Lake Charlevoix Shoreline Survey 2012

By Tip of the Mitt Watershed Council

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SUMMARY

Shoreline property management practices can negatively impact water quality and lake health. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess can adversely impact an aquatic ecosystem. Greenbelts provide many benefits to the lake ecosystem, which are lost when shoreline vegetation is removed. Erosion and shoreline alterations (seawalls, rip-rap, etc.) both have the potential to degrade water quality. During the late spring of 2012, the Tip of the Mitt Watershed Council conducted a comprehensive survey on Lake Charlevoix to document and assess shoreline conditions. The following parameters were surveyed for all individual properties: algae as a biological indicator of nutrient pollution, greenbelt status, shoreline erosion, shoreline alterations, nearshore substrate types, and stream inlets and outlets. The survey was funded by the Charlevoix County Community Foundation.

Survey results indicate that human activity along the Lake Charlevoix shoreline is likely impacting the lake ecosystem and water quality. *Cladophora*, an algal nutrient pollution indicator, was noted at over 20% of shoreline properties, of which 19% consisted of heavy growth (i.e., a strong indication of nutrient pollution). Approximately 46% of greenbelts on shoreline properties were found to be in poor condition, though 17% were in excellent condition. Moderate to severe erosion was documented at 14% of properties and nearly 80% had altered shorelines. Relative to other lakes in the region, Lake Charlevoix had a high percentage of properties with erosion and altered shorelines and a lower percentage with heavy *Cladophora* algae growth and poor greenbelts.

Numerous best management practices have been developed that help minimize negative impacts to water quality. A buffer of diverse, native plants can be maintained along the shoreline to filter pollutants and reduce erosion. Impacts from stormwater runoff can be reduced using rain barrels, rain gardens, grassy swales, and many other techniques. Leachate reaching the lake from septic systems can be minimized through regular maintenance. Improving shoreline property management will help protect water quality, strengthen the fisheries, and improve the quality of living and recreating on the lakes.

To achieve the full value of this survey, the association should engage in follow-up activities, including: 1) Educate riparian property owners about protecting water quality; 2) Send a survey summary to all shoreline residents along with information about what each person can do to help; 3) Contact property owners confidentially to encourage them to participate in identifying and rectifying any problems that exist on their property; and 4) Organize an informational session to present survey results and best management practices that help protect and improve lake water quality.

INTRODUCTION

Background:

Shoreline surveys are an important lake management tool used extensively on lakes in the Northern Lower Peninsula of Michigan. These surveys involve assessing shoreline properties to document conditions or activities that have the potential to affect water quality and the lake ecosystem. Shoreline surveys commonly include and assessment of: *Cladophora* algae growth as a nutrient pollution indicator, erosion, alterations (e.g., seawalls), greenbelts, emergent aquatic plants, wetlands, and tributary inlets and outlets. Periodic repetition of shoreline surveys is important for identifying new and chronic problem sites, determining long-term trends in near-shore nutrient inputs, greenbelts, erosion, and shoreline alterations associated with land-use changes, and for assessing the success of remedial actions. Prior shoreline surveys on Lake Charlevoix were conducted in 1996, 2000, and 2007.

The Lake Charlevoix Association sponsored the 1996 survey, which included all lakeshore properties. *Cladophora* was documented at 175 properties and questionnaires were sent to property owners with a response rate of 33%. Likely causes of *Cladophora* growth were determined to be: 1. surface or wetland drainage or groundwater seepage (31%), 2. septic systems (24%), 3. unknown (22%), 4. lawn fertilization (10%), 5. residual septic system effects (10%), and 6. waterfowl (3%).

The 2000 survey was funded by a grant from the Michigan Department of Environmental Quality and the U.S. Environmental Protection Agency, with funding contributions by the Lake Charlevoix Association and the Watershed Council. The entire shoreline was surveyed for *Cladophora* growths, which were found at 140 properties (8%). Only half of the lake was surveyed for erosion, which was observed at approximately 20% of properties. Follow-up activities were recommended, but did not occur.

The 2007 survey was funded by local contributors and the Watershed Council. All shoreline properties were surveyed for nutrient pollution, erosion, greenbelts, and alterations. The survey found *Cladophora* at 17% of properties (288), erosion at 9%, poor greenbelts at 30%, and altered shorelines at 77%. In terms of follow-up activities for the 2007 survey, letters were mailed out to all riparians to inform them of the survey and providing a code number for confidentially viewing survey results for their properties. In addition, numerous telephone consultations were provided property owners by the Watershed Council and Lake Charlevoix Association.

During the late spring of 2012, the Watershed Council completed yet another comprehensive survey of the Lake Charlevoix shoreline, providing valuable information for lake management. This survey was funded by a grant awarded to the Watershed Council by the Charlevoix County Community Foundation. Through follow-up activities, such as on-site consultations, problems in shoreline areas that threaten the lake's water quality can be identified and corrected. These solutions are often simple and low cost, such as regular septic system maintenance, shoreline plantings, proper lawn care practices, and low impact development along the shoreline. Prevention of problem situations can also be achieved through publicity and education associated with the survey.

Shoreline development impacts:

Lake shorelines are the critical interface between land and water; where human activity has the greatest potential for degrading water quality. Developing shoreline properties for residential, commercial or other uses invariably has negative impacts on the lake ecosystem. During the development process, the natural landscape is altered in a variety of ways: vegetation is removed; the terrain is graded; utilities are installed; structures are built; and areas are paved. These changes to the landscape and subsequent human activity in the shoreline area have consequences on the aquatic ecosystem. Nutrients from wastes, contaminants from cars and roads, and soils from eroded areas are among some of the pollutants that end up in and negatively impact the lake following shoreline development. Water quality and lake ecosystem impacts from developed shoreline properties can be assessed through surveys that focus on factors such as nutrient pollution, lakeshore erosion, greenbelt health, and shoreline alterations.

Nutrient pollution can create a recreational nuisance, adversely impact aquatic ecosystems, and lead to conditions that pose a danger to human health. Although nutrients are necessary to sustain a healthy aquatic ecosystem, excess can result in nuisance and potentially harmful algal and aquatic plant growth. Excessive aquatic macrophyte growth (i.e., vascular aquatic plants) and heavy algal blooms that form mats and scum at the lake's surface can become a recreational nuisance. Algal blooms 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). Furthermore, excess algal and aquatic plant growth can degrade water quality by depleting the ecosystem's dissolved oxygen stores. During nighttime respiration, plants compete with other organisms for a limited oxygen supply and the decomposition of dead algae and plant material reduces dissolved oxygen supplies due to the aerobic activity of decomposers, which is particularly problematic in the deeper waters of stratified lakes.

