Douglas Lake Shoreline Survey 2015

By Tip of the Mitt Watershed Council

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SUMMARY

Shoreline property management practices can negatively impact water quality and lake ecosystem health. Greenbelts provide many benefits to the lake ecosystem, which are lost when shoreline vegetation is removed. Erosion and shoreline alterations (e.g., seawalls, rip-rap) both have the potential to degrade water quality. Nutrients are necessary to sustain a healthy aquatic ecosystem, but excess inputs from shoreline properties can adversely impact an aquatic ecosystem.

In the spring of 2015, the Tip of the Mitt Watershed Council surveyed Douglas Lake to document and assess shoreline conditions. The following parameters were surveyed for all individual properties: *Cladophora* algae as a biological indicator of nutrient pollution, greenbelt status, erosion, alterations (e.g. seawalls, riprap), nearshore substrate types, and stream inlets and outlets. The survey was funded by the Michigan Department of Environmental Quality Nonpoint Source Program as a step in the development of a nonpoint source pollution management plan for the Burt Lake Watershed.

Survey results provide evidence of poor riparian property management practices that have the potential to degrade the Douglas Lake ecosystem. *Cladophora* growth was found at 27% of properties, with 53% of growths rated as moderate to heavy density. Greenbelts were found to be in poor or very poor condition at 53% of shoreline properties. Moderate to severe erosion was documented at 17% of properties and shoreline alterations were noted at 60%. On a positive note, 19% of greenbelts, representing more than 40% of the shoreline, were in excellent condition. Relative to other lakes in the region, Douglas Lake had a high percentage of properties with poor greenbelts and altered shorelines, and a low percentage with heavy *Cladophora*. Comparisons with the shoreline survey conducted on Douglas Lake in 2002 showed largely negative changes in shoreline conditions.

Numerous best management practices help minimize negative impacts to water quality. Maintaining a buffer of diverse, native plants along the shoreline helps filter pollutants and reduce erosion. Rain barrels, rain gardens, grassy swales, and many other techniques mitigate stormwater runoff impacts. Improving shoreline property management will help protect water quality, strengthen fisheries, and improve the quality of life and recreation on the lake.

To achieve the full value of this survey, these follow-up actions are recommended: 1) Educate riparian property owners about best management practices that protect water quality; 2) Send survey summaries 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 informational sessions 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 an assessment of: *Cladophora* algae growth as a nutrient pollution indicator, erosion, alterations (e.g., seawalls), greenbelts (i.e., shoreline vegetation), emergent aquatic plants, wetlands, and tributary inlets and outlets. Survey results provide the means to carry out follow-up actions that address problems in shoreline areas. Solutions, such as shoreline plantings and rain garden installation are generally simple and low cost. Education and outreach to shoreline property owners is also important, because it encourages the adoption of best management practices that prevent degradation of surface waters.

During late May and early June of 2015, the Tip of the Mitt Watershed Council completed a comprehensive survey of the Douglas Lake shoreline. This survey was funded by the Michigan Department of Environmental Quality Nonpoint Source Program as a step in the development of a nonpoint source pollution management plan for the Burt Lake Watershed. This was the third shoreline survey carried out on Douglas Lake. Periodic repetition of shoreline surveys is important for: identifying both 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 assessing the success of remedial actions.

Shoreline Development Impacts

Lake shoreline properties are the critical interface between land and water; where human activity has the highest potential for degrading water quality. Developing shoreline properties for residential, commercial or other uses invariably affects 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.

Nutrients are necessary to sustain a healthy aquatic ecosystem, but 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 lake's dissolved oxygen stores. Nighttime respiration, when plants compete with other organisms for oxygen, coupled with the decomposition of dead algae and plant material by aerobic bacteria, reduces a water body's dissolved oxygen stores. This is particularly problematic in the deeper waters of stratified lakes.

Large lakes, such as Douglas Lake, are generally more resilient to water quality impacts caused by nutrient pollution than small lakes. Large lakes have greater water volume and therefore, increased capacity for diluting pollutants and storing dissolved oxygen. However, the deep areas of Douglas Lake have a greater propensity to stratify, which prevents mixing of the water column and replenishment of dissolved oxygen stores. Stratification sometimes results in dissolved oxygen deficits at the lake bottom.

Surface waters receive nutrients through a variety of natural and cultural (human) sources. Natural sources of nutrients include stream inflows, groundwater inputs, surface runoff from riparian areas, and atmospheric deposition. Springs, streams, and artesian wells are often naturally high in nutrients due to the geologic strata they encounter and riparian wetlands can discharge nutrients during wet weather. 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., leaking sewer 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 (conductivity measures the water's ability to conduct an electric current, which is determined by the concentration of charged particles). Biologically, nutrient pollution can be detected along the lake shore by noting the presence of *Cladophora* algae.

Cladophora is a branched, filamentous green algae 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 by stabilizing the shoreline with plant root structures that protect against wave action and ice. The canopy of the greenbelt shades near-shore areas, which helps maintain cooler water temperatures and higher dissolved oxygen levels. In addition, greenbelts provide infiltration to reduce overland surface flow carried by stormwater from rain 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 also entail the loss of shoreline vegetation and 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 conduit of water and water-borne pollutants. Inlet streams may provide exceptionally high quality waters that benefit the lake ecosystem, but conversely have the potential to deliver contaminants from throughout the watershed and pollute the lake. Outlet streams flush water out of the lake, providing the means to expel contaminants that have accumulated in the lake ecosystem. The relatively higher nutrient levels in streams, relative to lakes, is important when assessing shore survey data because *Cladophora* growth is often heavier in shoreline areas adjacent to inlet tributaries.

