A Shoreline Nutrient Pollution Survey on Lake Charlevoix, 2007

By Tip of the Mitt Watershed Council

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SUMMARY

During the summer of 2007, the Tip of the Mitt Watershed Council conducted a shoreline survey on Lake Charlevoix with funding provided by local contributors and Tip of the Mitt Watershed Council members. The shoreline was surveyed for nutrient pollution, though other factors that could impact the lake's water quality were also documented. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess can adversely impact the ecosystem, and indirectly pose a danger to human health. The entire shoreline of Lake Charlevoix was surveyed in kayaks to document *Cladophora* algae, a biological indicator of nutrient pollution, as well as greenbelts, bottomland vegetation, erosion, shoreline alterations, and substrates.

Data collected during the shoreline survey indicates that nutrient pollution is probably occurring in multiple locations in Lake Charlevoix. Additionally, based on past surveys, there has been an increase in nutrient pollution over time. After compiling field data and generating maps, five areas in the main basin of the lake and seven areas in the South Arm appeared to be contributing relatively more nutrient pollution. Although survey results indicate nutrient pollution along the Lake Charlevoix shoreline, factors such as wind, wave action, currents, and ground water paths make it difficult to determine pollution sources with certainty.

To achieve the full value of this survey, it is recommended that the Lake Charlevoix Association work with the Watershed Council on follow-up activities aimed at educating riparian property owners about preserving water quality, and to help them rectify any problem situations. Summary information regarding the survey should be provided to all shoreline residents along with information about what each person can do to help, but specific information for individual properties should remain confidential. Individual property owners should be contacted confidentially and encouraged to participate in identifying and rectifying any problems that may exist on their property. Ideally, shoreline surveys should be repeated every 3-5 years as shoreline ownership, management, and conditions change continually.

INTRODUCTION

Background:

During the summer of 2007, Tip of the Mitt Watershed Council staff conducted a survey on Lake Charlevoix to document shoreline conditions that potentially impact water quality. The entire shoreline was surveyed for a biological indicator of nutrient pollution called *Cladophora*, which is an alga that helps identify locations of potential nutrient pollution. Other shoreline features documented during the survey included greenbelts, bottomland vegetation, erosion, shoreline alterations, and near-shore substrate types. Funding for the survey was provided by local contributors and Tip of the Mitt Watershed Council members.

Nutrient pollution can have adverse impacts on an aquatic ecosystem, and indirectly pose a danger to human health. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess will stimulate unnatural plant growth. Increased abundance of aquatic macrophytes (higher or vascular plants) can become a nuisance to recreation in shallow areas (typically less than 20 feet of depth). An increase in algal blooms also has the potential to become a recreational nuisance when algal mats and scum are formed on the lake's surface. However, algal blooms can also pose a public health risk as some species produce toxins including hepatotoxins (toxins that cause liver damage) and neurotoxins (toxins that affect the nervous system). Excess growth of both macrophytes and algae has the potential to degrade water quality by depleting the ecosystem's dissolved oxygen stores. Plants respire at night, consuming dissolved oxygen and thus, competing with other organisms and potentially depleting the water's oxygen supply. Furthermore, as vascular plants and algae die, the aerobic activity of decomposers has the potential to deplete dissolved oxygen supplies, particularly in the deeper waters of stratified lakes.

In general, large, deep lakes such as Charlevoix are less sensitive to nutrient pollution. Large lakes with greater water volume have a bigger buffer and thus greater resistance to nutrient pollution. The large lakes tend to have greater dissolved oxygen stores and the greater volume allows for greater dilution of nutrients. By contrast, small lakes generally have smaller stores of dissolved oxygen, a lesser ability to dilute nutrients and therefore, are more susceptible to the indirect impacts of nutrient pollution. Small lakes with extensive shallow areas are at even greater risk as there are more habitats to support excessive aquatic macrophyte growth. Lake Charlevoix is one of the largest and deepest inland lakes in the State of Michigan (17,256 acres, maximum depth = ~122 feet) and thus, comparatively resilient to nutrient pollution. Additionally, Lake Charlevoix is a drainage lake with inflows and an outflow, which provides a mechanism to flush excess nutrients out of the system.

Surface waters receive nutrients through a variety of natural and cultural sources. Natural sources of nutrients include stream inflows, groundwater inputs, surface runoff, organic inputs from the riparian (shoreline) area and atmospheric deposition. Springs, streams, and artesian wells are often naturally high in nutrients due to the geologic strata they encounter and wetland seepages may discharge nutrients at certain times of the year. Cultural (human) sources include septic and sewer systems, fertilizer application in riparian areas, and stormwater runoff from roads, driveways, parking lots, roofs, and other impervious surfaces. Poor agricultural practices, soil erosion, and wetland destruction also contribute to nutrient pollution. Additionally, some cultural sources (e.g., malfunctioning septic systems and animal wastes) pose a potential health risk due to bacterial and viral contamination.

Severe nutrient pollution is detectable through chemical analyses of water samples, physical water measurements, and the utilization of biological indicators (a.k.a., bioindicators). Chemical analyses of water samples to determine nutrient pollution is effective, though costlier and more labor intensive than the other methods. Typically, samples are analyzed to determine nutrient concentrations (usually forms of phosphorus and nitrogen), but other chemical constituent concentrations can be measured, such as chloride, which are related to human activity and often elevated in areas impacted by malfunctioning septic or sewer systems. Physical measurements are primarily used to detect malfunctioning septic and sewer systems, which can cause localized increases in water temperature and conductivity (i.e., the water's ability to conduct an electric current). Biologically, nutrient pollution is commonly detected by noting the presence of *Cladophora* algae. During the Lake Charlevoix shoreline survey, only biological indicators (*Cladophora*) were used to identify potential areas of nutrient pollution.

Cladophora is a branched, filamentous green algal species that occurs naturally in small amounts in northern Michigan lakes. Its occurrence is governed by specific environmental requirements for temperature, substrate, nutrients, and other factors. It is found most commonly in the wave splash zone and shallow shoreline areas of lakes, and can also be found in streams. It grows best on stable substrates such as rocks and logs, though artificial substrates such as concrete or wood seawalls are also suitable. *Cladophora* prefers water temperatures in a range of 50 to 70 degrees Fahrenheit, which means that the optimal time for its growth and thus, detection, in northern Michigan lakes is from late May to early July, and from September and October.

The nutrient requirements for *Cladophora* to achieve large, dense growths are typically greater than the nutrient availability in the lakes of northern Michigan. Therefore, the presence of *Cladophora* can indicate locations where relatively high concentrations of nutrients, particularly phosphorus, are entering a lake. Although the size of the growth on an individual basis is important in helping to interpret the cause of the growth, growth features of *Cladophora* are greatly influenced by such factors as current patterns, shoreline topography, size and distribution of substrate, and the amount of wave action the shoreline is subject to. Therefore, the description has limited value when making year to year comparisons at a single location or estimating the relative amount of shoreline nutrient input. Rather, the presence or absence of any significant growth at a single site over several years is the most valuable comparison. It can reveal the existence of chronic nutrient loading problems, and help interpret the cause of the problems and assess the effectiveness of any remedial actions. Comparisons of the total number of algal growths can reveal trends in nutrient input due to changing land use.

According to Tip of the Mitt Watershed Council records, this survey provides the third comprehensive data set documenting shoreline nutrient pollution on Lake Charlevoix; a valuable data set that can be used as a lake management tool. Coupled with follow-up questionnaires and on-site visits, controllable sources of nutrients to the lake can be identified. Subsequently, a reduction in nutrient loading can often be achieved by working with homeowners to solve problems. These solutions are often simple and low cost, such as regular septic system maintenance, proper lawn care practices, and wise land use along the shoreline. Prevention of problem situations can also be achieved through the publicity and education associated with the survey. Periodic repetition of shoreline surveys is important for identifying chronic problem sites as well as recent occurrences. They are also valuable for determining long-term trends of near-shore nutrient inputs associated with land use changes, and for assessing the success of remedial actions.

Study area:

Lake Charlevoix is located in the northern Lower Peninsula of Michigan on the west side of Charlevoix County. A total of seven townships (Bay, Charlevoix, Evangeline, Eveline, Hayes, South Arm, and Wilson) and three cities (Boyne City, Charlevoix, East Jordan) surround the lake. Based upon hydrographic maps from the State of Michigan, the surface area of Lake Charlevoix is approximately 17,256 acres and the shoreline distance totals 60 miles. The deepest point is located near the center of the main basin and is reported to be 122 feet deep.