Large, deep lakes, such as Lake Charlevoix, are more resilient to water quality impacts caused by nutrient pollution than small lakes because they have greater water volume and therefore, greater capacity for diluting pollutants and storing dissolved oxygen. In addition, Lake Charlevoix is a drainage lake with inflows and outflows, which provide the means to flush excess nutrients out of the system. In spite of Lake Charlevoix' resilience to nutrient pollution due to lake size and flushing, unnaturally high nutrient concentrations can occur and cause problems in localized areas, particularly near sources in shoreline areas.

Surface waters receive nutrients through a variety of natural and cultural (human) sources. Natural sources of nutrients include stream inflows, groundwater inputs, surface runoff, organic inputs from riparian (shoreline) areas, 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 sources include septic and sewer systems, fertilizer application, 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. Furthermore, some cultural sources (e.g., malfunctioning septic systems and animal wastes) pose a potential health risk due to exposure to bacteria and viruses.

Severe nutrient pollution is detectable through chemical analyses of water samples, physical water measurements, and the utilization of biological indicators (a.k.a., bio-indicators). Chemical analyses of water samples to check for nutrient pollution can be effective, though costlier and more labor intensive than other methods. Typically, water 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 can be detected along the lake shore by noting the presence of *Cladophora* algae.

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. *Cladophora* 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 during the months of May, June, September, and October.

The nutrient requirements for *Cladophora* to achieve large, dense growths are typically greater than the nutrient availability in Northern Michigan lakes. Therefore, shoreline locations where relatively high concentrations of nutrients, particularly phosphorus, are entering a lake can be identified by noting the presence of *Cladophora*. *Cladophora* growth features are greatly influenced by such factors as current patterns, shoreline topography, size and distribution of substrate, and the amount of wave action on the shoreline. Therefore, the description has limited value when making year to year comparisons at a single location or estimating the relative amount of shoreline nutrient inputs. 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, 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 inputs due to changing land use.

Erosion along the shoreline has the potential to degrade a lake's water quality. Stormwater runoff through eroded areas and wave action along the shoreline carries sediments into the lake and negatively impacts the lake ecosystem in a variety of ways. Sediments clog the gills of fish, aquatic insects and other aquatic organisms. Excessive sediments smother fish spawning beds and fill interstitial spaces that provide habitat for a variety of aquatic organisms. While moving through the water column, sediments absorb sunlight energy and increase water temperatures. In addition, nutrients adhere to sediments that wash in from eroded areas.

Shoreline greenbelts are essential for maintaining a healthy aquatic ecosystem. A greenbelt consisting of a variety of native woody and herbaceous plant species provides habitat for near-shore aquatic organisms as well as terrestrial animals. Greenbelts naturally function to control erosion; stabilizing the shoreline with plant root structures that protect against wave action and ice. The canopy of the greenbelt provides shade to near-shore areas, which helps to maintain cooler water temperatures and higher dissolved oxygen levels. In addition, greenbelts provide infiltration to reduce overland surface flow carried by stormwater from rain events and snowmelt, as well as filtration of pollutants.

Shoreline property development often results in altering or hardening the lake shoreline. Seawalls, riprap, groins, boathouses, and beach sand are among the most common shoreline alterations utilized to control erosion or improve recreational lake access and use. These changes to the shoreline often result in shoreline vegetation loss and the myriad benefits associated with greenbelts. Of particular concern is the habitat loss in critical shoreline areas brought on by shoreline alterations.

Tributary streams influence a lake's water quality because they are the primary conduits of water from the watershed. Inlet streams may provide exceptionally high quality waters that benefit the lake ecosystem, but conversely have the potential to deliver polluted waters that degrade the lake's water quality. Outlet streams flush water out of the lake, providing the means to remove contaminants that have accumulated in the lake ecosystem. With regards to shore surveys, noting the location of inlet tributaries is very helpful when evaluating shoreline algae conditions because nutrient concentrations are generally higher in streams than in lakes. The relatively higher nutrient levels delivered from streams often lead to heavier *Cladophora* and other algae growth in nearby shoreline areas.

Responsible, low-impact, shoreline property development and management is paramount for protecting water quality. Maintaining a healthy greenbelt, regular septic tank pumping, treating stormwater with rain gardens, correcting erosion sites, and eliminating fertilizer, herbicide, and pesticide application are among many low-cost best management practices that minimize the impact of shoreline properties on lake water quality. Responsible stewardship on the part of shoreline property owners and living in harmony with the lake is vitally important for sustaining a healthy and thriving lake ecosystem.

Study area:

Lake Charlevoix is located in the northern Lower Peninsula of Michigan on the west side of Charlevoix County. Based upon digitization of the Lake Charlevoix shoreline using 2004 digital orthophotography, the surface area of Lake Charlevoix is approximately 17,051 acres and the shoreline distance totals 60 miles. 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.

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. Bathymetry maps from the State of Michigan show the deepest point to be 122 feet deep and located near the center of the main basin. 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. Sections of both of these rivers are considered high-quality Blue Ribbon trout streams by the Michigan Department of Natural Resources (MDNR) and the Jordan River was the first river in the state designated as a Natural Scenic River. Of the multitude of small inlet streams, the largest include Horton, Loeb, Monroe, 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.