Responsible, low-impact, shoreline property development and management is paramount for protecting water quality. Maintaining a healthy greenbelt, stormwater control with rain gardens, correcting erosion sites, and eliminating fertilizer and pesticide application are among many low-cost best management practices that minimize negative impacts of shoreline property management 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

Douglas Lake is located in Munro Township in northwestern Cheboygan County, Michigan. The lake covers an area of 3,780 acres and has 15.5 miles of shoreline (Cheboygan County GIS, 2012). Major landmarks in the western half of the lake include Marl Bay, Maple Bay, and Pell's Island; North Fishtail Bay and South Fishtail Bay lie to the east. Residential urbanization is seen along the shore of the western half of the lake, while the shoreline of North and South Fishtail Bay remains mostly undeveloped.

Douglas Lake is a kettle lake with five deep kettle holes that were formed by retreating glaciers thousands of years ago (Figure 1). The maximum depth in the lake is 80 feet in kettle holes between Pells Island and Grapevine Point and northwest of Pells Island. The majority of the lake has a depth of less than 30 feet. Lancaster (or Bessie) Creek and Beavertail Creek are the major inlets of Douglas Lake at the northeastern and northwestern shores, respectively. The Maple River East Branch is the major outlet of the lake in the southwestern shore of Maple Bay.

The Douglas Lake Watershed covers 27,364 acres; nearly equally split between Emmet and Cheboygan Counties. It stretches 12 miles from near Bliss to the northwest to the Interstate 75 Riggsville Road exit (Figure 2). Seepage from the hills northwest of Levering feeds expansive wetland complexes in the middle of the watershed that ultimately drain into Lancaster and Douglas Lakes. The Maple River Watershed, including Douglas Lake, comprises the northwest portion of the greater Cheboygan River Watershed, water from which ultimately drains into Lake Huron at the City of Cheboygan.

Land cover statistics for the Douglas Lake Watershed were generated using data from the NOAA's Coastal Change Analysis Program (Table 1). Based on 2010 data, a large portion 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/residential (1.6%) and a moderate amount of agricultural (17.6%), relative to other Northern Michigan watersheds. During the 25 year period between 1985 and 2010, agricultural lands increased by nearly 2%, while all other land cover types stayed approximately the same or decreased by less than 0.5%.

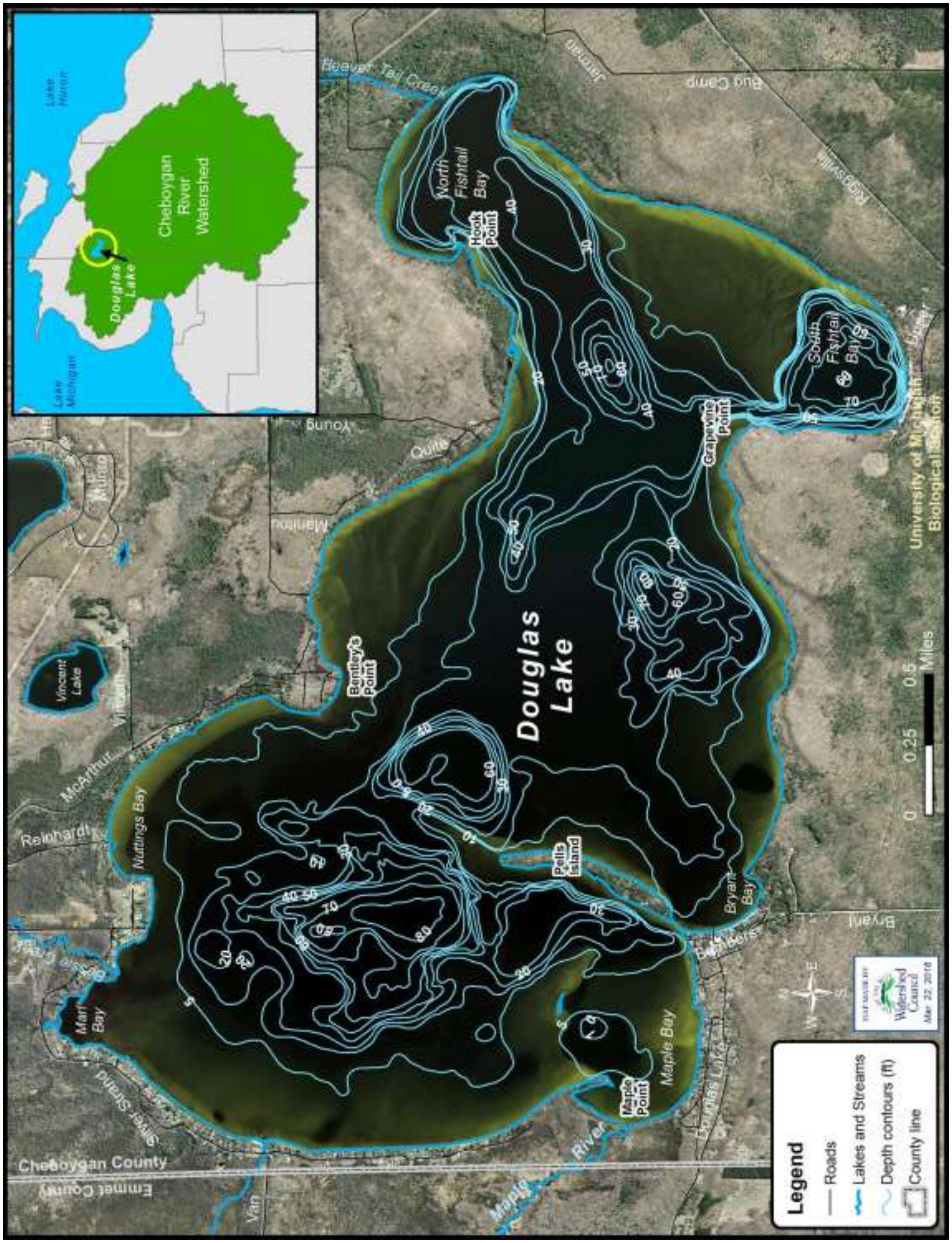


Figure 1. Map of the Douglas Lake features.

