Crooked-Pickerel Lakes Shoreline Survey 2012

By Tip of the Mitt Watershed Council

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Table of Contents

List of Tables

Page

List of Figures

Page

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 shoreline survey on Crooked and Pickerel Lakes to assess such 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 Petoskey-Harbor Springs Area Community Foundation.

Survey results indicate that human activity along the Crooked and Pickerel Lakes shoreline is likely impacting the lake ecosystem and water quality. *Cladophora*, an algal nutrient pollution indicator, was noted at nearly one third of shoreline properties, of which 30% consisted of heavy growth (i.e., a strong indication of nutrient pollution). Over 50% of greenbelts on shoreline properties were found to be in poor condition, though 36% were in excellent condition. Moderate to severe erosion was documented at 14% of properties and approximately 65% had altered shorelines. Relative to other lakes in the region, Crooked and Pickerel Lakes had a high percentage of properties with heavy *Cladophora* algae growth, poor greenbelts, erosion, and altered shorelines.

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:

During the late spring of 2012, a shoreline survey was conducted on Crooked and Pickerel Lakes by the Tip of the Mitt Watershed Council to document shoreline conditions that potentially impact water quality. All shoreline properties were surveyed to document the following: *Cladophora* algae growth as a nutrient pollution indicator, erosion, alterations, greenbelts, emergent aquatic plants, and tributary inlets and outlets. This survey was funded by a grant awarded to the Watershed Council by the Petoskey-Harbor Springs Area Community Foundation.

Only one prior shoreline survey had been performed on Crooked and Pickerel Lakes, a nutrient pollution survey conducted by Watershed Council staff in 1988. A device called a Septic Leachate Detector (SLD) was employed to assess lakefront water quality at 213 homes on 9.6 miles of shoreline. Moderate SLD responses indicated possible problems at 67 homes, while stronger responses and therefore, stronger evidence of problems were found at 24 homes. Follow-up work with riparian owners revealed sub-standard septic systems at over 50% of participating homes, indicating a strong possibility of water quality impacts.

The 2012 survey consisted of a much more comprehensive assessment of shoreline conditions on Pickerel and Crooked Lakes, providing a valuable dataset that can be used to improve lake management. 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. 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.

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.

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 Crooked and Pickerel, 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, both Crooked and Pickerel Lakes are drainage lakes with inflows and outflows, which provide the means to flush excess nutrients out of the system. In spite of Crooked and Pickerel Lakes' 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 the lakes of Northern Michigan. Therefore, shoreline locations where relatively high concentrations of nutrients, particularly phosphorus, are entering a lake can be identified by noting the presence of *Cladophora*. Although the size of the growth on an individual basis is important in helping to interpret the cause of 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 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 a mechanism to reduce overland surface flow and absorb pollutants carried by stormwater from rain events and snowmelt.

Tributaries have great potential for influencing a lake's water quality as they are one of the primary conduits through which water is delivered to a lake from its 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:

Crooked and Pickerel Lakes are located in southeast Emmet County in the northern tip of the Lower Peninsula of Michigan (Figure 1). The lakes are split between Springvale and Littlefield Townships, with the western edge of Crooked Lake touching upon Little Traverse and Bear Creek Townships. Oden Island, in the middle of Crooked Lake, effectively splits the lake into two basins to the east and west of the island, though the far western area of the lake (to the west of Graham Point) could be considered a third distinct basin. Pickerel Lake, located to the east of Crooked Lake and connected by a half-mile channel, is composed of two basins to the northwest and southeast of a narrow area located in front of Ellsworth Point.

Based upon digitization of aerial orthophotography (Emmet County 2008), the Crooked Lake shoreline measures 16.3 miles and the lake surface area totals 2,351 acres whereas Pickerel Lake has 7.1 miles of shoreline and 1082.5 acres of surface area. The connecting channel between the lakes accounts for an additional 1.3 miles of shoreline and 13.3 acres of surface area. Crooked Lake measures approximately 3.5 miles from west to east at its widest point and 1.75 miles from north to south. From northwest to southeast, Pickerel Lake measures roughly 2.5 miles and has a maximum width of less than a mile.

Crooked and Pickerel Lakes contain extensive shallow areas, but there are deep pockets in both lakes as well. Maps from the Michigan Department of Natural Resources

(MDNR) Institute for Fisheries Research indicate that the deepest point in Crooked Lake, 50 feet, is located to the west of Oden Island. There are two deep holes in Pickerel Lake that approach 70 feet of depth and which are located in the northwest basin. The broad near-shore shallow areas of both lakes support large communities of emergent vegetation.