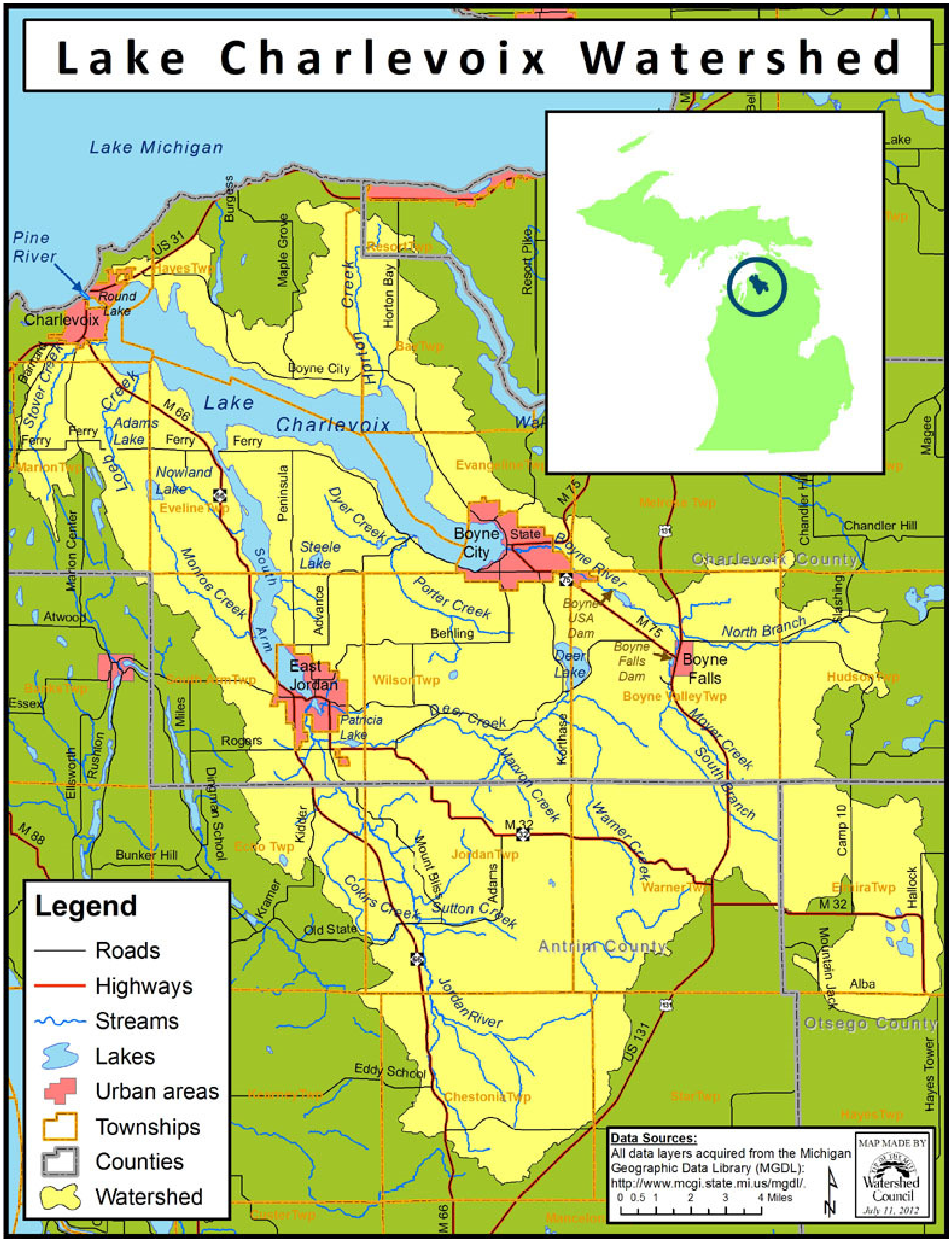

Figure 1. Map of the Lake Charlevoix watershed.

However, the cumulative impact of extensive landscape development throughout the watershed is likely to have serious adverse impacts on the lake's water quality.

Land cover statistics for the Lake Charlevoix Watershed were generated using remotely sensed data from the Coastal Great Lakes Land Cover project (Table 1). Based on the 2006 data, the majority of the watershed's land cover is natural, consisting of forest, grasslands, and wetlands. Of land cover types that typically lead to water quality degradation, there is little urban or residential (~4.5%) and a moderate amount of agriculture (~16.4%) in the watershed. During the five-year period between 2001 and 2006, both agricultural and urban land-cover area increased slightly (1-2%).

Table 1. Lake Charlevoix watershed land-cover statistics (NOAA 2006).

Landcover Type	2000 acres	2000 percent	2006 acres	2006 percent	Change (acres)	Change (percent)
Agriculture	33159	15.59	34840.2	16.38	1681.5	0.8
Barren	734	0.35	486.1	0.23	-247.8	-0.1
Forested	100032	47.04	101762.3	47.85	1730.2	0.8
Grassland	24029	11.30	15053.8	7.08	-8975.6	-4.2
Scrub/shrub	4883	2.30	5584.6	2.63	701.6	0.3
Urban	6097	2.87	9542.5	4.49	3445.7	1.6
Water	18676	8.78	18499.7	8.70	-175.8	-0.1
Wetlands	25042	11.78	26895.0	12.65	1852.6	0.9
TOTAL	212652	100.00	212664.2	100.00	NA	NA

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).

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. 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).

Table 2. Lake Charlevoix data from the CWQM program.

	DO	pH	Conductivity	Chloride	Nitrate	TN	TP
Units	PPM	Units	microSiemens	PPM	PPB	PPB	PPB
Average	12.01	8.05	285.58	7.90	381.27	557.61	6.1
Minimum	10.05	7.55	225.00	4.00	104.00	332.00	1.0
Maximum	14.04	8.39	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.*

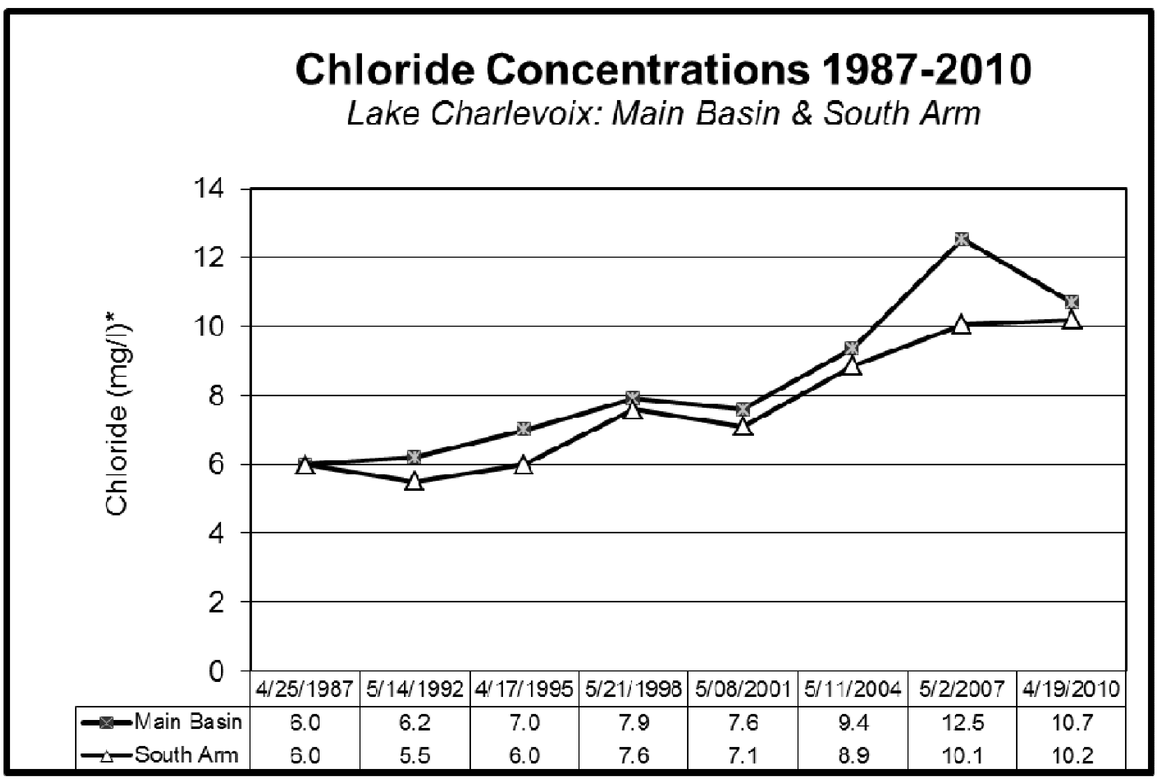

Figure 2. Chloride concentrations in Lake Charlevoix.
**mg/l = milligrams per liter or parts per million.*