Stretching from northwest to southeast, Lake Charlevoix is a glacially formed lake that has two distinct arms that are separated by a peninsula. The main basin of Lake Charlevoix measures nearly 14 miles from the City of Charlevoix to Boyne City and ranges from one to two miles in width. The South

Arm, extending south from the main basin over 8 miles to East Jordan, is shallower and narrower with a maximum depth of 52 feet and widths of less than one mile.

There are two main inlet rivers and multiple small streams flowing into Lake Charlevoix. The Boyne River flows into the southeast end of the main basin and the Jordan River flows into the south end of the South Arm. These rivers are considered to be very pristine with high-quality waters and both are designated Blue Ribbon trout streams. Furthermore, the Jordan River is a Natural Scenic River as designated by the State of Michigan. Of the multitude of small inlet streams, the largest include Horton, Loeb, Porter, and Stover Creeks. The only outlet is the Pine River, located in the northwest end and flowing through Round Lake before exiting into Lake Michigan.

Mirroring the lake's directional layout, the Lake Charlevoix watershed extends from headwaters in the southeast to the outlet in the northwest (Figure 1). The Lake Charlevoix watershed covers 233,837 acres; primarily in Charlevoix County, but also extending into Antrim and Otsego Counties. It has a watershed area to lake surface area ratio of 11:1, which is a moderate ratio in relation to other lakes (e.g., Walloon Lake has a ratio of 5:1 and Huffman Lake has a ratio of 46:1). This ratio provides a statistic for gauging susceptibility of lake water quality to changes in watershed land cover; the higher the ratio, the more land per area of water and thus, the greater the buffer for protecting water quality. With an 11:1 ratio, the Lake Charlevoix watershed has a protective buffer to safeguard water quality against small areas of development. However, the cumulative impact of extensive landscape development throughout the watershed is likely to have serious adverse impacts on the lake's water quality.

According to land cover statistics from a 2000 land cover analysis the majority of the Lake Charlevoix watershed is forested (NOAA, 2003). Of land cover types that typically lead to water quality degradation, there is little urban or residential and a moderate amount of agriculture in the watershed (Table 1).

Figure 1. Map of the Lake Charlevoix watershed.

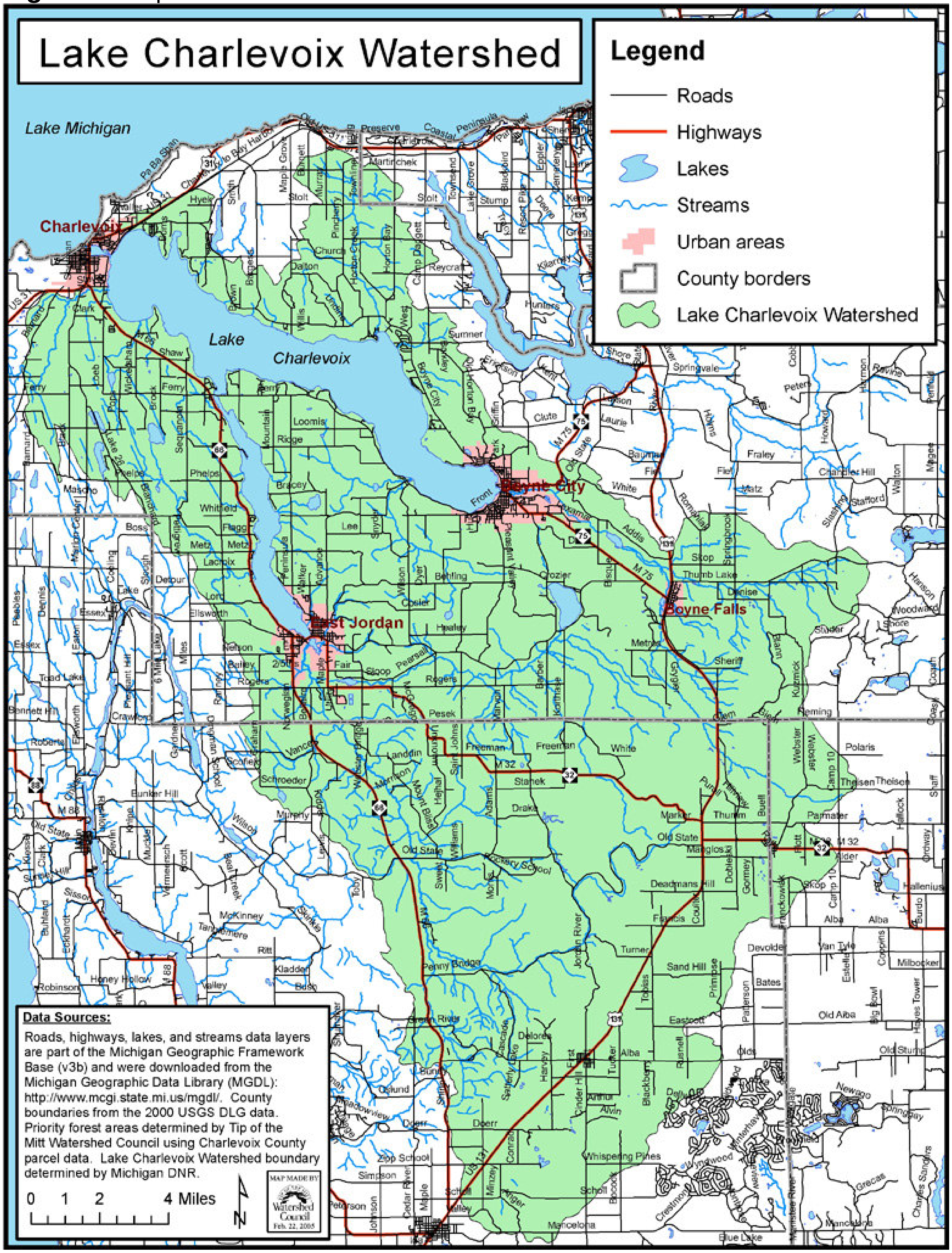


Table 1. Lake Charlevoix watershed land cover, 2000.

Land Cover Type	Acres	Percent
Agriculture	42,433	18.14
Barren	893	0.38
Forested	107,051	45.78
Grassland	27,222	11.64
Scrub/Shrub	5,769	2.47
Urban/residential	6,667	2.85
Wetland	25,175	10.76
Water	18,654	7.98

Based upon data collected in programs coordinated by Tip of the Mitt Watershed Council, Lake Charlevoix contains high quality waters that are typical for the region. As part of the Watershed Council's Comprehensive Water Quality Monitoring Program (CWQM), numerous parameters have been monitored in Lake Charlevoix on a triennial basis since 1987. Both dissolved oxygen and pH consistently comply with standards established by the State of Michigan (Table 2). Conductivity and chloride levels have increased slightly over time, which indicates that there is some impact from urban, residential and agricultural land use (Figure 2). Typical of high-quality lakes in northern Michigan, nutrient concentrations on Lake Charlevoix have been quite low (total phosphorus, nitrate and total nitrogen).

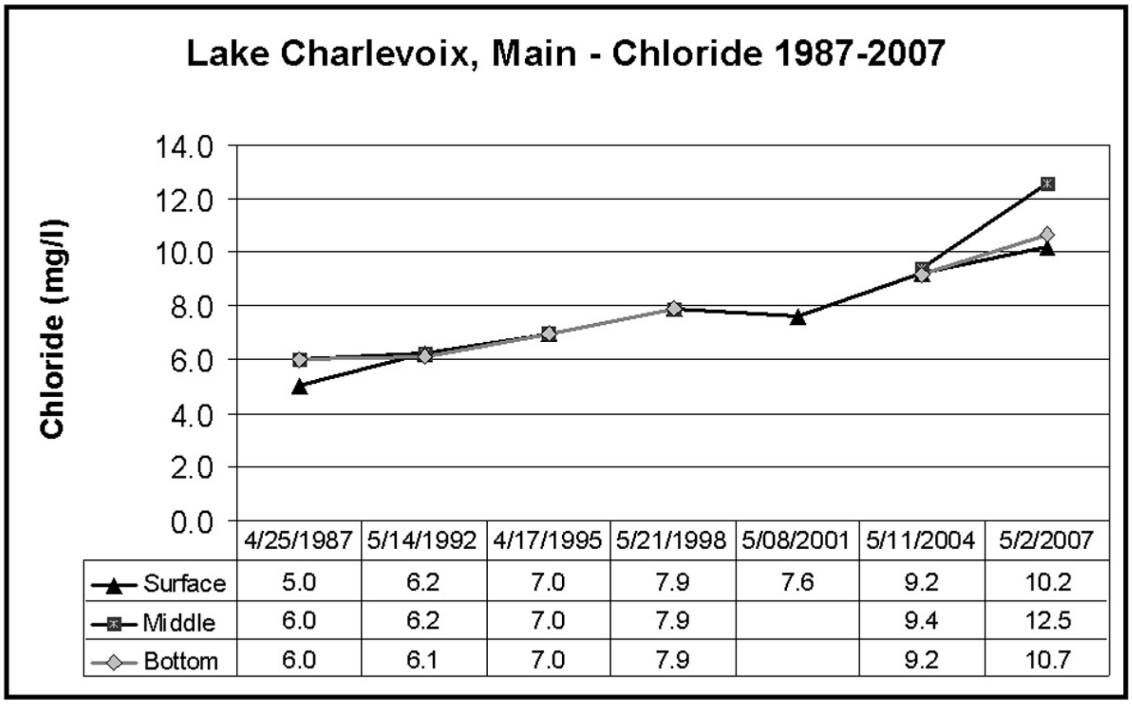
Table 2. Lake Charlevoix data from the CWQM program.

	Temperature	DO	pH	Conductivity	Chloride	Nitrate	TN	TP
Units	˚Celsius	PPM	Units	microSiemens	PPM	PPB	PPB	PPB
Average	7.71	11.92	8.00	287.06	7.49	380.00	580.00	6.8
Minimum	3.88	10.05	7.55	225.00	4.00	104.00	332.00	1.0
Maximum	15.26	13.02	8.36	321.40	12.50	571.00	910.00	20.00

*DO = dissolved oxygen, TN = total nitrogen, TP = total phosphorus, PPM = parts per million, PPB=parts per billion.

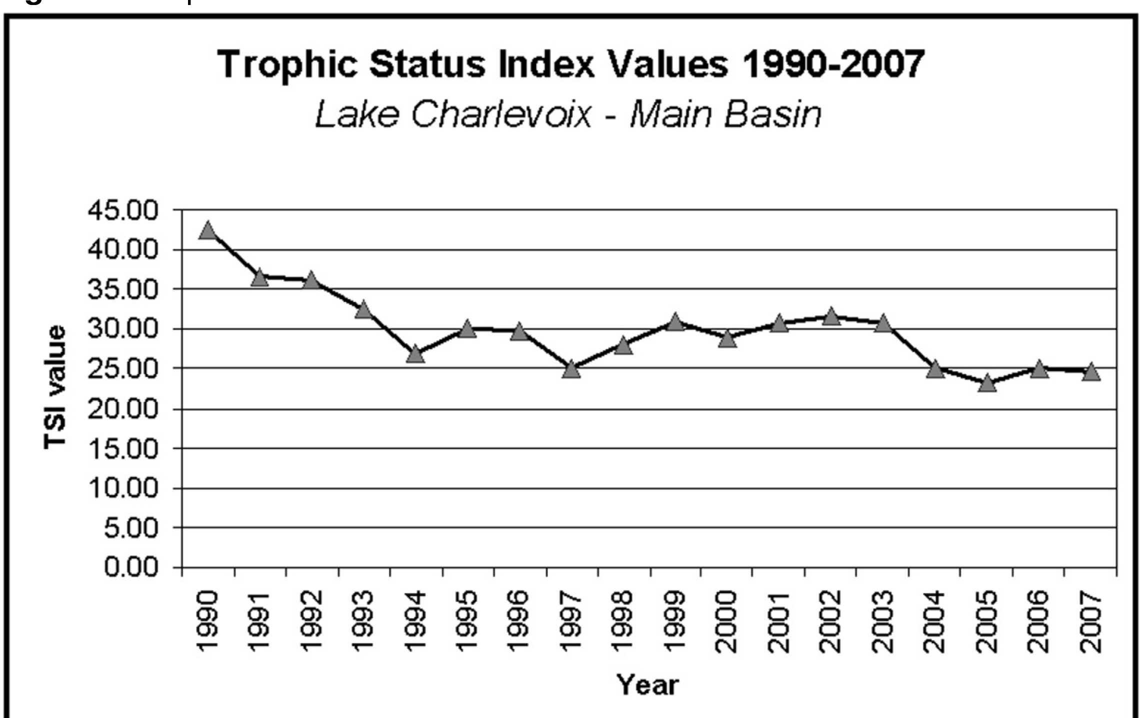
Data collected as part of Tip of the Mitt Watershed Council's Volunteer Lake Monitoring Program show Lake Charlevoix to be an oligotrophic lake. Trophic status index values, which are calculated using Secchi disc depth and chlorophyll-a concentration data, have ranged from 27 to 34 for Lake Charlevoix (Figure 3). Lakes with TSI values of 38 or less are classified as oligotrophic.

Figure 2. Chloride concentrations in Lake Charlevoix.



	4/25/1987	5/14/1992	4/17/1995	5/21/1998	5/08/2001	5/11/2004	5/2/2007
Surface	5.0	6.2	7.0	7.9	7.6	9.2	10.2
Middle	6.0	6.2	7.0	7.9		9.4	12.5
Bottom	6.0	6.1	7.0	7.9		9.2	10.7

Figure 3. Trophic status index values in Lake Charlevoix.



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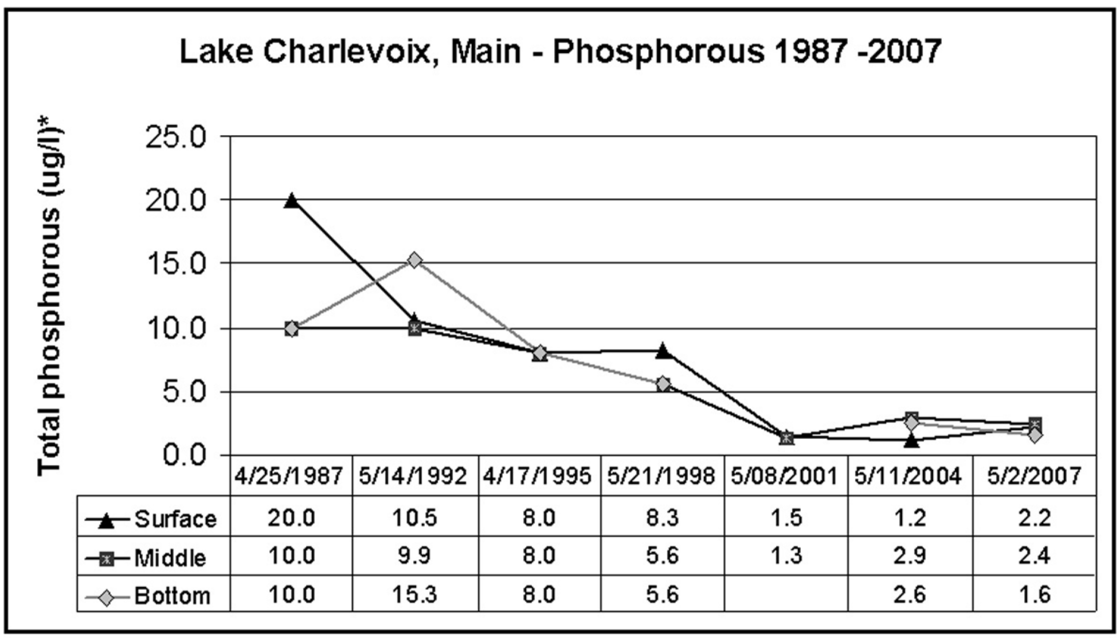
Lower values (0-38) indicate an oligotrophic or low productive system, medium values (39-49) indicate a mesotrophic or moderately productive system, and higher values (50+) indicate a Eutrophic or highly productive system.

Oligotrophic lakes are characteristically deep, clear, nutrient-poor water bodies. Phosphorus data from the CWQM program supports this characterization as concentrations have typically been less than 10 parts per billion and have been dropping since monitoring began in 1987 (Figure 4).

Decreases in the phosphorus concentrations in Lake Charlevoix occurred in conjunction with other trends in water quality data. Water clarity as measured by Secchi disc depth has been increasing over time, particularly since the early 1990s (Figure 5). In addition, algae abundance as indicated by chlorophyll-a concentrations has been dropping since the early 1990s (Figure 6). Both of these phenomena coincide closely with the introduction of zebra mussels into Lake Michigan in 1989 and the presumed migration into Lake Charlevoix shortly after, as there are no barriers separating the lakes. Zebra mussels are the probable explanation for changes in all three water quality parameters as they reduce algae abundance by filter-feeding upon phytoplanktonic algae, which increases water clarity by clearing the water column, and subsequently alters nutrient cycles that could result in decreased phosphorus concentrations.

Figure 4. Phosphorus concentrations in Lake Charlevoix.



	4/25/1987	5/14/1992	4/17/1995	5/21/1998	5/08/2001	5/11/2004	5/2/2007
Surface	20.0	10.5	8.0	8.3	1.5	1.2	2.2
Middle	10.0	9.9	8.0	5.6	1.3	2.9	2.4
Bottom	10.0	15.3	8.0	5.6		2.6	1.6

*ug/l = micrograms/liter = parts per billion

Figure 5. Average Secchi disc depths in Lake Charlevoix.

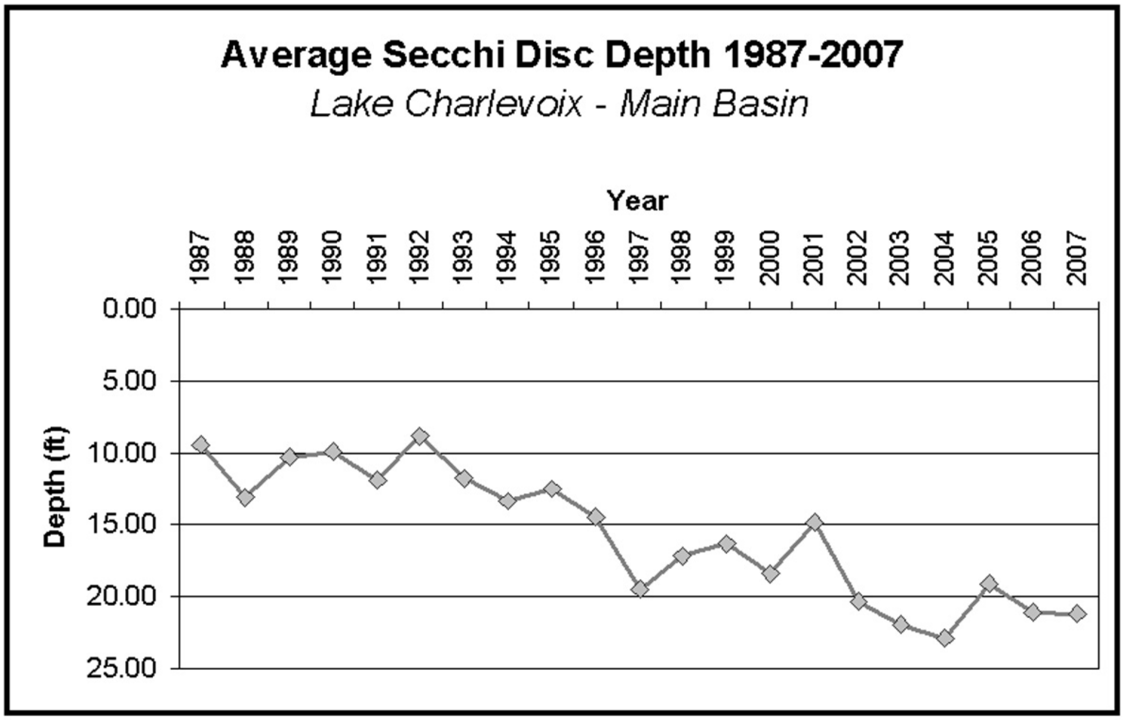
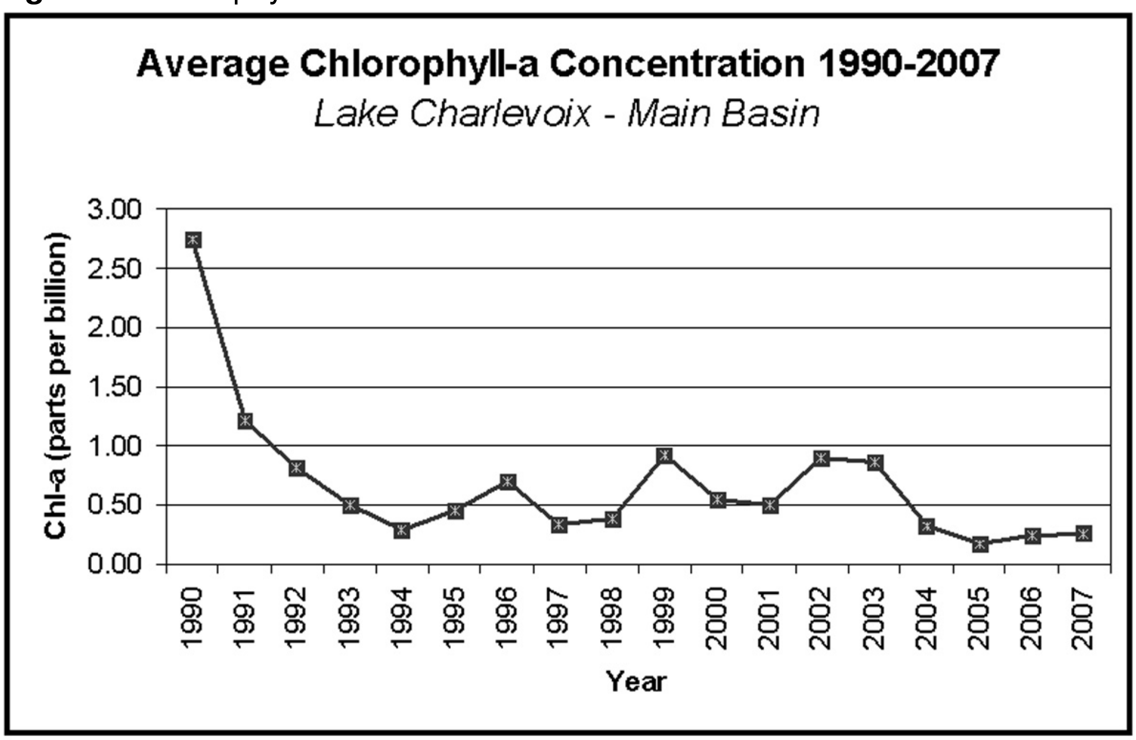


Figure 6. Chlorophyll-a concentrations in Lake Charlevoix.



*ug/l = micrograms/liter = parts per billion

METHODS

The entire Lake Charlevoix shoreline was surveyed in kayaks from June 25, 2007 to August 8, 2007 to document signs of nutrient pollution and shoreline features. Traveling as close to the shoreline as possible (usually within 20 feet), nearshore areas were examined for the presence of *Cladophora.* Shoreline features were noted for each parcel and each parcel was photographed with a digital GPS camera. Shoreline features noted included greenbelts, bottomland vegetation, erosion, shoreline alterations, and substrate types. All information was recorded on field data sheets, subsequently inputted into a database, and used in conjunction with GPS data to link field data and photographs with parcel (equalization) data.

Nutrient Pollution Indicators

Many species of filamentous green algae are commonly found growing in the nearshore regions of lakes. Positive identification of these species usually requires the aid of a microscope. However, *Cladophora* typically has an appearance and texture that is quite distinct to a trained surveyor, and these were the sole criteria upon which identification was based.

Other species of filamentous green algae can respond to an external nutrient source in much the same way as *Cladophora*, although their value as an indicator species is not thought to be as reliable. When other species occur in especially noticeable, large, dense growths, they are recorded on the survey maps and described the same as those of *Cladophora*.

Among other things, the distribution and size of each *Cladophora* growth is dependent on the amount of suitable substrate present. The extent of suitable substrate should therefore be taken into account when interpreting the occurrence of individual growths, and assessing the overall distribution of *Cladophora* along a particular stretch of shoreline. The presence or absence of suitable *Cladophora* growth substrate was determined by substrate types recorded during the survey.

In the database, properties with habitat suitable for *Cladophora* growth on their shorelines were listed as “yes” and those without any habitat listed as “no”.

When *Cladophora* was observed, it was described in terms of the shoreline length of the growth, relative growth density, and observed shoreline features potentially contributing to the growth. Shoreline length and growth density are subjective estimates. Growth density is determined by estimating the percentage of substrate covered with *Cladophora.* The categories and determinations for growth density are as follows:

Table 3. Categories and determinations for *Cladophora* density.