Crooked and Pickerel Lakes are drainage lakes of glacial origin. The largest inlet streams on Crooked Lake include Round Creek on the west end, Oden Creek on the north shore, Minnehaha Creek near the southern tip and the Black Hole channel connecting to Pickerel Lake on the east end. Inlet streams to Pickerel Lake include Cedar Creek on the east end, Mud Creek on the west side and an unnamed creek on the east end of the north shore. Water leaves Pickerel Lake through the Black Hole channel and flows out of Crooked Lake in the northeast corner into the Crooked River.

Following the retreat of glaciers (~14,000 years ago) that covered the region during the last ice age, water flowed west across the state, through the Crooked-Pickerel Lakes' area and out to Little Traverse Bay. During the Lake Nipissing stage, some 4,000 years ago, dunes rose up to the west of Round Lake and cut off stream flow into Little Traverse Bay (Spur and Zumberge, 1956). The dune formation effectively reversed the course of the streams and rivers, gradually forming the current Inland Waterway flow path across the State to the east-northeast, discharging into Lake Huron at the City of Cheboygan.

Based on GIS files developed by the Watershed Council using existing watershed boundary and elevation data from the State of Michigan, the Crooked and Pickerel Lakes watershed encompasses 75,557 acres, which includes the lake area (Figure 1). The watershed size without the lake area totals 72,110 acres, resulting in a watershed area to lake area ratio of 20.92. The ratio provides a statistic for assessing impacts from agricultural, urban, and other development in the watershed. Crooked and Pickerel Lakes collectively have over 20 acres of land in the watershed for each acre of the lakes' surface area, which is a considerable buffer for moderating water quality impacts from landscape development and human activity in the watershed.

Land cover statistics for the Crooked and Pickerel Lakes watershed were generated using remotely sensed data from the Coastal Great Lakes Land Cover project (Table 1). Based on the 2006 data, there is little agricultural landcover within the watershed (~9.8%) and even less urban (~3.3%). The majority of the watershed's landcover is natural, consisting of forest, grasslands, and wetlands. During the five-year period

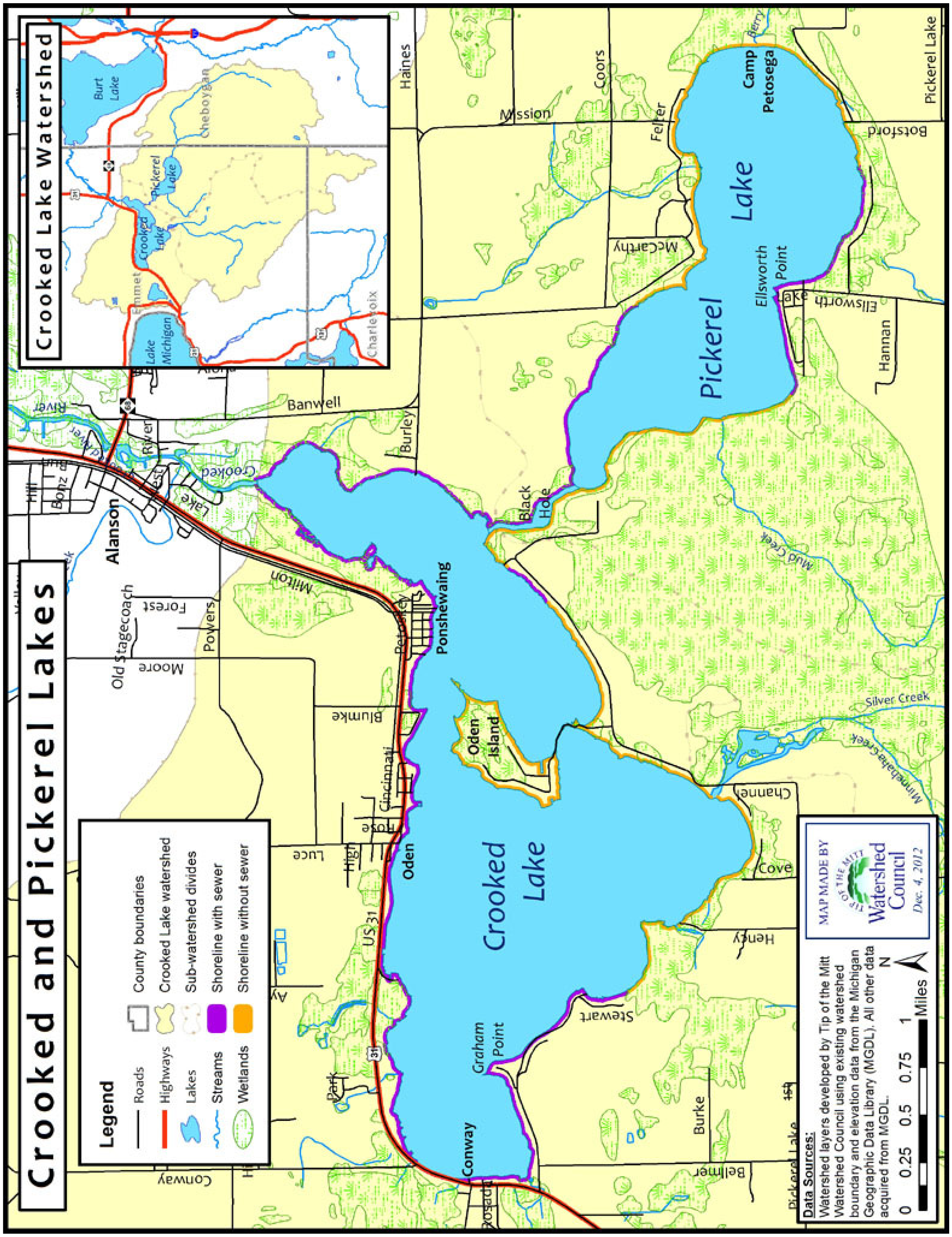

Figure 1. Crooked Lake, Pickerel Lake, and watershed.

between 2001 and 2006, both agricultural and urban land-cover area increased slightly (by less than 1%).

Table 1. Crooked and Pickerel Lakes watershed land-cover statistics.

Land Cover Type	Acres (2001)	Percent (2001)	Acres (2006)	Percent (2006)	Percent Change
Agriculture	6891.24	9.12	7369.45	9.75	0.63
Barren	313.91	0.42	270.49	0.36	-0.06
Forested	42848.18	56.70	44139.80	58.38	1.68
Grassland	9685.70	12.82	6010.48	7.95	-4.87
Scrub/shrub	2193.04	2.90	2862.49	3.79	0.88
Urban	1869.81	2.47	2482.86	3.28	0.81
Water	3997.20	5.29	3970.57	5.25	-0.04
Wetlands	7770.27	10.28	8496.16	11.24	0.96
TOTAL	75569.34	100.00	75602.31	100.00	NA

Properties along the shoreline in the majority of Crooked Lake and the northwest portion of Pickerel Lake are serviced by sanitary sewers, which convey waste to the Harbor Springs Area Sewage Authority on Hathaway Road for treatment. Sewer lines on Crooked Lake service properties from the end of Stewart Lane to the south of Graham Point clockwise around the lake to the north side of the connecting channel to Pickerel Lake (Figure 1). Pickerel Lake properties that are serviced by sewer lines extend from the north side of the connecting channel to the Lakeview Road end. In addition, private sewer systems are maintained along a section of Channel Road on Crooked Lake and along Trails End, North Ellsworth, and Township Park Roads on Pickerel Lake.

The water quality of Crooked and Pickerel Lakes has been monitored for decades as part of the Tip of the Mitt Volunteer Lake Monitoring Program (TOMVLMP) and the Comprehensive Water Quality Monitoring Program (CWQM). Volunteers in the TOMVLMP monitor water clarity and chlorophyll-a concentrations to assess water quality and biological productivity. Water clarity is usually determined by two key factors: sediments and planktonic algae. Chlorophyll-a, a pigment found in the algae, helps determine if changes in water clarity are due to changes in the amount of algae versus sediments. Averaged Secchi disc depth data from the TOMVLMP show that water clarity has ranged from 7 to 14 feet, gradually increasing in Pickerel Lake from 1993 to 2007 (Figure 2). The increased clarity could be the result of invasive zebra mussels (*Dreissena polymorpha*), which feed on planktonic algae and were first documented in both Crooked and Pickerel Lakes in 1993 (USGS 2012). However, chlorophyll-a concentrations in the lakes have not decreased (Figure 3). Lack of clear trends and irregularities in the data may be the result of inconsistent data collection or simply due to natural variability.

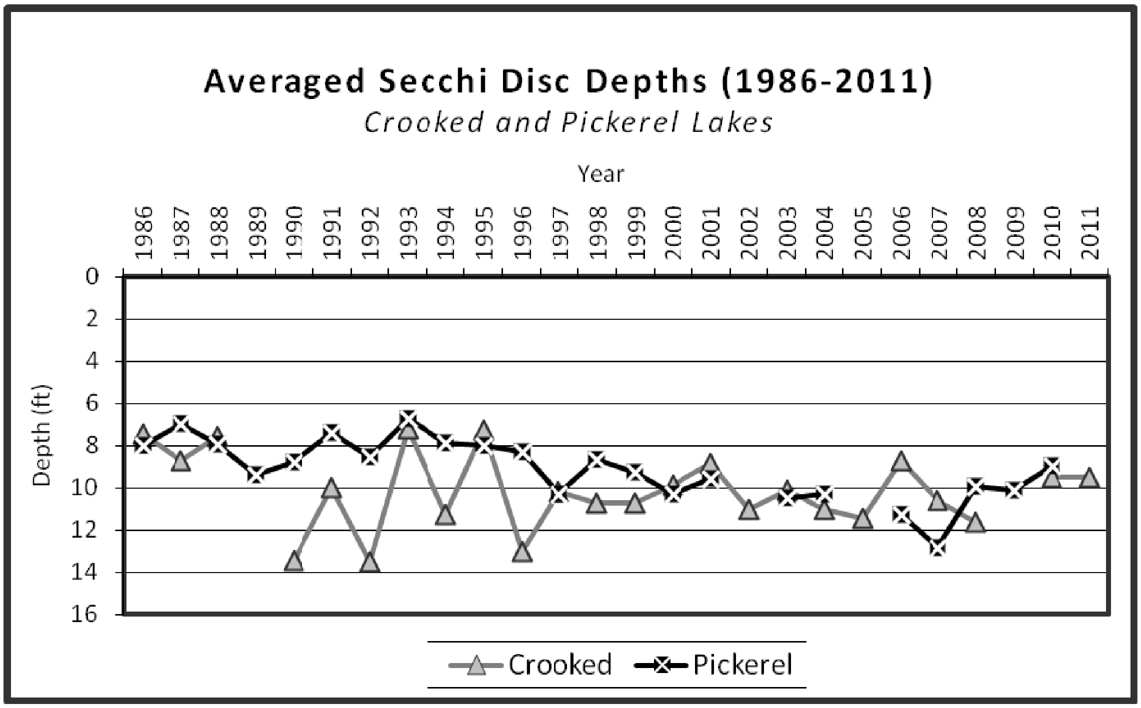

Figure 2. Secchi disc depth data from Crooked and Pickerel Lakes.

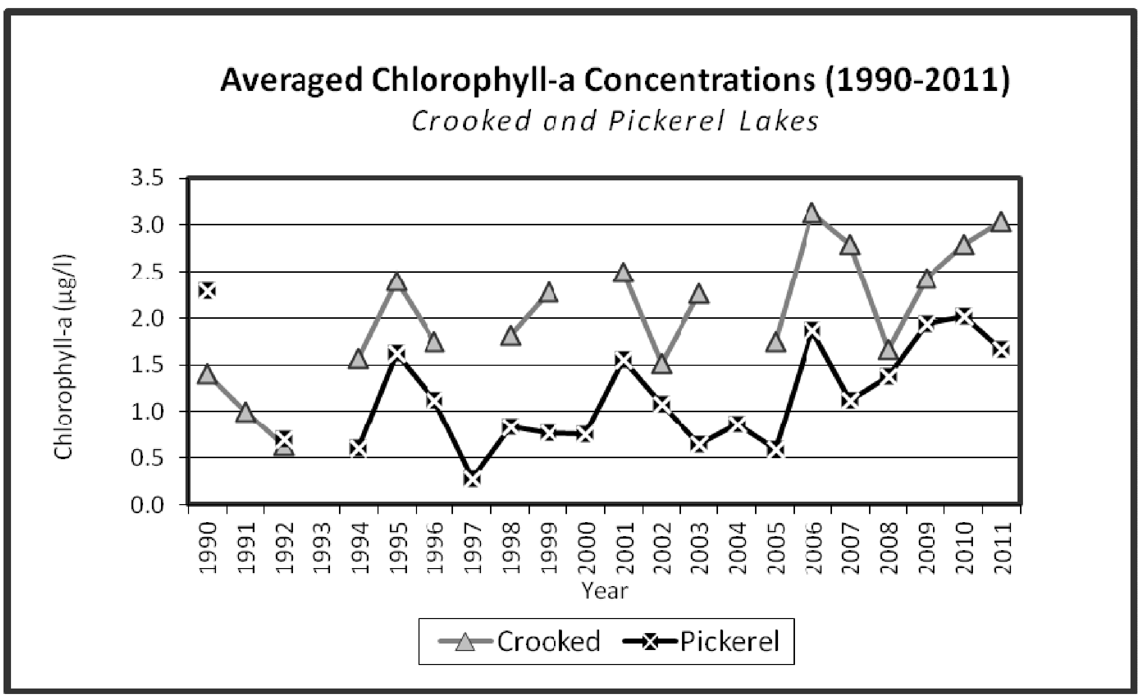

Figure 3. Chlorophyll-a data from Crooked and Pickerel Lakes.

The biological productivity of the lakes was determined by inputting water clarity data into Carlson's trophic status index equations (Carlson 1977). Based TOMVLMP data, the trophic status of both Crooked and Pickerel Lakes border between mesotrophy and oligotrophy (Figure 4). Oligotrophic lakes are typically large, deep, clear, and nutrient poor. In general, oligotrophic lakes contain high quality waters, but paradoxically have lackluster fisheries due to low biological productivity. Mesotrophic lakes are moderately productive. Low total phosphorus concentrations documented in Crooked and Pickerel Lakes in the CWQM program (<=12 ug/l) also indicate low biological productivity (Figure 5). Phosphorus concentrations in both lakes have varied throughout time, but show no definitive trends.

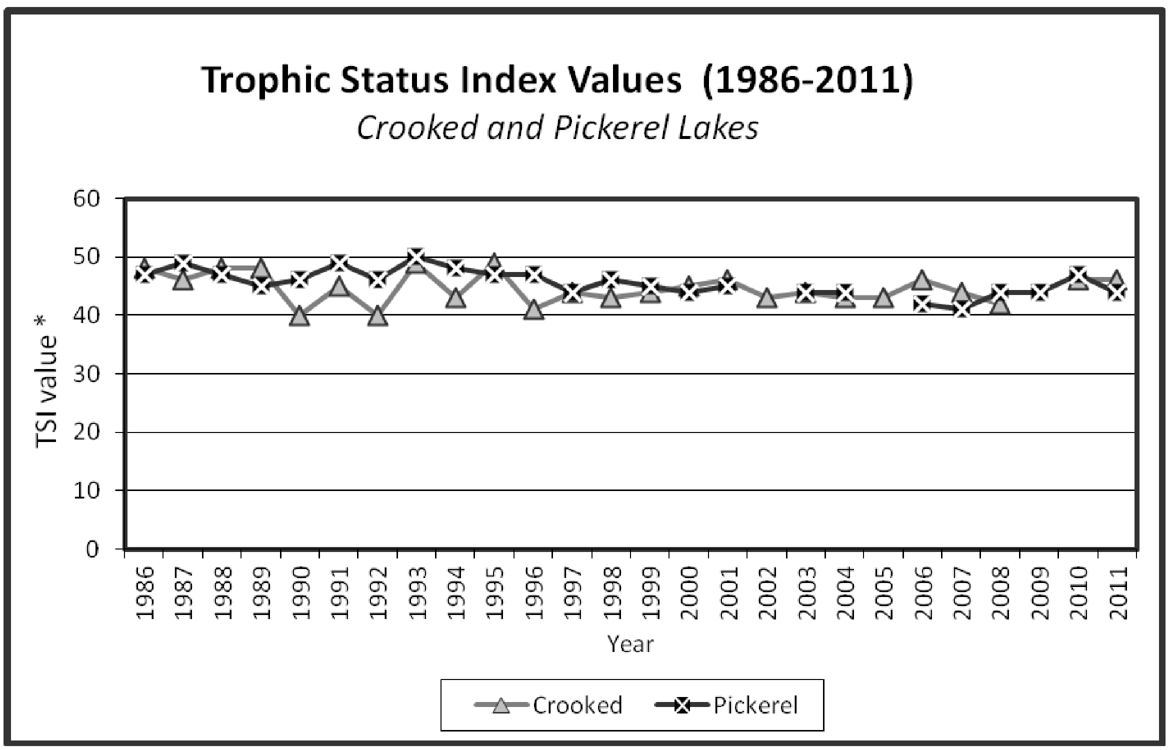

Figure 4. Trophic status index data from Crooked and Pickerel Lakes.

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

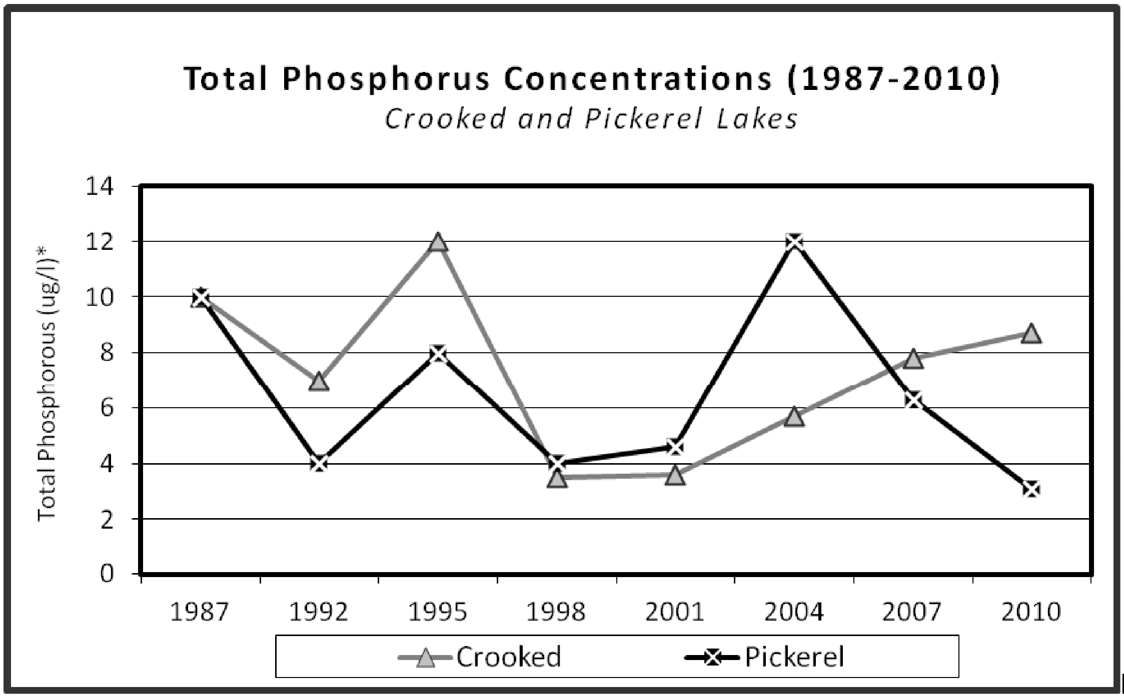

Figure 5. Phosphorus data from Crooked and Pickerel Lakes.
**Total phosphorus measured in ug/l, which is milligrams per liter or parts per billion.*

Surveys by MDNR show that Crooked and Pickerel Lakes support a mix of fish species typical for lakes of Northern Michigan. Fish species collected during a 2001 survey include alewife, black bullhead, black crappie, bluegill, bowfin, brown bullhead, brown trout, burbot, common carp, largemouth bass, longnose gar, northern pike, pumpkinseed, rainbow trout, rock bass, smallmouth bass, walleyes, white sucker, yellow bullhead, and yellow perch (Hanchin et. al., 2005). Additional forage fish collected with seine nets in a 1954 survey include a number of shiners, darters, and other species. Walleye and pike populations are generally characterized as having slow growth rates, which may be the result of inadequate forage.

METHODS

The shorelines of Crooked and Pickerel Lakes were comprehensively surveyed in late May and early June of 2012 to document shoreline conditions that potentially impact water quality at every lakeshore property. 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. In addition, all shoreline properties were photographed with a GPS camera. 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.

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* 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 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 30' 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 2. 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	BS = beach sand
BH = permanent boathouse	DP = discharge pipe

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

Tributaries (i.e., rivers and 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, but later listed in a separate column in the database.

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 photographs and GPS data were uploaded to a computer at the Watershed Council office and processed for use.

Field data were linked to Emmet County property data in a GIS with the aid of GPS and 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 Crooked and Pickerel Lakes shoreline layer. The new map layer consists of a narrow 100-foot 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 Little Traverse Township Boat Launch and traveling counter-clockwise around the entire perimeter of both lakes and the connecting channel. 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 699 parcels on Crooked and Pickerel Lakes, as well as the connecting channel (478 parcels on Crooked Lake, 217 on Pickerel, and 4 exclusive to the channel). The length of shoreline per parcel varied from less than 20 feet to more than a mile. Approximately 76% (532) of shoreline properties on Crooked and Pickerel Lakes were considered to be developed.

Habitat generally considered suitable for *Cladophora* growth was present along at least part of the shoreline of 567 properties (81%). Noticeable growths of *Cladophora* or other filamentous green algae were found along the shoreline at 220 parcels, representing 31% of the total or 39% of properties with suitable habitat (Table 3). At properties where *Cladophora* growth was observed, nearly 30% consisted of heavy or very heavy growth whereas approximately 37% of parcels had growth in the light or very light categories. Pickerel Lake had a higher percentage of parcels with *Cladophora* growth in the moderate through very heavy categories than Crooked Lake (63.75% of the total versus 47.14%).

Table 3. *Cladophora* density results.

***Cladophora* Density**	**Both Lakes # parcels**	**Both Lakes % parcels**	**Crooked Lake # parcels**	**Crooked Lake % parcels**	**Pickerel Lake # parcels**	**Pickerel Lake % parcels**
Very Heavy	36	16.36	23	16.43	13	16.25
Heavy	27	12.27	14	10.00	13	16.25
Moderate to Heavy	20	9.09	14	10.00	6	7.50
Moderate	34	15.45	15	10.71	19	23.75
Light to Moderate	21	9.55	15	10.71	6	7.50
Light	40	18.18	22	15.71	18	22.50
Very light	42	19.09	37	26.43	5	6.25
TOTAL	220	100.00	140	100.00	80	100.00

Greenbelt scores ranged from 0 (little to no greenbelt) to 7 (exemplary greenbelt). Over a third of greenbelts (36%) along the Crooked and Pickerel Lakes shoreline were found to be in good or excellent condition (Table 4). However, over half of shoreline properties (51%) received a greenbelt rating in the poor or very poor categories. The percentage of parcels with poor or very poor greenbelts, as well as the percentage with good or excellent greenbelts on Crooked Lake was comparable to Pickerel Lake.

Table 4. Greenbelt rating results.

Greenbelt Rating	Both Lakes # parcels	Both Lakes % parcels	Crooked Lake # parcels	Crooked Lake % parcels	Pickerel Lake # parcels	Pickerel Lake % parcels
0 = Very Poor*	166	23.75	127	26.57	39	17.97
1-2 = Poor	188	26.90	115	24.06	73	33.64
3-4 = Moderate	95	13.59	62	12.97	33	15.21
5-6 = Good	100	14.31	74	15.48	26	11.98
7 = Excellent	150	21.46	100	20.92	46	21.20
TOTAL	699	100.00	478	100.00	217	100.00

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

Some form of shoreline alteration was noted at 451 shoreline properties (65%) on Crooked and Pickerel Lakes (Table 5). The majority of alterations consisted of riprap (54%), while seawalls, including seawalls combined with riprap, accounted for 37% of shoreline alterations. Comparing the lakes show that seawalls were more prevalent on Pickerel Lake than on Crooked Lake in terms of percentages.

Table 5. Shoreline alteration results.

Alteration Type	Both Lakes # parcels	Both Lakes % parcels	Crooked Lake # parcels	Crooked Lake % parcels	Pickerel Lake # parcels	Pickerel Lake % parcels
Riprap (small)	167	37.03	124	39.74	43	30.94
Riprap (boulder)	75	16.63	41	13.14	34	24.46
Seawalls	69	15.30	35	11.22	34	24.46
Mixed*	100	22.17	77	24.68	23	16.55
Other †	40	8.87	35	11.22	5	3.60
TOTAL	451	100.00	312	100.00	139	100.00

**Mixed means both riprap and seawall present.*
†Other includes rock groins, boat ramps, boat houses, or beach sand.

Erosion was noted at 270 parcels (~39%) on the shorelines of Crooked and Pickerel Lakes (Table 6). Over 60% of shoreline properties with erosion were classified as minor in terms of severity, while only 11% of properties were experiencing severe erosion. There were higher percentages of parcels with moderate to severe erosion on Crooked Lake than on Pickerel Lake.

Table 6. Shoreline erosion results.

Erosion Category	Both Lakes # parcels	Both Lakes % parcels	Crooked Lake # parcels	Crooked Lake % parcels	Pickerel Lake # parcels	Pickerel Lake % parcels
Minor	172	63.70	102	60.71	70	68.63
Moderate	68	25.19	44	26.19	24	23.53
Severe	30	11.11	22	13.10	8	7.84
TOTAL	270	100.00	168	100.00	102	100.00

Tributaries (e.g., streams, creeks) were documented at 35 properties, with 19 on Crooked Lake and 16 on Pickerel Lake. The actual number could be lower because tributaries located between land parcels are sometimes tallied for both properties.

Emergent aquatic plants were documented in the nearshore area of 168 properties (24%), 133 properties on Crooked Lake and 35 on Pickerel Lake. This figure is likely conservative because some surveyors were not consistent in documenting emergent aquatic plants.

Maps were developed to display and examine patterns in the occurrence of *Cladophora* growths and poor greenbelts on the shorelines of Crooked and Pickerel Lakes. Clusters of properties where *Cladophora* growth was documented on the Crooked Lake shoreline occurred in four primary areas: 1) in the northwest corner starting at North Conway Road and extending approximately one mile to the east; 2) on the south shore to the east of Graham Point along Graham Road; 3) on the south shore along Channel Drive to the east of the Oden Island Bridge; and 4) on the north shore in the vicinity of Ponshewaing. In Pickerel Lake, clusters of properties with *Cladophora* growth occurred in three proximate clusters on the south shore: 1) to the west of Ellsworth Point along Trailsend Road; 2) to the east of Ellsworth Point along Township Park Road; and 3) southwest from Camp Petosega along Botsford Lane. Additionally, there was a small grouping of heavy *Cladophora* growth in the southwest portion of Oden Island in Crooked Lake.

Groupings of properties with poor greenbelts occurred throughout both lakes, but were more prevalent in Crooked Lake. In Crooked Lake, clusters of poor greenbelts occurred in five areas: 1) throughout most of the western basin to the west of Graham Point; 2) on the central north shore from Windjammer Marina to Indiana Road (across from Blumke Road); 3) on the north shore in the vicinity of Ponshewaing; 4) on the south shore near the Minnehaha Creek outlet; and 5) on the southeast shore from the Oden

Island Bridge northeast to the MDNR boat launch. In Pickerel Lake, clusters of properties with poor greenbelts also occurred primarily in five shoreline areas: 1) from Ellsworth Point west along Trailsend Road and east along Township Park Road; 2) southwest from Camp Petosega along Botsford Lane; 3) near the Mission Road end along Felter Lane; 4) on the central north shore along McCarthy Road and Felter Lane; and 5) in the northwest corner of the lake along South Beach Drive. In addition, there was a small grouping of poor greenbelts in Pickerel Lake from the Lakeview Road end to the west.

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 Crooked and Pickerel Lakes.

Relative to shore surveys conducted on other lakes in the region, Crooked and Pickerel Lakes were near the average in terms of the percentage of properties with *Cladophora* growth, but above the average with respect to heavy *Cladophora* growth (Table 7). 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 Crooked and Pickerel Lakes 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.

It is commonly thought that sanitary sewers more effectively reduce nutrient pollution and protect water quality than septic systems. Survey results did not show nutrient pollution indicators to be more prevalent in shoreline areas serviced by septic systems as opposed to sewers (Figures 1 and 6). In fact, clusters of properties with *Cladophora* growth on Crooked Lake were more common in shoreline areas where sanitary sewers are used to convey and treat waste. There were a number of breaks in the sewer line and raw sewage spills on the north side of Crooked Lake in the 1980s and 1990s (NEMCOG 1995), though there have been few and minor problems with the sanitary

Table 7. 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%
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		30%	21%	9%	39%	54%

**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.*

sewer since that time period. In addition, sewer systems are known to leak a variable amount of waste per mile of sewer line, dependent on factors such as diameter and condition. This process, called exfiltration, can contribute to nutrient pollution in lakes and result in exceedance of water quality standards (Amick 2000). Another factor to consider in regards to sanitary sewers is that they can lead to increased development around a lake by allowing building construction in areas that were previously limited due to insufficient conditions for the installation of a septic system, which could cumulatively increase nutrient pollution from sewer system leakage, stormwater runoff, fertilizer application, and other anthropogenic sources.

The poor greenbelts documented on over half of shoreline properties on Crooked and Pickerel Lakes was well above the average for lakes in this region (Table 7). One of every four properties on Crooked Lake was found to have virtually no shoreline vegetation beyond turf grass. This lack of vegetation on the lake shoreline, 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 high percentage of properties with greenbelts in poor condition, over 20% of properties on both lakes received a perfect score, indicating exemplary greenbelt health. Properties with healthy, intact greenbelts provide a model 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 Crooked and Pickerel Lakes because the percentage of properties experiencing moderate to severe shoreline erosion was much higher than other lakes for which data are available (Table 7). During recent years, the Watershed Council has received numerous calls from riparian land owners on Crooked and Pickerel Lakes concerning accelerated erosion on their shorelines. Manipulation of lake water levels via the locks on the Crooked River has been suggested by some residents as the cause of shoreline erosion. 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 ecosystems of both Pickerel and Crooked Lakes.

The percent of properties with altered shoreline on Crooked and Pickerel Lakes was above the average, but similar to many of the lakes in the region. Approximately 37% of shoreline alterations consisted of small riprap, which is one of the least damaging types in regards to lake ecosystem health (Table 5). Conversely, about 37% of noted alterations were seawalls or seawalls mixed with riprap. Seawalls are nowadays 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 Crooked and Pickerel Lakes.

There is little information available for determining if shoreline conditions on Crooked and Pickerel Lakes have changed over time. The only previous study, the Septic Leachate Detector Survey of Pickerel-Crooked Lakes (TOMWC 1988), documented the number of properties that exhibited signs of nutrient pollution. Although physical indicators (fluorescence) were used in the prior survey versus biological in the current survey (*Cladophora*), the percentage of properties showing signs of nutrient pollution from the two surveys were roughly equivalent at 31%.

In spite of the problems exposed by this survey, monitoring data from Crooked and Pickerel Lakes show that water quality remains high. However, the water quality data does not necessarily reflect what is occurring in nearshore areas because it is collected in open water, far from the shoreline. Furthermore, interpreting such data is confounded by the alteration of the lake's nutrient cycling caused by invasive zebra mussels. Due to low nutrient levels (both naturally and due to zebra mussels), the large volume of water in the lakes due to their size, and the volume of water flushing through them, Crooked and Pickerel Lakes are somewhat resilient to nutrient pollution. However, such resiliency 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 general 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 of properties with *Cladophora* growths of 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 with the Watershed Council to perform site assessments and even conduct ground water testing to determine if septic or sewer leachate is polluting the lake. 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.

5. Inform owners of properties with poor/very poor greenbelt scores and those with moderately to severely eroded shorelines of specific results for their property. Supply these property owners with information (e.g., brochures) regarding the benefits of greenbelts and/or the problems associated with erosion. Encourage property owners to improve greenbelts using a mix of native plants and to correct erosion problems. Property owners have the option to contract the Watershed Council to perform site assessments and carry out projects to improve greenbelts and/or correct erosion problems.

6. 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. The Watershed Council is available to assist with this approach.

7. 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.

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. The information collected by staff and volunteers is extremely valuable for assessing water quality, determining trends, and guiding lake management efforts. The Pickerel-Crooked Lake Association has done an outstanding job of encouraging volunteerism among its members and should continue to do so to ensure both lakes are adequately monitored.

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