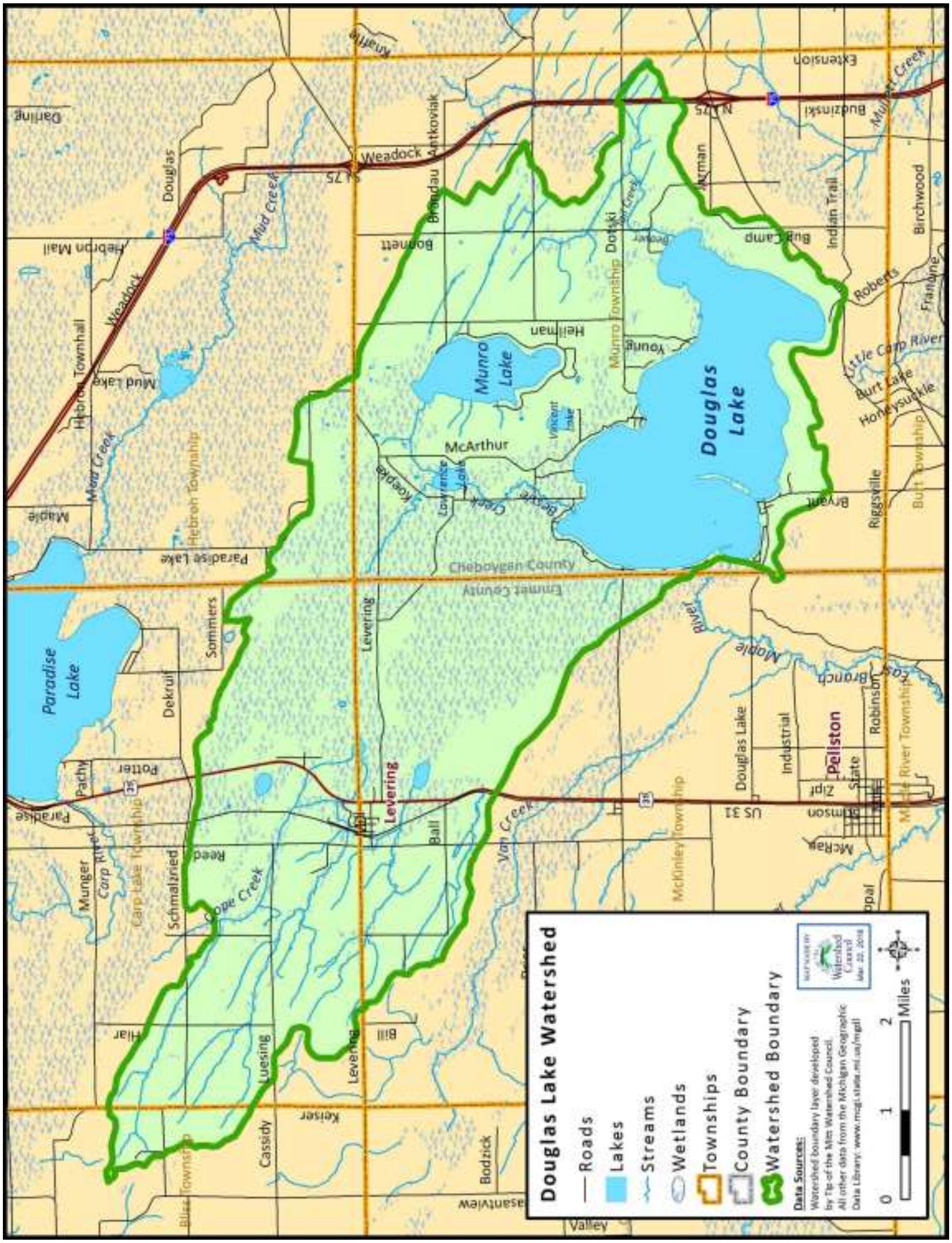


Figure 2. Douglas Lake Watershed.

Table 1. Douglas Lake Watershed land cover statistics (NOAA 1985, 2010).

Land Cover Type	1985 acres	1985 percent	2010 acres	2010 percent	Change (acres)	Change (percent)
Agriculture	4,319	15.78%	4,816	17.60%	497	1.82%
Barren	49	0.18%	22	0.08%	-27	-0.10%
Forest	6,615	24.17%	6,491	23.72%	-124	-0.45%
Grassland	1,567	5.73%	1,478	5.40%	-89	-0.33%
Scrub/Shrub	671	2.45%	555	2.03%	-116	-0.42%
Urban	516	1.89%	435	1.59%	-81	-0.30%
Water	4,437	16.21%	4,425	16.17%	-11	-0.04%
Wetland	9,190	33.58%	9,142	33.41%	-48	-0.18%
TOTAL	27,364	100.00%	27,364	100.00%	NA	NA

