016 survey. A native species, the North American common reed (*Phragmites australis americanus*), was found growing at heavy densities in White Goose Bay. Four distinct stands of native *Phragmites* were mapped and identified as native (Figure 17). Native *Phragmites* is thought to be a beneficial aquatic plant, with very little risk of reaching nuisance levels.

Figure 17. Three of the four distinct stands of native *Phragmites* in White Goose Bay

Management of aquatic invasive species is best approached on a watershed-wide scale. With many aquatic invasive plants possessing the ability to spread rapidly through seed production and fragmentation, infestations readily spread in a downstream direction. Burt Lake's immediate watershed contains invasive plants that pose risks for Burt Lake. During 2014 and 2015, the Watershed Council conducted plant surveys of Round, Crooked, and Pickerel Lakes, as well as the upper portion of the Crooked River. This effort, funded by the Pickerel-Crooked Lakes Association along with local units of government, identified stands of both Eurasian watermilfoil and curly-leaf pondweed in Crooked River (Figure 18).

Downstream spread of invasive species in the Crooked River is likely, given the high boat traffic and relatively unobstructed river flow. The curly-leaf pondweed is thought to have originated in a well-documented infestation near the mouth of Oden Creek in Crooked Lake. Eurasian watermilfoil is thought to have originated from plant fragment introduction to the Crooked River. The 2014-15 survey extended to the remnants of Hay Lake, leaving roughly 3.6 miles of river channel unsurveyed. University of Michigan Students, in efforts to produce the 2016 Burt Lake Management Plan, documented curly-leaf pondweed as far downstream as the Emmet-Cheboygan County line, less than a quarter mile from Burt Lake.