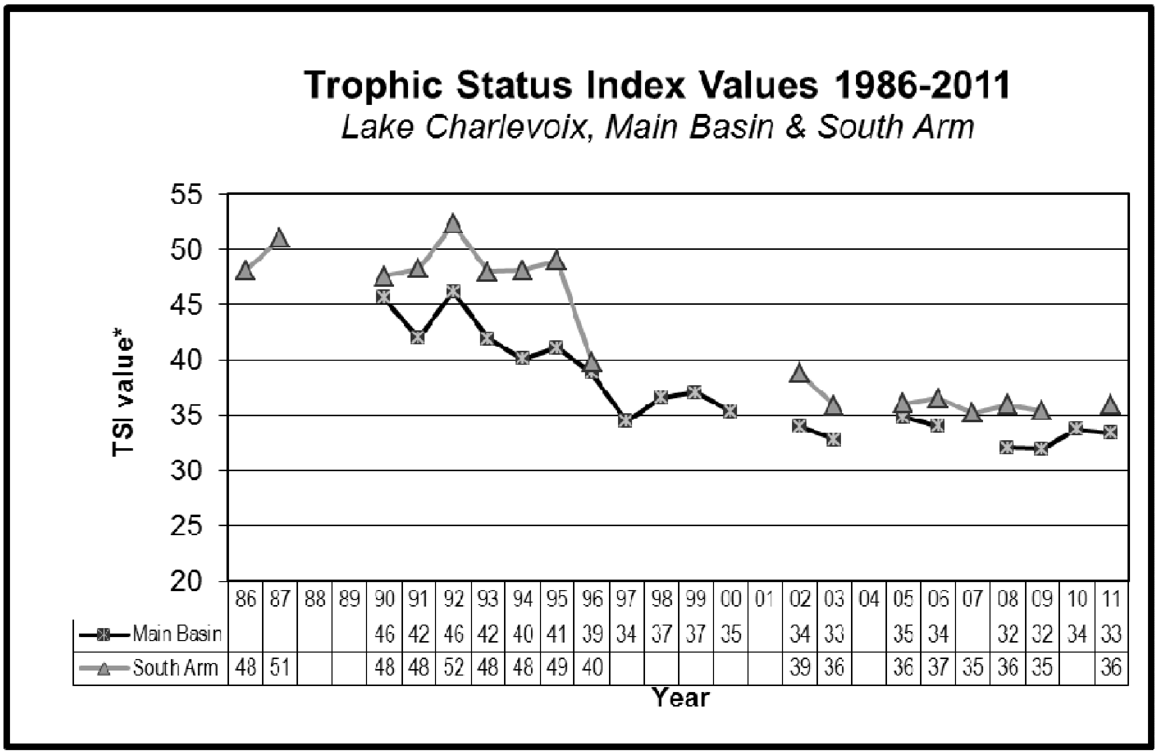

Figure 3. Trophic status index values in Lake Charlevoix.
** Lower values (0-38) indicate an oligotrophic or low productive system, medium values (39-49) indicate a mesotrophic or moderately productive system, and higher values (50+) indicate a Eutrophic or highly productive system*.

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.

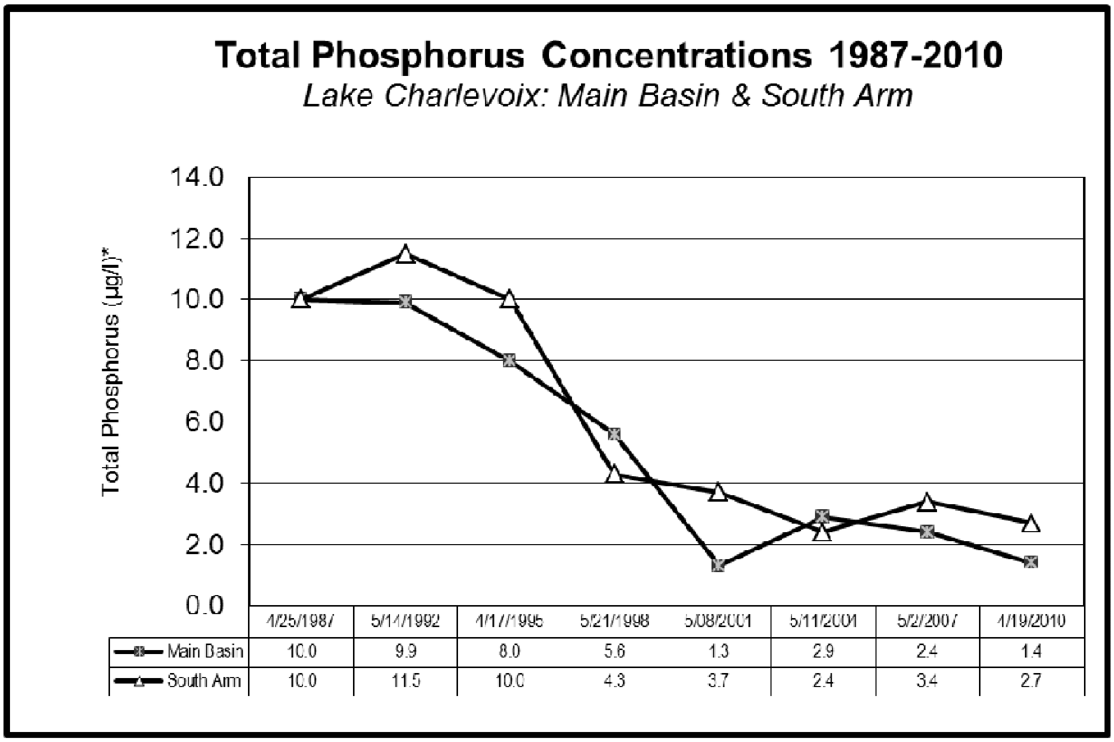

Figure 4. Total phosphorus concentrations in Lake Charlevoix.
*ug/l = micrograms/liter = parts per billion

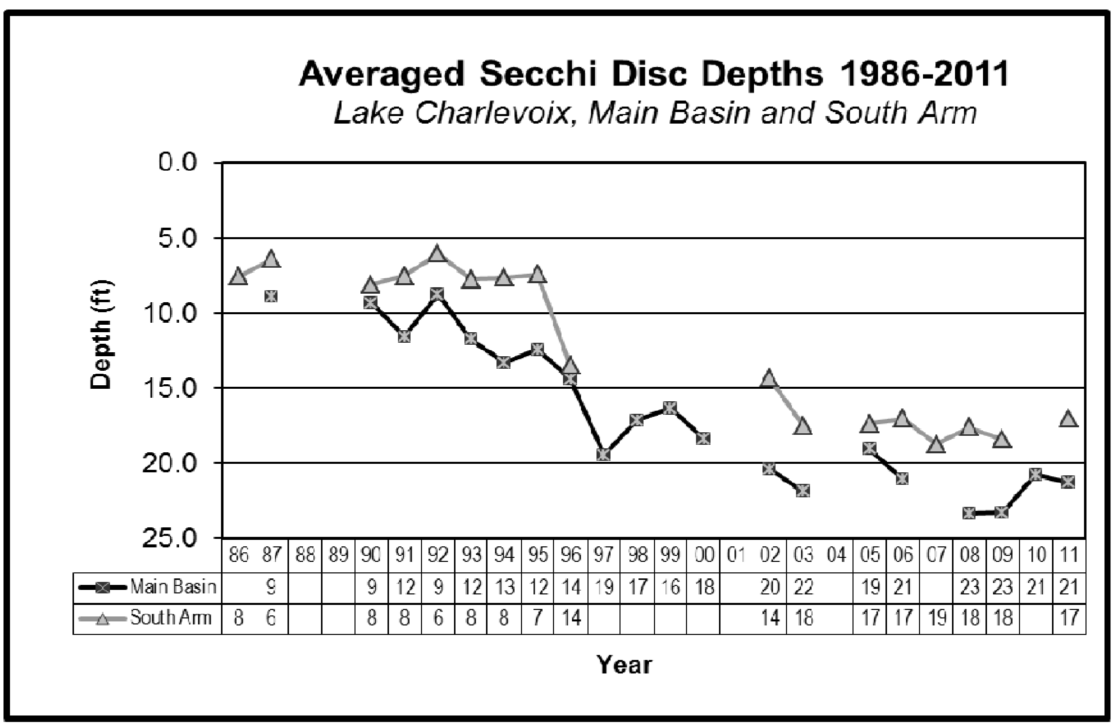

Figure 5. Water transparency in Lake Charlevoix.

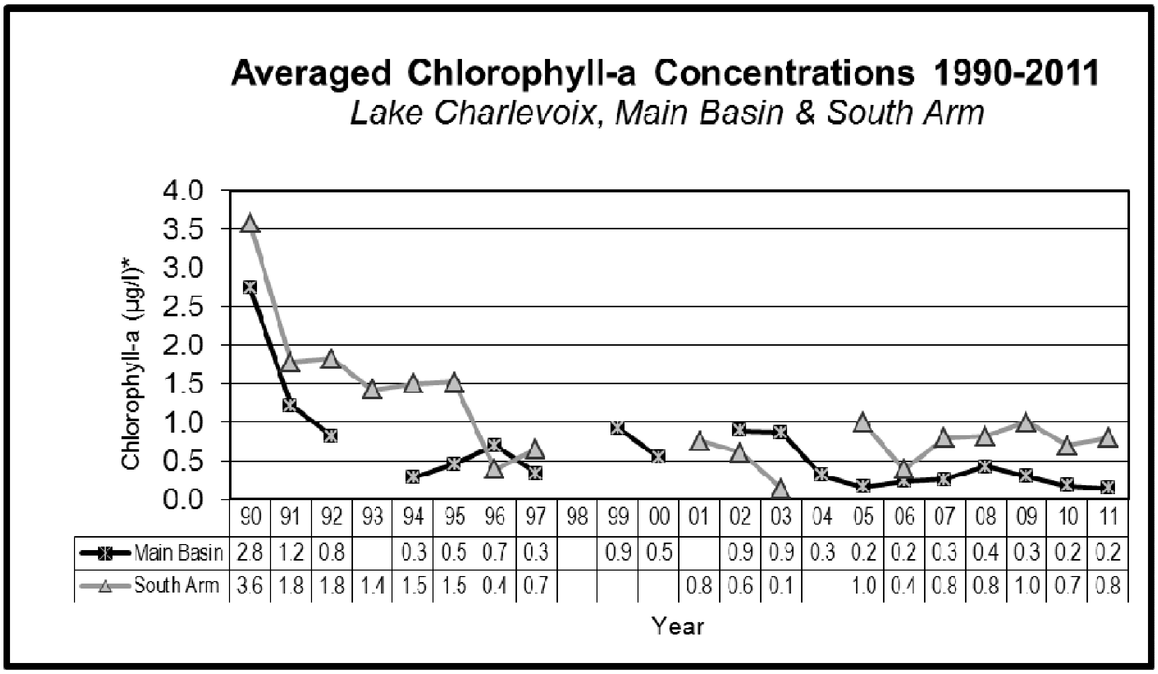

Figure 6. Chlorophyll-a concentrations in Lake Charlevoix.
*ug/l = micrograms/liter = parts per billion

The MDNR Fisheries Division has designated Lake Charlevoix as a Type E Trout Lake (MDNR 2009). A variety of fish species have been stocked in Lake Charlevoix since 1900, including walleye, brown trout, rainbow trout, and lake trout. In addition, multiple fish surveys have been conducted on Lake Charlevoix by MDNR. The most recent in 2006-07 found 31 different fish species including common game fish, such as walleye, northern pike, and small mouth bass, as well as non-game fish ranging from longnose gar to invasive round gobies. Angler surveys during the same time period (2006-07) revealed 57,000 hours of angling effort resulting in a catch that included more than 43,000 yellow perch and 8,700 smallmouth bass.

METHODS

The Lake Charlevoix shoreline was comprehensively surveyed in early June of 2012 to document conditions and activities at every lakeshore property that potentially impact water quality. Shoreline conditions were surveyed by traveling in kayak as close to the shoreline as possible (usually within 20 feet) and noting *Cladophora* growth, substrate type, erosion, greenbelt health, shoreline alterations, emergent aquatic plants, and tributary streams. Information for each property was recorded on field datasheets, subsequently inputted into a database, and used in conjunction with GPS data to link field data and photographs with property owner data from county equalization records. In addition, all shoreline properties were photographed with a GPS camera.

Field Survey Parameters

Shoreline property features were documented by noting physical features on a datasheet, such as building descriptions, public access sites, and county road endings, as well as with photographs. Due to datasheet space limits, building descriptions were recorded in an abbreviated cryptic style. For example, *Red 2 sty, brn rf, wht trm, fldstn chim, lg pine* signifies 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 parcels were noted on field datasheets 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, large parcels that had structures 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.

Cladophora algae growth observed in the nearshore area was noted on field datasheets. Many species of filamentous green algae are commonly found growing in the nearshore regions of lakes and positive identification of these species usually requires the aid of a microscope, but *Cladophora* usually has an appearance and texture that is quite distinct.

Surveyors were trained to recognize these traits, which 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*, though their value as an indicator species is not thought to be as reliable. When other species occurred in especially noticeable, large, dense growths, they were recorded on the datasheets and described the same as those of *Cladophora*.

When *Cladophora* was observed, it was described in terms of the length of shoreline with growth, the density of growth, and any observed shoreline features potentially contributing to the growth. For example, "MHx30' – seeps" denotes an area of moderate to heavy *Cladophora* growth along approximately 30 feet of the shoreline with groundwater seeps in the vicinity suspected of contributing to the growth. Both shoreline length and growth density were subjective estimates. Growth density is determined by estimating the percentage of substrate covered with *Cladophora* using the following categorization system:

Table 3. Categorization system 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.*

Nearshore substrate types were noted during the survey because, among other things, the distribution and size of each *Cladophora* growth is dependent on the amount of suitable substrate present. Therefore, the extent of suitable substrate has to be taken into account when interpreting the occurrence of individual growths, and assessing the overall distribution of *Cladophora* along a particular stretch of shoreline. Substrate types were noted during the survey, using the following abbreviations: *m* = soft muck or marl, s = sand, *g* = gravel (0.1" to 2.5" diameter), *r* = rock (2.5" to 10" diameter), *b* = boulder (>10" diameter), and *w* = woody debris. Substrate types suitable for *Cladophora* growth include *g, r, b,* and *w*. The extent of suitable substrate along the shoreline of individual properties in terms of distance (i.e., linear footage) was not documented.

Erosion was noted based on shoreline areas that exhibited: areas of bare soil, leaning or downed trees, exposed tree roots, undercut banks, slumping hunks of sod, or excessive deposits of sediments. Similar to *Cladophora*, shoreline erosion was recorded on field datasheets with estimates of its extent and relative severity (minor, moderate, or severe). For example “Mx20” indicated 20 feet of shoreline with moderate erosion. Additional information about the nature of the erosion, such as possible causes, was also noted.

Greenbelts (i.e., shoreline vegetation) were rated based on the length of shoreline with a greenbelt and the average depth of the greenbelt from the water’s edge landward into the property. Ratings for length ranged from zero to four while depth ranged from zero to three and were based on the following:

Length	0: None, 1: 1-10%, 2: 10-25%, 3: 25-75%, 4: >75%
Depth	0: None, 1: <10 ft, 2: 10-40 ft, 3: >40 ft

Greenbelt ratings for length and depth were summed to produce an overall greenbelt score. Greenbelt scores ranged from 0 to 7, representing the greenbelt status or health. Scores of 0 were considered very poor, 1-2: poor, 3-4: moderate, 5-6: good, and 7: excellent.

Shoreline alterations were surveyed and noted with the following abbreviated descriptions:

SB = steel bulkhead (i.e., seawall)	BB = boulder bulkhead
CB = concrete bulkhead	RR = rock rip-rap
WB = wood bulkhead	BR = Mixed boulder/rock riprap
BH = permanent boathouse	BS = beach sand
G = groin	DP = discharge pipe

Abbreviations were sometimes mixed or vary from what is listed above.

Tributary streams were noted on the field datasheets and included in a separate column in the database. Additional information regarding shoreline property features or shoreline conditions recorded on field datasheets was included in the database in a "comments" column. Emergent aquatic plants in nearshore areas, such as bulrush and cattail, were also noted in the comments column of the field datasheet.

Data Processing

Upon completing field work, all field data were transferred to computer. Information from field datasheets was inputted into a Microsoft Excel® workbook. Digital GPS photographs were uploaded to a computer at the Watershed Council office and processed for use.

Field data were linked to the Charlevoix County property data in a GIS with the aid of GPS photographs. The linked field and equalization data allows shoreline conditions documented during the survey to be referenced by property identification number or property owner name. Occasionally, errors occur wherein field data are not linked to the appropriate parcel.

In order to display survey results without pinpointing specific parcels, a new map layer was developed using the parcel map data layer acquired from the county equalization departments and a Lake Charlevoix shoreline layer. The new map layer consists of a narrow 100-meter band following the shoreline, split into polygons that contain field and equalization data. This data layer was overlaid with other GIS data from the State of Michigan to produce a poster-size map to display survey results.

Final products include a comprehensive database, a complete set of GPS digital photographs, GIS data layers of shoreline parcels that include both county equalization and shore survey data, and a map displaying results. The shoreline survey database contains a sequential listing of properties beginning at the Pine River outlet 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 GIS data layers and on hard-copy maps. GPS photographs were renamed using the same identification numbers and are linked to a GIS data layer.

RESULTS

This survey documented shoreline conditions at 1,718 properties on Lake Charlevoix. Approximately 85% (1464) of shoreline properties on Lake Charlevoix were considered to be developed. The length of shoreline per parcel varied from less than 20 feet to more than a mile.

Habitat generally considered suitable for *Cladophora* growth was present along at least part of the shoreline of 1027 properties (60%). Noticeable growths of *Cladophora* or other filamentous green algae were found along the shoreline at 370 properties, representing 22% of the total or 36% of properties with suitable habitat (Table 4). At properties where *Cladophora* growth was observed, nearly 20% consisted of heavy or very heavy growth whereas approximately 45% were classified as light or very light.

Table 4. *Cladophora* density results.

***Cladophora* Density**	**Number of Properties**	**Percent of Properties***
Very Heavy	36	9.73
Heavy	33	8.92
Moderate to Heavy	50	13.51
Moderate	48	12.97
Light to Moderate	35	9.46
Light	93	25.14
Very light	75	20.27
TOTAL	370	100.00

**Percent of properties with Cladophora growth.*

Greenbelt scores ranged from 0 (little to no greenbelt) to 7 (exemplary greenbelt). Over a third of greenbelts (35%) along the Lake Charlevoix shoreline were found to be in good or excellent condition (Table 5). However, nearly half of shoreline property greenbelts (46%) rated in the poor or very poor categories.

Some form of shoreline alteration was noted at 1,354 shoreline properties (79%) on Lake Charlevoix (Table 6). The majority of alterations consisted of riprap (61%), while seawalls, including seawalls combined with riprap or other structures, accounted for 18% of shoreline alterations. Beach sand, whether from fill or vegetation and topsoil removal to expose underlying sand, was documented at nearly 20% of properties.

Table 5. Greenbelt rating results.

Greenbelt Rating	Number of Properties	Percent of Properties
0 = Very Poor*	357	20.78
1-2 = Poor	429	24.97
3-4 = Moderate	330	19.21
5-6 = Good	315	18.34
7 = Excellent	287	16.71
TOTAL	1,718	100.00

**Very poor indicative of a property with no vegetation beyond mowed turf grass at the lake edge.*

Table 6. Shoreline alteration results.

Alteration Type	Number of Properties	Percent of Properties*
Riprap (small rock)	511	37.52
Riprap (boulder and rock)	287	21.07
Riprap with other structures†	39	2.86
Seawalls	100	7.93
Seawalls with riprap or other†	135	9.91
Other †	23	1.69
Beach sand®	259	19.02
TOTAL	1,354	100.00

**Percent of properties with shoreline alterations.*

†Other includes rock groins, boat ramps, boat houses, or modifications.

®Beach sand includes sand fill or exposing sand by removing vegetation.

Erosion was noted at 593 properties (~35%) on the Lake Charlevoix shoreline (Table 7). Nearly half (44%) of shoreline properties with erosion were classified as minor in terms of severity, while only 13% of properties were experiencing severe erosion.

Table 7. Shoreline erosion results.

Erosion Category	Number of Properties	Percent of Properties
Minor	263	44.35
Moderate	253	42.66
Severe	77	12.98
TOTAL	593	100.00

Tributary streams were documented at 123 properties. The actual number could be lower because tributaries located between land parcels are sometimes tallied for both properties.

Maps were developed to display and examine patterns in the occurrence of *Cladophora* growths, erosion, and poor greenbelts on the Lake Charlevoix shoreline. Clusters of properties with observed *Cladophora* growth occurred in four primary areas: 1) in the northwest corner of the main basin from north of the Pine River outlet clockwise around the lake to just past Woods Creek Road; 2) in a few major clusters on the north side of the lake between Young State Park and Horton Bay; 3) in the Boyne City area about one mile north and south of the Boyne River outlet; 4) along one mile of shoreline to the northwest of Advance; and 5) in scattered clusters along the length of the west side of the South Arm. The biggest clusters with the densest algae growth were found along the shoreline from Boyne City to Horton Bay.

Clusters of properties with moderate to severe erosion were concentrated in five areas of Lake Charlevoix: 1) toward the middle of the north shore of the main basin following a section of Boyne City Road from Brown Road to Stephens Road; 2) from Horton Bay two miles to the southeast; 3) from Hemingway Point south through the narrows into the South Arm and extending to Sanderson Road; 4) along the west shore of the South Arm from East Jordan one mile; and 5) on the west side of the South Arm from the Monroe Creek outlet north to Metz Road. There were several other smaller groupings of shoreline parcels with erosion in the South Arm, the biggest on the east side from the Chanda Creek outlet south to Lalonde Road.

Groupings of properties with poor greenbelts occurred throughout Lake Charlevoix, but the most concentrated occurred in four areas: 1) along the western lake edge starting near the Loeb Creek outlet and extending clockwise around the lake to Woods Creek Road; 2) from Young State Park through Boyne City and continuing to about a mile past Advance; 3) in the South Arm from East Jordan north to Metz Road; and 4) in the South Arm from the Ironton area south to Holy Island. In addition, there were multiple isolated clusters or properties in three areas: 1) in the Horton Bay area, extending up to two miles in either direction; 2) along the south shore of the main basin from Whiting Park west to Commodore Road; and 3) along most of South Arm’s eastern shoreline.

DISCUSSION

Development of shoreline parcels negatively impacts a lake's water quality due to a multitude of factors. Among the most serious impacts are: 1) loss of vegetation that would otherwise provide habitat and food in nearshore areas, absorb and filter pollutants in stormwater runoff, and stabilize shoreline areas to prevent erosion, 2) increased impervious surface area such as roofs, driveways and roads, which leads to greater inputs of stormwater runoff and associated pollutants, and 3) waste and byproducts of human activity such as septic leachate, fertilizers and decomposing yard waste that potentially reach and contaminate the lake water. Results from the 2012 shoreline survey indicate that nutrient pollution, poor greenbelts, shoreline alterations, and erosion pose a threat to the water quality and overall health of Lake Charlevoix.

Relative to shore surveys conducted on other lakes in the region, Lake Charlevoix was well below the average in terms of the percentage of properties with *Cladophora* growth, but it was near the average with respect to heavy *Cladophora* growth (Table 8). Of the shoreline areas showing evidence of nutrient pollution, some of the algae growth is undoubtedly associated with leaking sewer and septic system leachate or other factors associated with development and human activities, but others are probably due to natural factors. There are numerous streams, springs, and seeps flowing into Lake Charlevoix at different points along the shoreline that may be delivering nutrients that naturally increase algal growth. Where human-caused nutrient pollution is occurring, the source has to be identified in order to address the problem. Although impeded by factors such as wind, wave action, currents, and groundwater paths, efforts by trained personnel to identify specific nutrient input sources on individual properties are often successful.

Although the percentage of poor greenbelts on Lake Charlevoix riparian properties was below the average for lakes in this region (Table 8), one of every five properties was found to have virtually no shoreline vegetation beyond turf grass. This lack of vegetation on the lakeshore, which provides habitat and acts as a food source, impacts aquatic fauna ranging from minute crustaceans to top predator fish. Furthermore, the absence of vegetation leads to greater amounts of shoreline erosion and less filtration of pollutants. In spite of the number of properties with greenbelts in poor condition, approximately 17% of properties on Lake Charlevoix received a perfect score, indicating exemplary greenbelt health. Properties with healthy, intact greenbelts provide a model

Table 8. Shore survey statistics from Northern Michigan lakes.

Lake Name	Survey Date	*Cladophora**	Heavy Algae*	Erosion*	Poor Greenbelts*	Alterations*
Black Lake	2005	20%	21%	ND	ND	ND
Burt Lake	2009	47%	29%	4%	36%	46%
Crooked Lake	2012	29%	26%	14%	51%	65%
Huffman Lake	2006	60%	22%	ND	ND	76%
Charlevoix	2007	17%	20%	ND	30%	61%
Charlevoix	2012	22%	19%	14%	34%	79%
Larks Lake	2006	4%	0%	ND	12%	29%
Mullett Lake	2008	59%	50%	7%	64%	58%
Pickerel Lake	2012	27%	33%	15%	52%	64%
Sixmile Lake	2008	14%	5%	5%	34%	30%
Thumb Lake	2007	4%	0%	ND	ND	39%
Walloon Lake	2010	46%	24%	7%	36%	75%
AVERAGE		29%	21%	9%	39%	57%

**Percentages are in relation to number of parcels on the lake shore, except for "heavy algae", which is the percent of only parcels that had Cladophora growth. Erosion is the percentage of parcels with moderate to severe erosion and poor greenbelts include those in the poor or very poor categories. ND=no data.*

for improvement for other shoreline properties. Improvements in the quality of greenbelts throughout the shoreline would invariably have positive impacts on the lake's water quality and ecosystem in general.

Erosion is a concern on Lake Charlevoix because the percentage of properties experiencing moderate to severe shoreline erosion is among the highest for lakes in this region (Table 8). Erosion documented on many of these properties consisted of barren or eroded shoreline areas resulting from beach sand fill or exposure (i.e., removing vegetation and topsoil to expose underlying sand). Regardless of the cause, corrective actions to address existing erosion, preferably using bioengineering, as well as preventative measures, such as improving riparian vegetation (greenbelt) conditions, will benefit the Lake Charlevoix ecosystem.

The percent of properties with altered shoreline on Lake Charlevoix was the highest for lakes surveyed in the region, but similar to other lakes like Walloon and Huffman (Table 8). Approximately 38% of shoreline alterations consisted of small riprap, which is one of the least damaging types in regards to lake ecosystem health (Table 6). Conversely, about 18% of noted alterations were seawalls or seawalls mixed with riprap or other structures. Seawalls are now frowned upon by water resource managers due to negative impacts that range from near-shore habitat loss to ice-induced erosion in neighboring shoreline areas. Reducing the length of altered shoreline, particularly in terms of seawalls, will improve the quality of Lake Charlevoix.

Comparisons between 2007 and 2012 survey data show a modest increase in the percentage of properties with *Cladophora* (5%), but roughly the same percentage of properties with heavy algae growth (Table 8). *Cladophora* was observed during both surveys at 84 properties, where growth density increased at 54 properties, decreased at 22, and stayed the same at eight. Of these 84 properties, algae growth at 33 was classified as heavy or very heavy and an additional 24 properties had moderate to moderately heavy growth. The percentage of shoreline properties with poor greenbelts also increased slightly from 2007 to 2012 (4%). There was a large increase in the percent of properties with shoreline alterations, though much this increase may have largely been due to beach sand. There was no erosion data from the 2007 survey for making comparisons.

Monitoring data from Lake Charlevoix show that water quality remains high in spite of the problems exposed by this survey. However, the water quality data is collected in open water (i.e., far from the shoreline) and does not necessarily reflect what is occurring in nearshore areas. Furthermore, interpreting such data is confounded by the alteration of the lake's nutrient cycling caused by invasive zebra and quagga mussels. Due to low nutrient levels (naturally and because of invasive mussels), the large volume of water in the lake, and the volume of water flushing through, Lake Charlevoix is somewhat resilient to nutrient pollution. Such resiliency however, is not without limits. To prevent potentially serious and irreversible changes to the lake ecosystem, changes need to be made in shoreline property management.

Numerous best management practices have been developed that help minimize negative impacts to water quality and which can be utilized during, or retroactively after the development of shoreline parcels. A buffer of diverse, native plants can be maintained along the shoreline to filter pollutants and reduce erosion. Impacts from stormwater runoff generated from roofs, roads, and driveways can be reduced using rain barrels, rain gardens, grassy swales, and many other techniques. Leachate reaching the lake from septic systems can be minimized by pumping the septic tank regularly, having all components of the septic system inspected regularly and replacing the septic system when necessary. Mulch can be composted far from the shoreline and fertilizers applied sparingly, if at all. Improving shoreline property management will help protect water quality, strengthen the fisheries, and improve the quality of living and recreating on the lakes.

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 (e.g., do not publish a list or map of sites where *Cladophora* algae growths were found) as some property owners may be sensitive to publicizing information regarding their property.

2. Send a <u>general</u> summary of survey results to all shoreline residents, along with a packet of informational brochures produced by the Watershed Council and other organizations to provide information about dangers to the lake ecosystem and public health as a result of poor shoreline property management practices, as well as practical, feasible, and effective actions to protect water quality.

3. Organize and sponsor informational sessions to present findings of the survey to shoreline residents and provide ideas and options for improving shoreline management practices that would help protect and improve lake water quality.

4. Inform owners confidentially of properties with moderate to heavy *Cladophora* growths, moderate to severely eroded shorelines, and poor or very poor greenbelt scores of specific results for their property. Encourage riparians to work with the Lake Association and Watershed Council to identify and correct problems. Send them a questionnaire to fill out and return (or make available electronically) to help interpret causes of the growth and provide recommendations for addressing problems. If property owners need further assistance, they can contract with the Watershed Council or other qualified organizations or businesses to perform site assessments to evaluate and remedy problems with nutrient pollution, erosion, and greenbelts.

5. Utilize the internet and the Lake Association's web page to share survey information. A general summary report and this detailed report can be posted on the Association's web page because they do not contain any property-specific information. Property-specific information can be shared via the Association's web page by randomizing and encrypting the shoreline survey database and providing property owners with a code number that refers specifically to survey results from their property. In addition, questionnaires about property

characteristics could be filled out through free internet services linked to the web site. The Watershed Council is available to assist with this approach.

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 Lake Association and 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. Ensure that shoreline survey results are shared with the Lake Charlevoix Watershed Advisory Committee for use in watershed management planning. Results should be incorporated into the Lake Charlevoix Watershed Management Plan when updated.

8. 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, as well as identify chronic problem areas. During each subsequent survey, more details about shoreline features are added to the database, which can be utilized for other water resource management applications.

9. Continue to support the Tip of the Mitt Watershed Council monitoring programs, as well as those of other organizations. The information collected by staff and volunteers is extremely valuable for assessing water quality, determining trends, and guiding lake management efforts.

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