Water Quality Summary

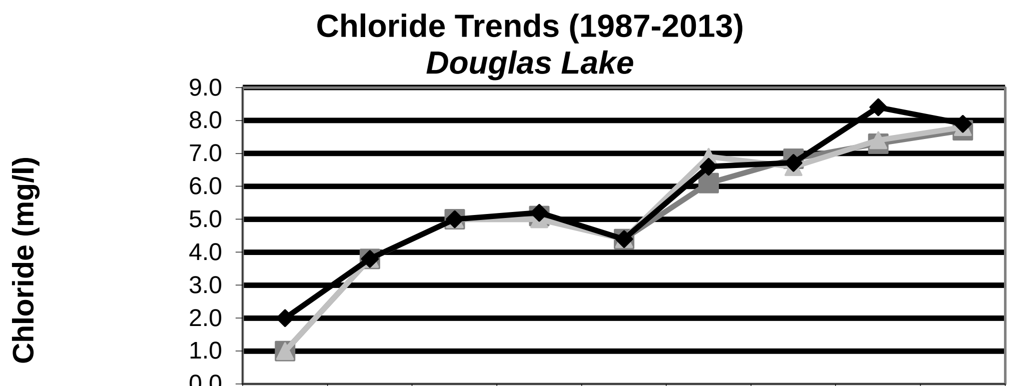
Based on water quality data collected in programs coordinated by Tip of the Mitt Watershed Council, Douglas Lake contains high quality waters typical for this region. As part of the Watershed Council's Comprehensive Water Quality Monitoring Program (CWQM), numerous parameters have been monitored in Douglas Lake on a triennial basis since 1987. Both dissolved oxygen and pH consistently comply with standards established by the State of Michigan (Table 2). Chloride levels have increased considerably over time, which indicates some degree of impacts from watershed development (Figure 3). Typical of high-quality lakes in Northern Michigan, nutrient concentrations on Douglas Lake are very low. CWQM program data show low phosphorus levels in Douglas Lake, less than 10 micrograms per liter (µg/L) on average and declining since 2001 (Figure 4). Phosphorus is found in short supply relative to nitrogen and thus, limits algae and plant growth in Douglas Lake.

Table 2. Douglas Lake data from the CWQM program, 1987-2013.

	Dissolved Oxygen	pH	Specific Conductivity	Chloride	Nitrate-Nitrogen	Total Nitrogen	Total Phosphorus
Units*	**mg/L**	**Units**	**µS/cm**	**mg/L**	**µg/L**	**µg/L**	**µg/L**
Average[£]	10.9	7.9	218	5.3	45	454	8.9
Minimum[£]	9.2	7.2	190	1.0	20	362	5.9
Maximum[£]	12.8	8.3	236	7.8	59	580	13.0

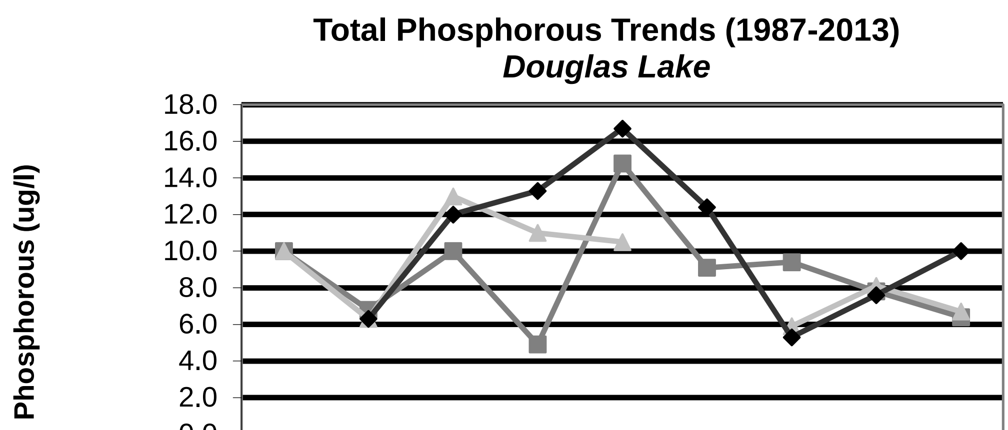
**mg/L = milligrams per liter, µg/L = micrograms per liter, µS/cm = microsiemens per centimeter.*

[£]*Statistics based on measurements from samples collected at mid-depth.*



	1987	1992	1995	1998	2001	2004	2007	2010	2013
Surface	1.0	3.8	5.0	5.1	4.4	6.1	6.8	7.3	7.7
Middle	1.0	3.8	5.0	5.0	4.4	6.9	6.6	7.4	7.8
Bottom	2.0	3.8	5.0	5.2	4.4	6.6	6.7	8.4	7.9

Figure 3. Chloride concentrations in Douglas Lake.



	1987	1992	1995	1998	2001	2004	2007	2010	2013
Surface	10.0	6.8	10.0	4.9	14.8	9.1	9.4	7.8	6.4
Middle	10.0	6.3	13.0	11.0	10.5		5.9	8.1	6.7
Bottom		6.3	12.0	13.3	16.7	12.4	5.3	7.6	10.0

Figure 4. Total phosphorus concentrations in Douglas Lake.

Douglas Lake has been determined a mesotrophic or moderately productive lake. However, trends evident in Tip of the Mitt Volunteer Lake Monitoring Program data show a reduction in biological productivity over time. Water clarity has gradually increased from an averaged Secchi disc depth of approximately 10 feet to 14 feet (Figure 5). Trophic Status Index values show that Douglas Lake now borders on oligotrophy (Figure 6). Oligotrophic lakes are characterized by cold, deep, clear water that is nutrient-poor.