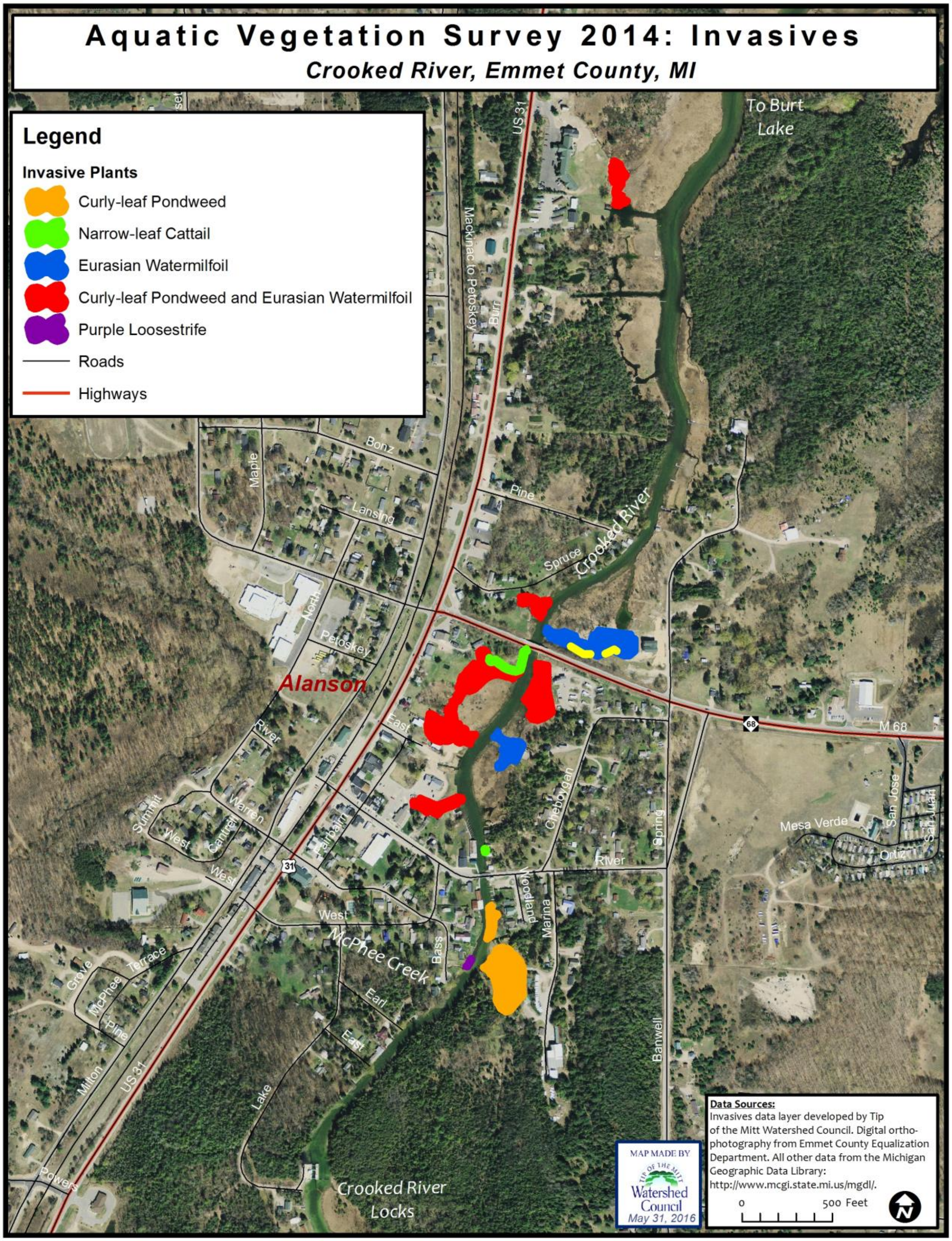


Figure 18. Invasive species found upstream in the Crooked River

Eurasian Watermilfoil was the only invasive plant documented in Burt Lake in 2016. The initial infestation near the end of King Road was mapped and found to have slightly increased in size. New infestations found throughout the southern portions of Burt Lake indicate that this plant has likely spread locally through seed and fragmentation. The new infestations documented directly southeast of the initial King Road infestation were sparse and patchy, making a true infestation acreage difficult to quantify. North and West of the King Road infestation, on the west side of the lake, Eurasian watermilfoil was found as a component of two plant communities, one on the shoal near Fisher Trail and the other on the drop off near Rotter Road. On the east side of The Lake, Eurasian watermilfoil was found growing on the drop off near Indian River, extending north past the northern terminus of Hillside Ave.

Despite being an invasive plant, Eurasian watermilfoil can grow amongst native plants in low or moderate densities. Areas of Lake Bottom that offer favorable growing conditions are receptive to colonization by the non-native, but do not immediately succumb to dense monoculture growth if there is a strong native plant community present. This is occurring in 21.4 acres of south Burt Lake, forming communities of multiple species with Eurasian watermilfoil as a component.

Recommendations

1. Educate and inform lake users. Human activity in a multitude of forms typically has the greatest impact on a lake's aquatic plant communities. Therefore, effectively managing the lake's aquatic plants requires information and education outreach projects that target shoreline property owners, watershed residents, and all lake users. Residents that remove native aquatic vegetation from the lake's bottom inadvertently increase the risk of invasive species becoming established. The practice of physical or chemical removal of native plants should be avoided, particularly in the southern portion of the lake, considering the risk for colonization by Eurasian watermilfoil. Lake associations can help prevent the introduction of non-native species, such as the various invasive plants found in nearby lakes, by posting signs and educating members and other lake users. Outreach activities should not be limited to dos and don'ts, but also include general information about aquatic plants and their importance to the lake ecosystem.

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

management, such as reducing lake nutrient loads and preventing the introduction of additional non-native species.

3. Develop a strategy to address the Eurasian watermilfoil found in Burt Lake. Due to the plant's history of outcompeting native vegetation and becoming a nuisance in other lakes, the Association should consider approaches to controlling Eurasian watermilfoil. While the Watershed Council does not generally endorse the use of herbicide in lakes, we find that strategic and limited use of herbicide often has fewer negative consequences than those associated with an unchecked infestation of invasive plants. The association may choose to differentiate between monoculture growth and those plant communities that contain native plants along with Eurasian watermilfoil. The aquatic plant community is a vital component of the aquatic ecosystem, such that good aquatic plant management translates to good lake ecosystem management. The Association has already taken an important step in aquatic plant management by sponsoring a comprehensive aquatic plant survey.

4. Gather more information on Eurasian watermilfoil found in Burt Lake. This survey documented patchy and irregular growth, making it difficult to define an exact infestation boundary in some areas. Better aerial imagery, paired with data from this survey, could provide more exact information that would increase the efficiency of treatments, lowering the cost. There are a number of services that utilize unmanned aerial vehicles to capture images from above. Some have specialized experience with aquatic plants, such as Zero Gravity Aerial in Traverse City. Additionally, should the Association choose not to treat mixed plant communities, the species composition of these communities should be tracked over time to document changes and assess possible out-competition of native vegetation by Eurasian watermilfoil.

5. Regularly survey the lake and watershed for other priority invaders. Other aquatic invasive species documented in nearby lakes and rivers include Eurasian *Phragmites* and curly leaf pondweed. These invaders have been documented in Crooked Lake, Mullett Lake, and the Lower Crooked River, and therefore, have high potential of infesting Burt Lake. The remaining 3.6 miles of Crooked River, not surveyed in the 2014-15 survey, should be surveyed for invasive species as soon as possible.

6. Collaborate with other watershed stakeholders to treat upstream infestations. As the downstream resource at risk from infestations in the Crooked River, all Burt Lake stakeholders, including The Association, should partner with other local entities. The Association should get involved in plant management activities on the Crooked River to ensure they work in a proactive fashion to stop infestations from spreading

downstream.