Density Category	Field Notation	Substrate Coverage
Very Light	(VL)	0% *
Light	(L)	1- 20%
Light to Moderate	(LM)	21-40%
Moderate	(M)	41-60%
Moderate to Heavy	(MH)	61-80%
Heavy	(H)	81-99%
Very Heavy	(VH)	90-100% *

**Very Light is noted when a green shimmer is noticed on hard substrate, but no filamentous growth present. Very Heavy overlaps with heavy and is distinguished by both high percentage of substrate coverage and long filamentous growth.*

Shoreline Features

Shoreline property features were documented by taking pictures with a Ricoh Caplio Pro G3 GPS camera and by noting property features on a data sheet, such as building descriptions, public access sites, and county road endings. Due to data sheet space limits, building descriptions were recorded in an abbreviated cryptic style. For example, *Red 2 sty, brn rf, wht trm, fldstn chim, lg pine* means that the property has a red two-story house with a brown roof, white trim, fieldstone chimney, and a large pine tree in the yard. Whenever possible, names of property owners and addresses were included.

Developed versus undeveloped parcels were noted during the survey and included as a separate column in the database. Properties described as developed indicate the presence of buildings or other significant permanent structures, including roadways, boat launching sites, and recreational properties (such as parks with pavilions and parking lots). Properties with only mowed or cleared areas, seasonal structures (such as docks or travel trailers), or unpaved pathways were not considered developed. Additionally, relatively large parcels that may have development in an area far from the water's edge were not considered developed. The length and area of developed versus undeveloped shoreline was not calculated.

Greenbelt information was documented during the survey above and below the ordinary high water mark. Greenbelts are vegetated areas along the shoreline that are the critical interface between land and water and which provide many benefits to the lake ecosystem. During this survey, greenbelts were rated based on length and depth. Greenbelt lengths were described using a numbering system representing the percentage of shoreline for a given property that had a greenbelt of any size (depth). Turf grass was not considered as greenbelt. Greenbelt depths were described with a numbering system based on the average distance that the greenbelt extended from the water's edge landward. Due to low lake levels it was necessary to distinguish between greenbelts both above and below the ordinary high water mark on many parcels. Therefore, where applicable greenbelts below the high water mark were rated based on length and depth and referred to as "bottomland vegetation" in the database. The numbering systems used to describe greenbelt and bottomland vegetation length and depth are as follow:

<u>Greenbelt Length:</u> 0 = none, 1 = less than 10% of shoreline, 2 = 10 to 25%, 3 = 25 to 75% and 4 = over 75%.
<u>Greenbelt Depth:</u> 1= less than 10 feet, 2 = 10 to 40 feet, 3 = greater than 40 feet.

All greenbelt and bottomland vegetation data represent approximations as lengths and depths were estimated rather than measured.

Shoreline alterations were recorded on field data sheets during the survey and entered into the database. Alterations to the lake shore have the potential to impact water quality in a variety of ways including the loss of riparian vegetation, degraded habitat in nearshore areas, and erosion. Shoreline alterations (structures) were noted with the following abbreviated descriptions:

BB = boulder bulkhead
CB = concrete bulkhead
O = other
RR = rock rip-rap
S = sand beach
SB = steel bulkhead (i.e., seawall)
WB = wood bulkhead

Sometimes abbreviations were mixed or vary from what is listed above. “Other” included features such as drainpipes or boathouses, which were noted in the “comments” column. In addition, any erosion observed on the shoreline was noted and included in a separate column in the database as being present or absent.

Substrate or bottom type is an important shoreline feature to document during nutrient pollution surveys because *Cladophora* growth is generally limited to hard substrates, such as rock, gravel and wood. In areas without hard substrate, such as sand and muck, *Cladophora* cannot be used as a reliable indicator of nutrient pollution. Thus, documenting substrate type aids in the evaluation of shoreline survey nutrient pollution data. Shoreline area substrates were noted on field data sheets using the following categories and abbreviations:

MK = muck
S = sand (0.1" diameter or less)
G = gravel (0.1" to 2.5" diameter)
R = rock (2.5" to 10" diameter)
B = boulder (10” or greater diameter)
WD = wood

If multiple substrate types were present along the shoreline of a parcel, then all were noted. The database contains separate columns for each substrate type.

Erosion was documented simply by noting the presence or absence of accelerated shoreline erosion. Erosion generally appears as areas of bare soil along the shoreline, leaning or downed trees or trees with exposed roots, undercut banks, slumping hunks of sod, and excessive deposits of sediments. Additional information about the nature of the erosion, such as relative severity (slight, moderate, or severe), height and length of bank, whether it occurs at the toe or the top of the bank, type of soils, rate of recession, and obvious causes, may have been included in the comments column.

Tributaries are one of the primary conduits through which water is delivered to a lake or river from its watershed. Tributaries also carry and deliver a variety of materials from throughout the watershed to the receiving water. This can include pollutants such as sediment, nutrients, bacteria, and toxins from human activities far removed from a lake or river. *Cladophora* growths and elevated conductivity levels often occur at the mouth of tributaries. Therefore, tributary streams were noted during the survey and included in a "tributary" column in the database. In addition, maps and aerial photographs were used to identify additional tributaries that were not noted during the field survey.

Additional information regarding shoreline property features or nutrient pollution that was written on field data sheets was also inputted into the database. This information was added to a column entitled "comments".

Data Processing

Upon completing field work, all field data was transferred to computer. Information recorded on field data sheets was inputted into a Microsoft Access® database. Digital photographs and GPS data were uploaded to a computer at the Watershed Council office and processed for use.

The database containing field sheet data, GPS data, digital photographs and county equalization data were all linked together in a Geographical Information System (GIS) to perform spatial analyses of data and develop maps. Parcel data acquired from the Charlevoix County GIS Department was used to produce a new GIS data layer of Lake Charlevoix shoreline parcels. Using GPS data points and digital photographs for guidance, field survey data from the database were joined to the county parcel data layer. Digital photographs were renamed to correspond to unique numbers assigned to shoreline parcels and linked to the shoreline parcel GIS data layer. The GIS data layer containing both field survey and equalization data was overlaid with other spatial data from the State of Michigan to produce the maps contained in this report.

Final products include a comprehensive database, a complete set of digital GPS photographs, and a GIS data layer of shoreline parcels. The shoreline survey database contains a sequential listing of properties beginning at the southern bank of the outlet to Round Lake (Belvedere Club) and traveling counter-clockwise around the entire perimeter of the lake. The database contains all data collected in the field and identification numbers in the database correspond to those in the GIS data layer and on the hard-copy map. Digital photographs were named using the same identification numbers and are linked to the GIS data layer.

RESULTS

This survey documented shoreline conditions at 1,694 land parcels on Lake Charlevoix. Some portion of the shoreline was developed at 1,442 of these parcels (85%). Habitat generally considered suitable for *Cladophora* growth was present along at least part of the shoreline of 1,336 properties (79% - Figure 7). Noticeable growths of *Cladophora* or other filamentous green algae were found along the shoreline of 288 parcels (17% - Figures 8, 9, & 10).

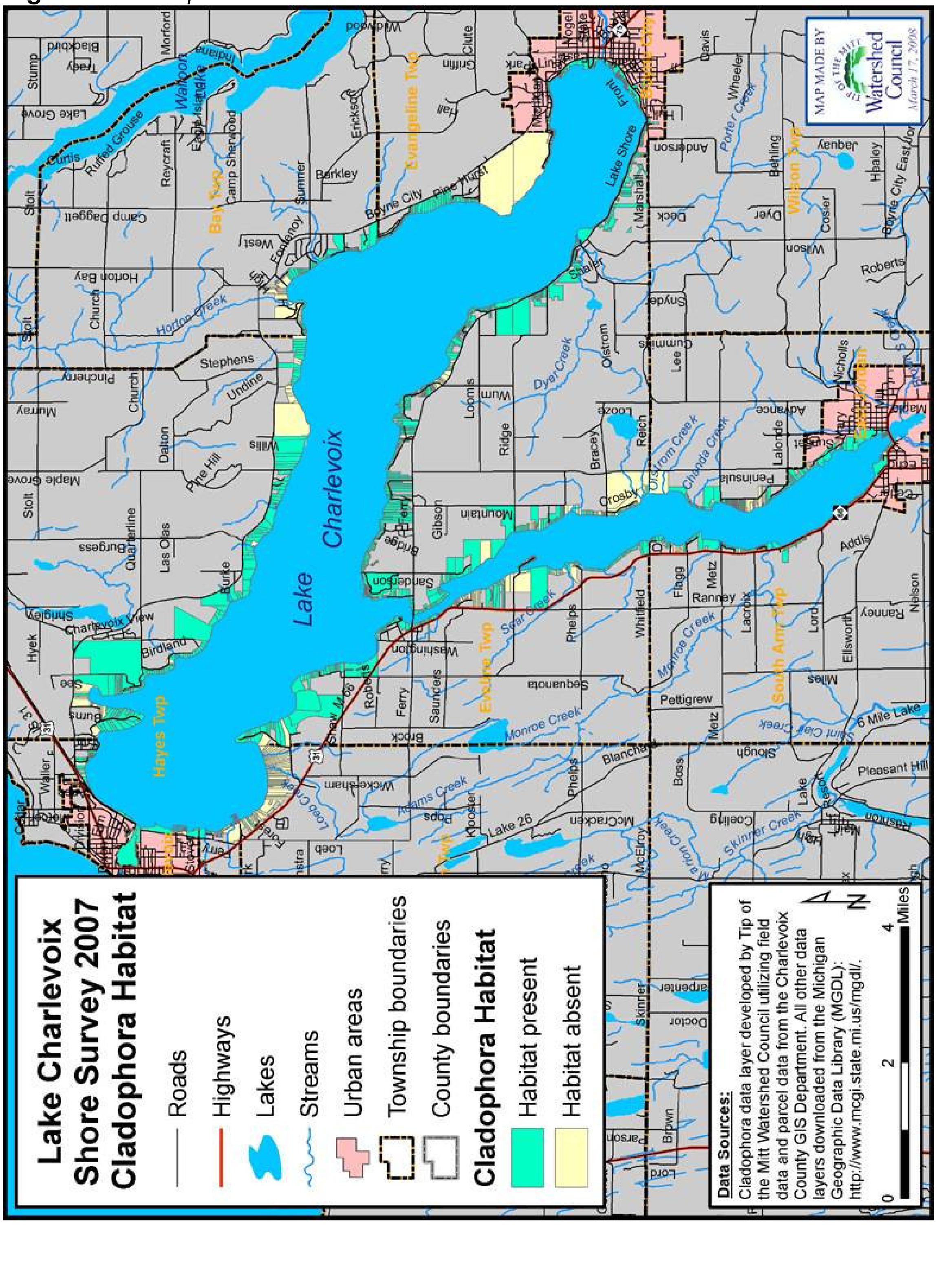
In the field *Cladophora* growth densities were noted in seven different categories, but subsequently reduced to three categories to facilitate data examination. At properties where *Cladophora* growth was observed, there were an equal number of light and moderate growths (Table 4). Over 20% of observed growths were in the heavy category, of which nearly half were very heavy. Most of the *Cladophora* growths were associated with developed shoreline properties (~93%).

Table 4. *Cladophora* growth density statistics for shoreline properties.

Density Category	Number of Properties	Percent of Properties
Light	114	39
Moderate	114	39
Heavy	60	22

There were shoreline areas where occurrences of *Cladophora* were clustered together. Maps displaying field survey data for shoreline parcels on Lake Charlevoix were reviewed to determine patterns in the occurrence of *Cladophora* growth (Figure 3). In the main basin the greatest concentration of parcels with *Cladophora* growth occurred at the following locations: along the east side of Twomile Point (Evergreen Point Drive), between Spring Road to Sho Sho Nie Beach Road to the southeast of Horton Bay, on Lakeshore Drive and Cedar Street to the west of Advance, along Glean Beach Road to the northeast of Boyne City, and throughout much of the shoreline in the Boyne City area. In the South Arm, *Cladophora* growths were grouped in these locations: at the narrows on the

Figure 7. *Cladophora* habitat on the Lake Charlevoix shoreline.



north end along both shores, just south of the narrows on the east side along Sanderson Road, Holy Island, the east side between Gaunt and Bracey Roads, on the east side along Lalonde Road, on the west side between Metz and Lacroix Roads, on the west side from Lord Road south to the East Jordan city limit, and in East Jordan in the embayment just north of the M32 bridge. Of these grouped occurrences of *Cladophora,* the heaviest and therefore, most alarming growths occurred in the main basin to the west of Advance and in the Boyne City area and in the South Arm from Lord Road south to the East Jordan city limit.

Based on statistics from past surveys, there has been an increase in the occurrence of *Cladophora* along the Lake Charlevoix shoreline. According to databases stored at Tip of the Mitt Watershed Council office, *Cladophora* was documented at 175 of 1625 parcels (~11%) in 1996 and 259 of 1619 parcels (16%) in 2000. Although the total number of parcels varied over time due to changes in technology (e.g., GPS and GIS), there was a noticeable increase (~6%) in the percentage of parcels with *Cladophora* over time. *Cladophora* densities for the 1996 and 2000 surveys were not recorded in the database and therefore, cannot be compared between time periods.

Greenbelts and bottomland vegetation observed and rated during the Lake Charlevoix shoreline survey were found to be in good shape, though there is room for improvement. Nearly 50% of all shoreline parcels had greenbelts along over 75% of their shorelines (Table 5). Of the 1,254 parcels with exposed bottomlands, over 50% maintained vegetation over 75% of the shoreline length. Greenbelt depths were, on average, greater than 10 feet on over 60% of the shoreline parcels. The percent of parcels with an average depth of greater than 10 feet was less for bottomland vegetation, but still approaching 50%. Over 20% of parcels had no greenbelts and approximately 25% of parcels with exposed bottomlands had removed the vegetation.

Table 5. Greenbelt statistics for shoreline properties.

Rating**	GB* Length Count	GB* Length Percent	GB* Depth Count	GB* Depth Percent	BV* Length Count	BV* Length Percent	BV* Depth Count	BV* Depth Percent
0	388	22.90	388	22.90	326	26.00	324	25.84
1	172	10.15	273	16.12	68	5.42	331	26.40
2	197	11.63	387	22.85	109	8.69	289	23.05
3	185	10.92	646	38.13	119	9.49	310	24.72
4	752	44.39			632	50.40		
NA					440	-------	440	-------

*GB = greenbelt, BV = bottomland vegetation.
**Rating descriptions: Greenbelt Length: 0=none, 1 = less than 10% of shoreline, 2 = 10 to 25%, 3 = 25 to 75% and 4 = over 75%. Greenbelt Depth: 1= less than 10 feet, 2 = 10 to 40 feet, 3 = greater than 40 feet. NA = not applicable due to lack of bottomlands.

Some form of shoreline alteration was noted at 1,038 (61%) of properties surveyed (Table 6). Most shoreline alterations consisted of riprap.

Table 6. Shoreline alteration statistics for shoreline properties.

Alteration Type	Number of parcels	Percent
Big boulder	9	13.24
Riprap	32	47.06
Riprap and wood	7	10.29
Wood	2	2.94
Barrels	2	2.94
None	16	23.53
Total	68	100.00

Sand was the most common nearshore substrate type on the Lake Charlevoix shoreline, followed by rock and then, gravel (Table 7). The least common substrate types were wood and “other”, which primarily consisted of clay. A total of 358 parcels (21%) did not have substrates suitable for *Cladophora* growth as they consisted of only sand and/or muck. This 21% of parcels without hard substrate require other field methods for detecting nutrient pollution.

Accelerated erosion was noted at 156 properties along the Lake Charlevoix shoreline. The severity of erosion at these properties was not noted, but may be evident in photographs taken during the survey.

A total of 41 tributary streams were noted during the survey or identified using maps and aerial photographs. The largest include the Boyne and Jordan Rivers as inlet tributaries and the Pine River as the only outlet. Other sizable

Table 7. Nearshore substrate type statistics for shoreline properties.

Substrate type	Number of parcels	Percent
Sand	1391	82.11
Gravel	925	54.60
Rock	1047	61.81
Boulder	241	14.23
Muck	337	19.89
Wood	37	2.18
Other	8	0.47

streams include Sear, Monroe, Chanda and Ostrum Creeks in the South Arm and Stover, Loeb, Porter, and Horton Creeks in the main basin. According to maps, there were a few more inlet tributaries, but these were not observed during the survey or visible on aerial photographs.

Figure 8. Lake Charlevoix Shore Survey 2007 results in west basin.

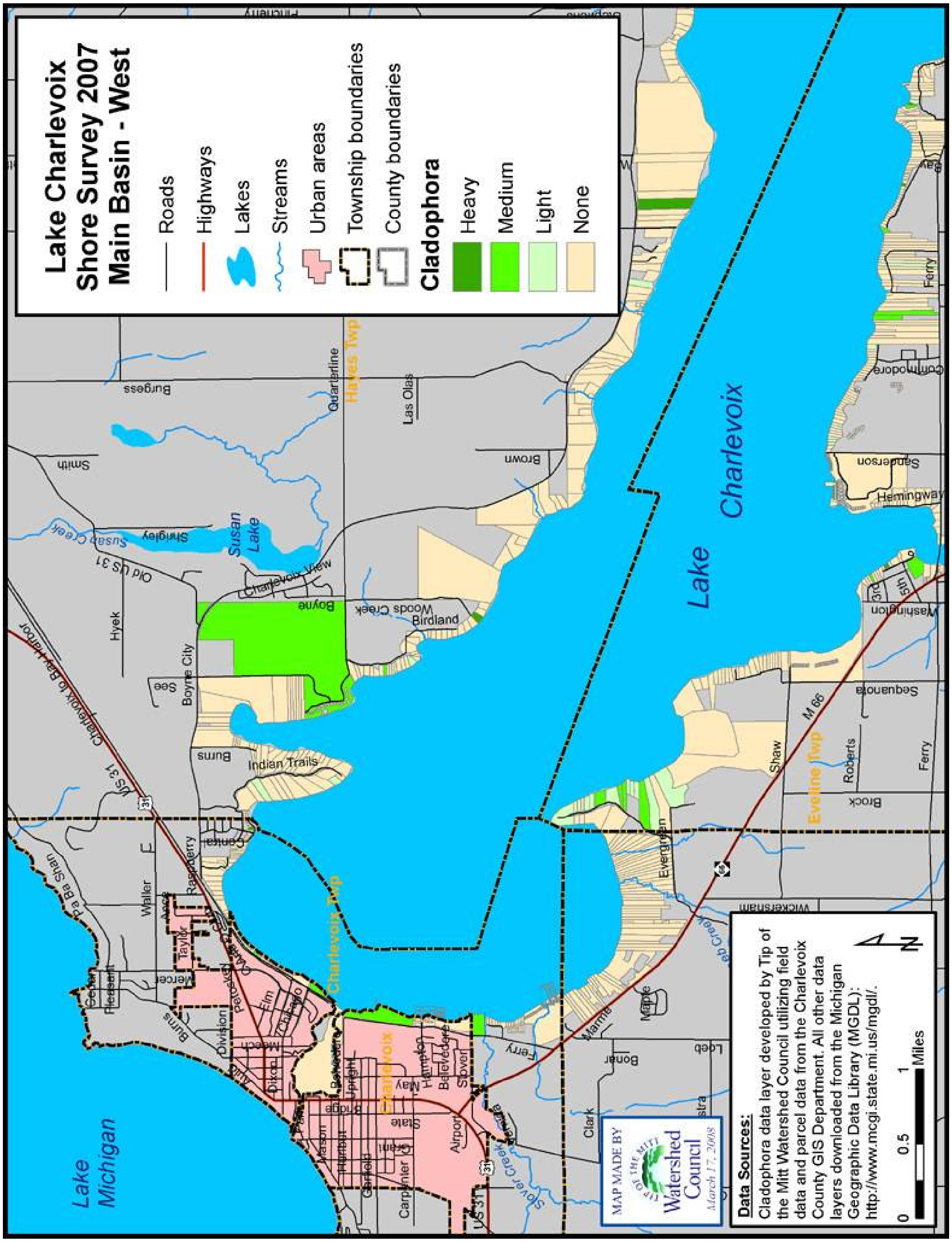


Figure 9. Lake Charlevoix Shore Survey 2007 results in east basin.

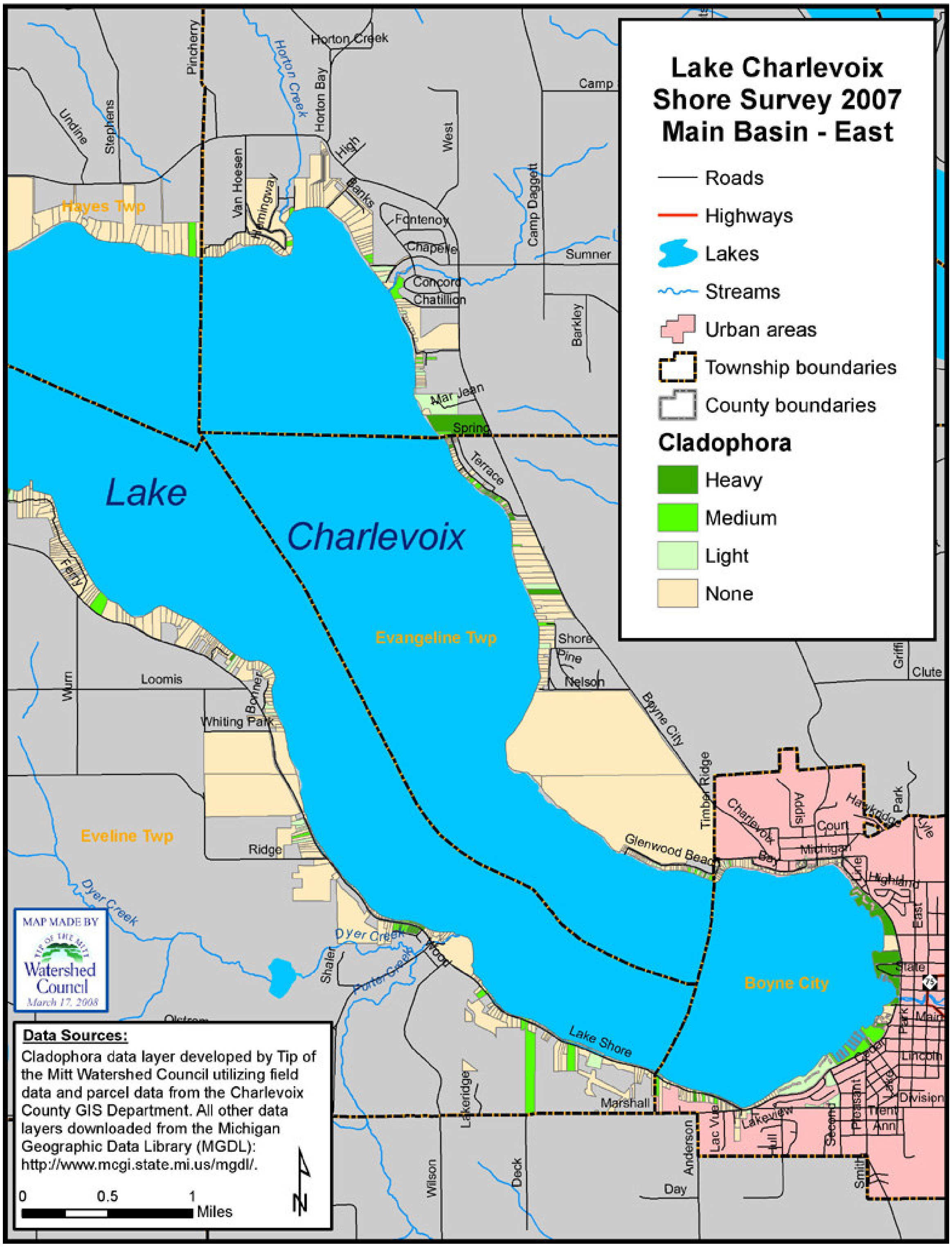
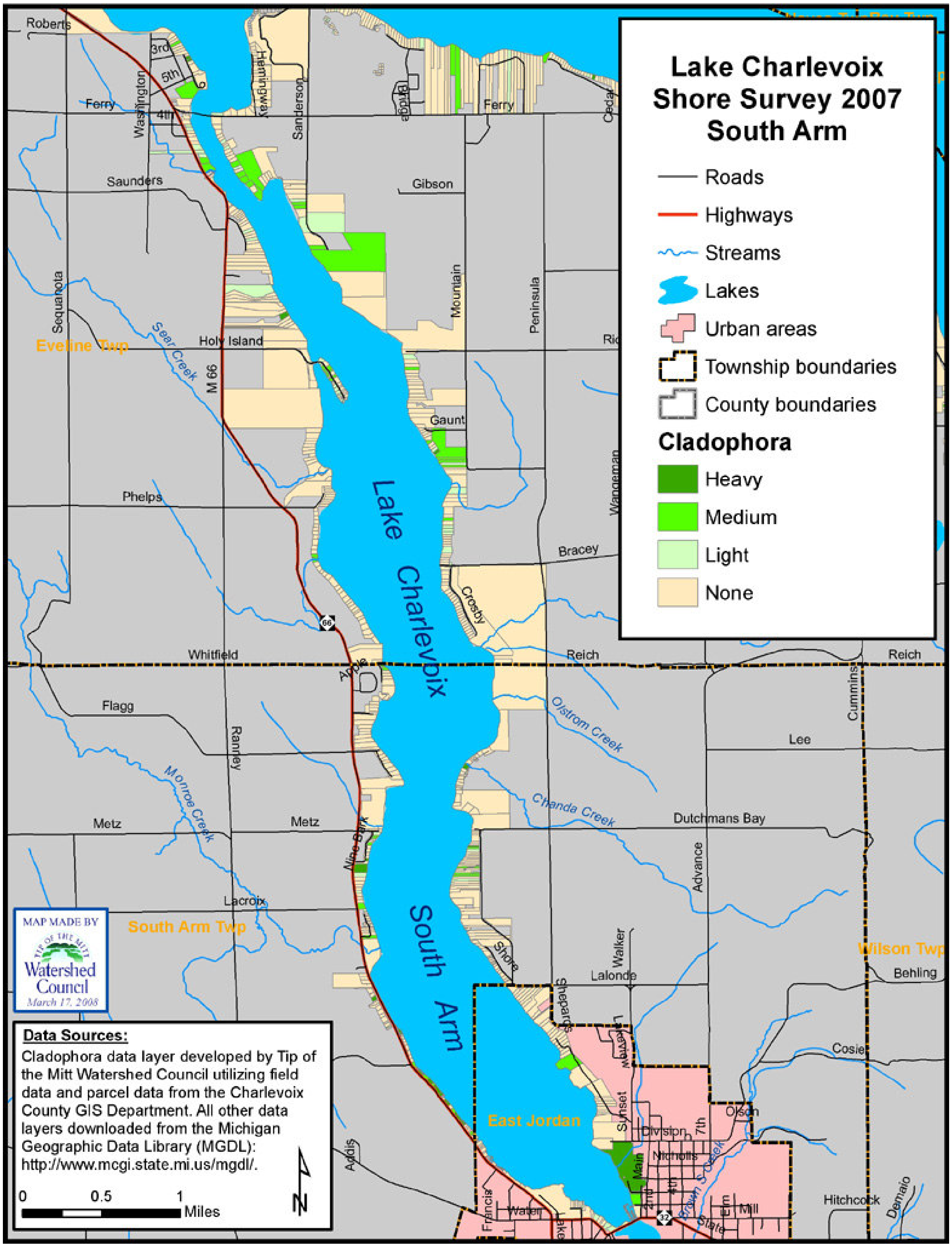


Figure 10. Lake Charlevoix Shore Survey 2007 results in South Arm.



DISCUSSION

Several areas along the Lake Charlevoix shoreline show evidence of nutrient pollution. Some areas of heavy *Cladophora* growth are undoubtedly associated with septic system leachate or other factors associated with development and human activities while others are probably due to natural factors. There are streams, springs and seeps flowing into Lake Charlevoix at different points along the shoreline that may be delivering nutrients that naturally increase algal growth.

Water quality data do not show evidence of nutrient pollution occurring in Lake Charlevoix, but interpreting such data has become complicated due to aquatic invasive species and consequent ecosystem changes. Nutrient pollution typically increases phosphorus levels, which leads to algal blooms that, in turn, reduce water clarity. Although shoreline survey results indicate that nutrient pollution is occurring, data from Tip of the Mitt Watershed Council water quality monitoring programs show trends of decreasing phosphorus concentrations, greater water clarity, and less phytoplanktonic algae. Unfortunately, parameters monitored in the Watershed Council programs are no longer reliable nutrient pollution indicators for Lake Charlevoix due to ecosystem disruptions caused by invasive mussels. Zebra mussels abound in Lake Charlevoix and quagga mussels may also be present as they are now quite common in Lake Michigan. These mussels alter ecosystem processes and nutrient cycles by filter-feeding heavily upon phytoplanktonic algae, which clears the water column, increases water transparency and results in phosphorus being pulled out of the water column and deposited on the lake bottom. Thus, water quality monitoring data do not support, yet neither do they refute results of the shoreline survey.

Definitively determining nutrient pollution sources is difficult due to a variety of factors including wind, wave action, currents, and groundwater paths. In some cases, a shoreline area may experience heavy *Cladophora* growth despite a property owner's best intentions and efforts to control and eliminate nutrient pollution sources. Winds and currents could deliver nutrients from adjacent parcels, a stream or river in the area could be delivering high levels of nutrients as compared to those typical of the lake, or groundwater seeps could be releasing abnormally high levels of nutrients along the shoreline. Despite all the potentially complicating factors, heavy *Cladophora* growth can usually be attributed to human activities in the immediate area.

One of the Lake Charlevoix shoreline areas with the strongest indication of nutrient pollution is that along Boyne City. The *Cladophora* growth in the Boyne City area may be partially due to natural factors, particularly the discharge from the Boyne River. However, the extent of dense *Cladophora* growth indicates that there are other sources of nutrients. Being an urban area, stormwater runoff is highly suspected as a source. In addition, effluent from the Boyne City Waste Water Treatment Plant is discharged into Lake Charlevoix just to the west of the city. Prevailing winds from the northwest probably carry this effluent back to Boyne City shoreline areas and, in spite of regulations to limit nutrient concentrations in effluent, the sheer volume may be enough to stimulate *Cladophora* growth in nearby shoreline areas.

Other areas with seemingly heavy *Cladophora* growth include a relatively short stretch of shoreline to the west of Advance and the shoreline area in the southwest corner of the South Arm, just north of East Jordan city limits. Similar to Boyne City, algae growth in the Advance area might be stimulated by relatively high levels of nutrients in discharge from nearby Porter Creek. However, the area of heavy algae growth was documented to the west and therefore, upwind, of the creek mouth. Land management practices at multiple residences in the area could also be contributing nutrients. In the case of the shoreline area in the southwest corner of the South Arm, field observations suggest that malfunctioning septic systems may be the cause of the algae growth.

Recommendations

The full value of a shoreline survey is only achieved when the information is used to educate riparian property owners about preserving water quality, and to help them rectify any problem situations. The following are recommended follow-up actions:

1. Keep the specific results of the survey confidential (i.e., do not publish a list of sites where filamentous algae or other problems were found) as some property owners may be sensitive to publicizing information regarding their property.

2. Send a general summary of the survey results to all shoreline residents, along with a packet of informational brochures produced by the Watershed Council and others to provide information about dangers to the lake ecosystem and public health as a result of nutrient pollution as well as practical, feasible, and effective actions to protect water quality. This would cost approximately $5 to $25 per household, depending on the complexity and type of materials distributed.

3. Inform owners of properties with *Cladophora* growths of the specific results for their property, ask them to fill out a questionnaire in an attempt to interpret causes of the growth, and offer individualized recommendations for water quality protection. Following the questionnaire survey, property owners have the option to contract the Watershed Council to perform site visits and even conduct ground water testing in an effort to gain more insight into the nature of the findings. Again, it should be stressed that all information regarding names, specific locations, and findings be kept confidential to encourage property owner participation in this project.

4. Survey lakeshore areas without *Cladophora* habitat using other techniques or equipment, such as the Watershed Council's "septic leachate detector". The map of *Cladophora* habitat developed during this project can help identify areas in need of additional survey work. Using the septic leachate detector in sandy and mucky shoreline areas will help locate additional nutrient pollution sources.

5. Repeat some version of the survey periodically (ideally every 3-5 years), coupled with the follow-up activities described previously, in order to promote water quality awareness and good management practices on an ongoing basis. During each subsequent survey, more information about shoreline features can be added to the database. The database will also facilitate future surveys, resulting in a reduction of staff hours needed for repeating the survey, and can be utilized for other water resource management applications.

6. Verify links made between shore survey results and land parcel data to ensure that information is being properly reported. Shoreline residents can assist the Watershed Council in determining if house descriptions in survey database match correctly with County land owner information. By doing so, property owners will receive the correct information regarding their parcel. This information is also useful for empowering the lake association to monitor shoreline activities, recruit new members, and compile and manage other water resource information.

7. Continue to support the Tip of the Mitt Watershed Council Volunteer Lake and Stream Monitoring programs by providing volunteer help. The information collected by volunteers is extremely valuable for identifying water quality issues and evaluating long-term trends. The Lake Charlevoix Association is encouraged to continue promoting these volunteer programs

among its members to ensure a steady supply of volunteer help. Volunteers should attend training sessions held by the Watershed Council to learn methodologies, so that complete and quality data is being collected. In addition, the Lake Charlevoix Association should continue funding the collection of phosphorus data by the volunteer lake monitors.

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