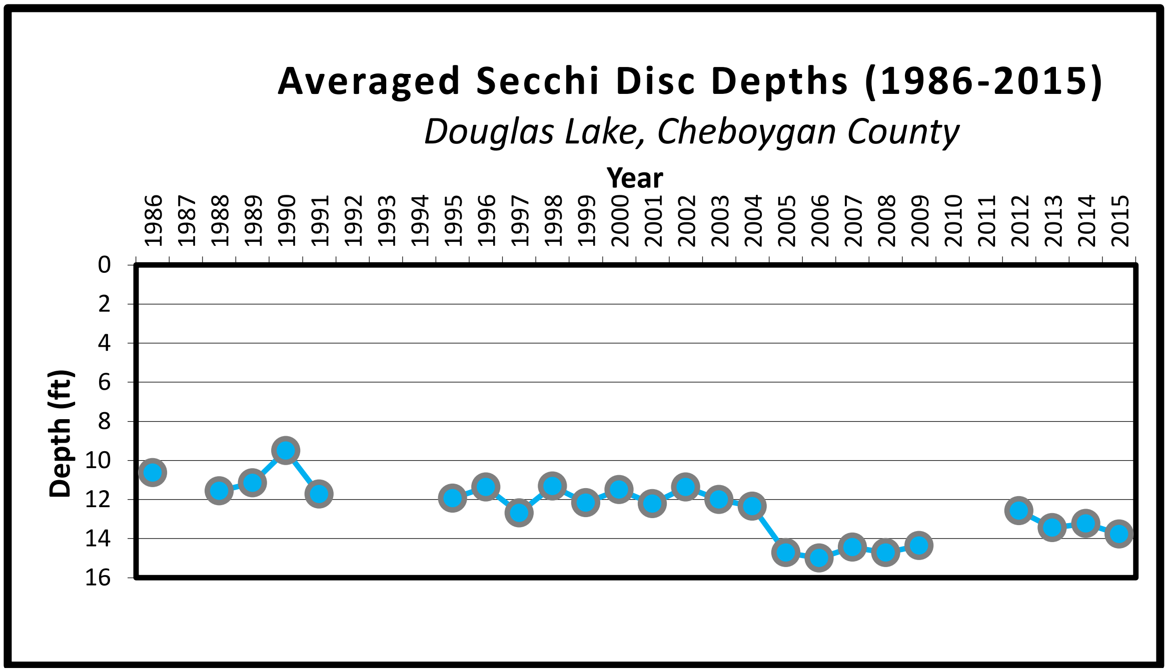
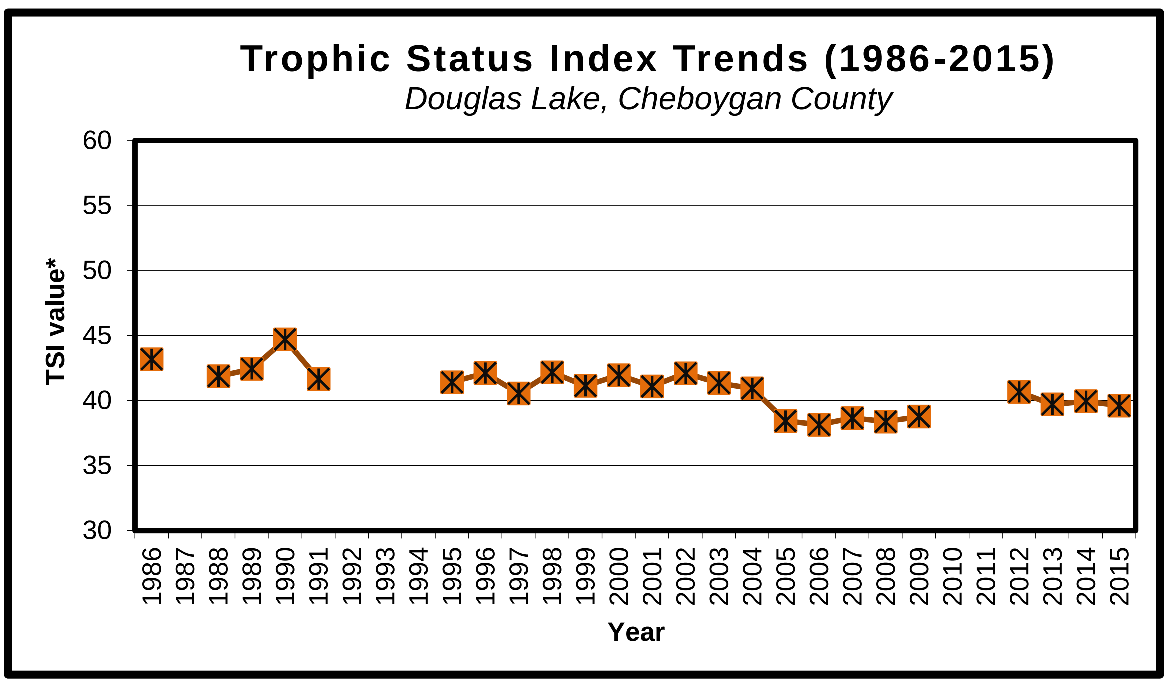


Figure 5. Water clarity in Douglas Lake.



**0-38 = oligotrophic or low productive system, 39-49 = mesotrophic or moderately productive system, and 50+ =eutrophic or highly productive system.*

Figure 6. Trophic status index values for Douglas Lake.

Prior Surveys

Prior shoreline surveys on Douglas Lake were performed in 1988 and 2002. All residential shoreline areas were surveyed in both of the earlier surveys. The 1988 survey was limited to nutrient pollution assessments, while the 2002 survey included nutrient pollution, shoreline erosion, greenbelt status, and shoreline alterations.

The Douglas Lake Improvement Association (DLIA) sponsored the 1988 shoreline survey (TOMWC 1988). Approximately 7.5 miles of the Douglas Lake shoreline were surveyed, containing 265 homes. A device called a Septic Leachate Detector (SLD) was used to identify locations of poorly functioning septic systems. The SLD indicated possible problem situations near 67 homes, with strong responses near 19 homes. Questionnaires regarding individual septic systems were set to residents of all 67 homes and 32 responses were received. Questionnaire responses indicated that 16 homes had sub-standard systems and 5 homes required better maintenance practices.

The project report for the shoreline survey of Douglas Lake in 2002 is available electronically at the TOMWC office. An electronic database containing results for 346 properties from the 2002 survey was also exists and is used to generate statistics. Cladophora was documented at 51 shoreline properties (14.7%) in 2002, of which 6 exhibited heavy-density growth and 12 had moderate-density growth (TOMWC 2002). Erosion was documented at 108 properties (31%), but severity information was not included. Over 70% of greenbelts were found to be in poor condition, with approximately 13% in pristine condition (Table 3). Alterations were found at 40% of properties, of which 67% were riprap, 31% seawalls, and the remaining 2% a mix of riprap and seawall.

Table 3. Greenbelt statistics from the 2002 shoreline survey.

Greenbelt Rating	**Number of Properties**	**Percent of Properties**
Very Poor	186	53.76%
Poor	62	17.92%
Moderate	34	9.83%
Good	20	5.78%
Excellent	44	12.72%
TOTAL	346	100.00%

METHODS

The Douglas Lake shoreline was comprehensively surveyed in late May and early June of 2015 to document conditions and activities that potentially impact water quality. All individual properties were surveyed by traveling in kayak as close to the shoreline as possible (usually within 10 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 and subsequently, inputted into a database. Shoreline properties were also photographed with a GPS camera, which were used to link field data 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* 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*.

Cladophora 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 was determined by estimating the percentage of substrate covered with *Cladophora* (Table 4).

Table 4. 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 exhibiting areas of bare soil, leaning or downed trees, exposed tree roots, undercut banks, slumping 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 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

Length and depth ratings were summed to produce an overall greenbelt score that ranged from 0 to 7. Scores represent greenbelt status or health with 0 considered very poor (no greenbelt), 1-2: poor, 3-4: moderate, 5-6: good, and 7: excellent (pristine).

Shoreline alterations were documented 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 a 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 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. In order to display survey results without pinpointing specific parcels, a new map layer was developed, which consisted 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 survey display maps.

Final products include a database with all field survey data, a complete set of GPS digital photographs, GIS data layers of shoreline parcels that include both county equalization and shore survey data, and maps displaying results. The shoreline survey database contains a sequential listing of properties beginning at the public boat launch at Douglas Lake Bar and traveling counter-clockwise around the entire perimeter of the lake. 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 also linked to a separate GIS data layer.

RESULTS

This survey documented shoreline conditions at 346 properties on Douglas Lake. Approximately 83% (288) of shoreline properties were considered to be developed. The length of shoreline per parcel varied from less than 20 feet to over 6000 feet.

Habitat generally considered suitable for *Cladophora* growth was present along at least part of the shoreline at 211 properties (61%). Noticeable growths of *Cladophora* or other filamentous green algae were found along the shoreline at 95 properties, representing 27% of the total or 33% of properties with suitable habitat (Table 5). At properties where *Cladophora* growth was observed, approximately 47% were classified as light or very light growth and six properties had heavy or very heavy growth.

Table 5. *Cladophora* density results.

Cladophora Density	Number of Properties	Percent of Properties*
Very Heavy	1	1
Heavy	5	5
Moderate to Heavy	11	12
Moderate	25	26
Light to Moderate	9	9
Light	31	33
Very Light	13	14
TOTAL	95	100

**Percent of properties with Cladophora growth.*

Greenbelt scores ranged from 0 (little to no greenbelt) to 7 (exemplary greenbelt). Approximately 32% of greenbelts were found to be in good or excellent condition (Table 6). Conversely, 53% of shoreline property greenbelts rated in the poor or very poor categories.

Some form of shoreline alteration was noted at 207 shoreline properties (60%) on Douglas Lake (Table 7). Riprap accounted for 59% of shoreline alterations, while seawalls, including seawalls combined with riprap or other structures, accounted for 33%. Beach sand, whether from fill or vegetation and topsoil removal to expose underlying sand, was documented at 17 properties.

Table 6. Greenbelt rating results.

Greenbelt Rating	Number of Properties	Percent of Properties
0 = Very Poor*	41	12
1-2 = Poor	141	41
3-4 = Moderate	52	15
5-6 = Good	45	13
7 = Excellent	67	19
TOTAL	346	100

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

Table 7. Shoreline alteration results.

Alteration Type	Number of Properties	Percent of Properties
Riprap	122	59
Seawall	34	16
Beach sand*	11	5
Riprap and seawall	32	15
Riprap and beach sand*	2	1
Seawall and beach sand*	1	0.5
Riprap, seawall, and beach sand*	3	1
Other alteration†	2	1
TOTAL	207	100

**Beach sand includes sand fill or exposing sand by removing vegetation.*
†Other includes rock groins, boat ramps, boat houses, or modifications.

Erosion was noted at 131 properties (38%) on the Douglas Lake shoreline (Table 8). Of these, only 11 properties were found to be experiencing severe erosion, while moderate erosion was documented at 47. The remainder (56%) were classified as minor.

Table 8. Shoreline erosion results.

Erosion Category	Number of Properties	Percent of Properties*
Minor	73	56
Moderate	47	36
Severe	11	8
TOTAL	131	100

**Percent of properties with erosion.*

Tributary streams were documented at 7 properties. The actual number varies from this total because tributaries are sometimes missed and those located at property borders are sometimes tallied for both properties.

Spatial patterns in the occurrence of *Cladophora* growths, erosion, and poor greenbelts were noticeable. Properties with moderate to heavy *Cladophora* growth were concentrated primarily south of Van Rd on the west shoreline, with a second cluster occurring at Bentley Point on the north shore. Properties with moderate to severe shoreline erosion were found in various locations throughout the lake, with clusters at Pells Island and adjacent areas on the south shore, as well as in the northwest corner of the lake. Groupings of properties with shoreline alteration and poor greenbelts corresponded with residential shorelines in the west half of the lake. Based on the property clusters described above, a map was developed highlighting the degraded shoreline areas (Figure 7).

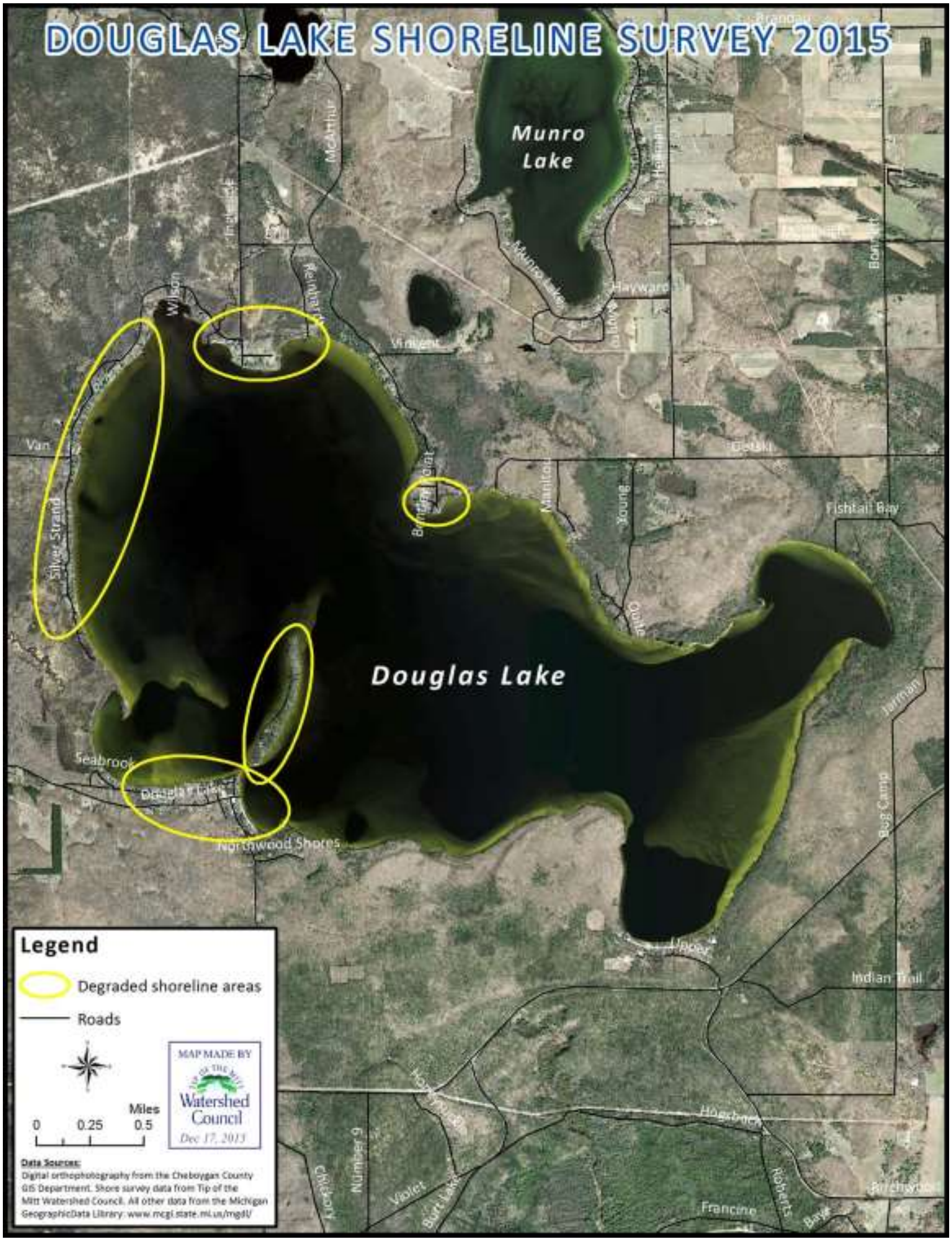


Figure 7. Survey results: degraded shoreline areas.

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 2015 survey indicate that poor greenbelts, shoreline alterations, and erosion pose the greatest threats to the water quality and nearshore health of Douglas Lake.

Relative to shore surveys conducted on other lakes in the region, Douglas Lake was well below the average in terms of the percentage of properties with *Cladophora* growth and heavy *Cladophora* growth (Table 9). *Cladophora* found on the west shore could be the result of anthropogenic sources of nutrient pollution, such as fertilizers, runoff from impervious surfaces, and septic system leachate in shoreline residential areas. However, it could also be due to natural factors, in particular, the inlet tributary near the intersection of Van and Silver Strand Roads. In Northern Michigan, streams typically have higher nutrient concentrations than lakes, which results in heavier Cladophora growth in shoreline areas near the inlet. On-site assessments by trained personnel can help determine if the algae growth is the result of human-caused nutrient pollution. Once the source of nutrient enrichment has been identified, actions can be taken to address the problem.

The percentage of properties with poor greenbelts on Douglas Lake (53%) was above the average for lakes in this region (Table 9). Lakeshore vegetation removal and the consequent loss of nearshore habitat and food sources impacts aquatic fauna ranging from minute crustaceans to top predator fish. Furthermore, the lack of vegetation leads to greater amounts of shoreline erosion and less filtration of pollutants. Although the percentage of properties with poor greenbelts was high, nearly 20% received a perfect score, indicating exemplary greenbelt health. Furthermore, several large properties owned by the University of Michigan Biological Station were among those receiving perfect scores, which account for approximately 40% of the Douglas Lake shoreline (6.3 miles). Properties such as these, with healthy, intact greenbelts, provide a model for improvement for other shoreline properties. Improvements in the quality of greenbelts throughout the shoreline will invariably have positive impacts on the lake's water quality and ecosystem in general.

Table 9. 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%
Charlevoix, Lake	2012	22%	19%	14%	34%	79%
Crooked Lake	2012	29%	26%	14%	51%	65%
Douglas Lake	2015	27%	6%	17%	53%	60%
Huffman Lake	2015	14%	0%	7%	57%	70%
Huron, Duncan Bay	2013	41%	2%	19%	45%	63%
Huron, Grass Bay	2013	0%	0%	4%	0%	8%
Lance Lake	2014	19%	0%	12%	35%	31%
Larks Lake	2006	4%	0%	ND	12%	29%
Mullett Lake	2008	59%	50%	7%	64%	58%
Pickerel Lake	2012	27%	33%	15%	52%	64%
Round Lake	2014	21%	0%	27%	44%	44%
Silver Lake	2014	3%	0%	70%	53%	65%
Six Mile Lake	2008	14%	5%	5%	34%	30%
Thumb Lake	2007	4%	0%	ND	ND	39%
Walloon Lake	2010	46%	24%	7%	36%	75%
Wildwood Lake	2014	5%	0%	22%	45%	50%
AVERAGE	NA	22%	12%	16%	41%	52%

**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.*

Shoreline erosion on Douglas Lake was at the average for lakes in this region (Table 9). The erosion on Pells Island occurred primarily on the east side, which is exposed to wave action from a fetch of up to 2.3 miles. Therefore, this erosion is primarily the result of natural physical forces. Many property owners on the island have hardened their shorelines with seawalls and riprap to reduce erosion. It is important that they maintain and enhance their greenbelts, and leave fallen trees in the water, to help reduce erosion.

The erosion documented in other areas of the lake consisted of two primary types: erosion occurring under shallow-rooted turf grass with no natural vegetation buffer and eroding beach sand. Regardless of the cause, corrective actions to address existing erosion, preferably using bioengineering techniques, as well as preventative measures, such as improving greenbelts, will benefit the Douglas Lake ecosystem.

The percentage of properties with shoreline alterations on Douglas Lake was above the regional lake average (Table 9). Most shoreline alterations (59%) consisted of small riprap, which is one of the least damaging types in regards to lake ecosystem health (Table 7). However, over 30% of noted alterations were seawalls or seawalls mixed with other alteration types, such as riprap or beach sand. 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 water quality and bolster the ecosystem of Douglas Lake.

Comparisons with the shoreline survey conducted on Douglas Lake in 2002 showed largely negative changes in shoreline conditions and associated property management. Cladophora occurrence increased by 12%, the majority of this increase occurring in the light and moderate density categories. There was little change in greenbelt conditions over time in terms of broad categories of poor, moderate, and good (grouping the top two and bottom two categories). Although the percentage of greenbelts rated as very poor decreased considerably since 2002, assessment methods varied between the two surveys. The percentage of shoreline properties with erosion increased by 7% over the 14-year period and alterations increased by 20%. Comparisons were not made with the shoreline survey conducted in 1988 because different parameters were assessed.

Numerous best management practices have been developed to minimize water quality and aquatic ecosystem degradation, which can be utilized during, or retroactively after shoreline property development. 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. 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 life and recreation on Douglas Lake.

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. Send a <u>general</u> summary of survey results to all shoreline residents, along with information about best shoreline property management practices. Also, provide practical, feasible, and effective action options to protect water quality. Keep the specific results of the survey confidential (e.g., do not publish a list or map of sites where shoreline erosion was found) as some property owners may be sensitive to publicizing information regarding their property.

2. Confidentially inform lakeshore property owners of shoreline survey results specific to their properties. The survey information can be made available via Watershed Council and partner web sites, with confidentiality ensured by randomizing the survey database and providing property owners with a code number specific to their property. This full report and a separate summary can be posted on web pages because they do not contain any property-specific information.

3. Encourage riparians property owners with moderate *Cladophora* growth, moderate to severely eroded shorelines, and poor or very poor greenbelt scores to work with the Watershed Council to identify and correct problems. Send these riparians a questionnaire to fill out and return (or make available electronically) to help interpret causes of the growth and provide recommendations for addressing problems. The Watershed Council or other qualified organizations or businesses can be contracted to perform site assessments to identify any problems and provide solutions.

4. Organize and implement 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.

5. Repeat some version of the survey periodically (ideally every 3-5 years), coupled with the follow-up activities described previously, in order to promote water quality awareness and good management practices on an ongoing basis, as well as identify chronic problem areas.

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