7. Monitor boat launches for aquatic invasive species. Volunteers from the Association can help prevent the introduction of aquatic invasive species and educate lake users by monitoring boat launches. Volunteers can inform and educate lake users about the impacts of invasive species and encourage them to take the necessary steps to prevent their spread, such as cleaning boats and trailers. It is important that monitoring be carried out during busy weekends, such as Memorial Day and the Fourth of July when boat launches are used the most and the potential for invasive species introduction is at its greatest. Special effort should be put forth to investigate the near-shore plant community at the Maple Bay boat launch to ensure Eurasian watermilfoil has not become established. Should trained Watershed Council staff be in the area during the growing season of 2017, an effort will be made to search for an infestation.

8. Preserve the lake ecosystem and natural diversity. Burt Lake contains a vibrant native aquatic plant population that may be considered a nuisance by many shoreline residents and other lake users. While pursuing nuisance plant management and control options, the Association should strive to protect the diverse assemblage of plants present in the lake, which are critical for sustaining a healthy fishery and maintaining a healthy aquatic ecosystem. The Maple River Spreads and other shoreline wetlands should be protected from alteration due to the water-quality benefits associated with their function.

9. Investigate potential nutrient pollution issues. Nutrient pollution from shoreline properties can lead to excessive plant growth and should be controlled wherever and whenever possible. The Association can make positive steps toward controlling nutrient pollution by communicating and working with shoreline property owners. In particular, property owners around the lake should be encouraged to properly maintain septic systems, replace old or failing septic systems, reduce or eliminate fertilizer use, compost and mulch far from the shoreline, and prevent stormwater from flowing directly into the lake. Shoreline surveys are an effective tool for locating sources of nutrient pollution. Information gathered from a shoreline survey can be used to work with lakeshore property owners to verify nutrient pollution, identify sources, and correct any problems. Shoreline surveys should be carried out once every 3-5 years to document conditions and address any problem areas; the last one conducted on Burt Lake was in 2009.

10. Regularly survey the aquatic plants of Burt Lake. To effectively manage the aquatic plant community of Burt Lake, periodic aquatic plant surveys should be conducted. Future surveys will provide the necessary data for determining trends over time, evaluating successes or failures of aquatic plant management projects, and documenting the

locations and spread of non-native aquatic plant species. Although dependent upon many different variables, surveying the aquatic plant community on a 5-10 year basis is generally sufficient.

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Appendix A. Aquatic Vegetation Survey Standard Operating Procedure.

Aquatic Vegetation Survey Standard Operating Procedure

Tip of the Mitt Watershed Council

Last updated: 4/24/15

Summary

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

Periodic aquatic vegetation surveys should be conducted on lakes to effectively manage the aquatic plant communities. Surveys are necessary to establish baseline data, examine trends, evaluate success or failure of aquatic plant management projects, and document the locations and spread of non-native aquatic plant species. Although dependent upon many different variables, surveying the aquatic plant community on a 5-10 year basis is generally sufficient.

Equipment and Preparation

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

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

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

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

Sampling Procedures

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

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

Include taxa found in additional grapple tosses.

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

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

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

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

f. Density categorization for community mapping is more subjective than the sample site procedure and based on the following:

    i. Very Heavy (VH) = >90% of the area mapped with vegetation.
    ii. Heavy (H) = 70-90% of the area mapped with vegetation.
    iii. Moderate-Heavy (MH) = >60-70% of the area mapped with vegetation.
    iv. Moderate (M) = 40-60% of the area mapped with vegetation.
    v. Light-Moderate (LM) = 30-40% of the area mapped with vegetation.
    vi. Light (L) = 10-30% of the area mapped with vegetation.
    vii. Very Light (VL) = <10% of the area mapped with vegetation.

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

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

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

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

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

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

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

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

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

Appendix B. Aquatic Vegetation Survey standard field datasheet.

Aquatic Vegetation Survey Form

Tip of the Mitt Watershed Council

Project Name: ________________________________ **Lake Name:** ___________________________

Surveyor Name(s): ____

SITE ID: **Date:** **Water Depth:** **Plant Community Density:**

Photo #s: **Latitude:** **Longitude:**

Plant Species Name	North	South	East	West	Abund.	Comments:
						TOTAL SPECIES:

SITE ID: **Date:** **Water Depth:** **Plant Community Density:**

Photo #s: **Latitude:** **Longitude:**

Plant Species Name	North	South	East	West	Abund.	Comments:
						TOTAL SPECIES:

SITE ID: **Date:** **Water Depth:** **Plant Community Density:**

Photo #s: **Latitude:** **Longitude:**

Plant Species Name	North	South	East	West	Abund.	Comments:
						TOTAL SPECIES: