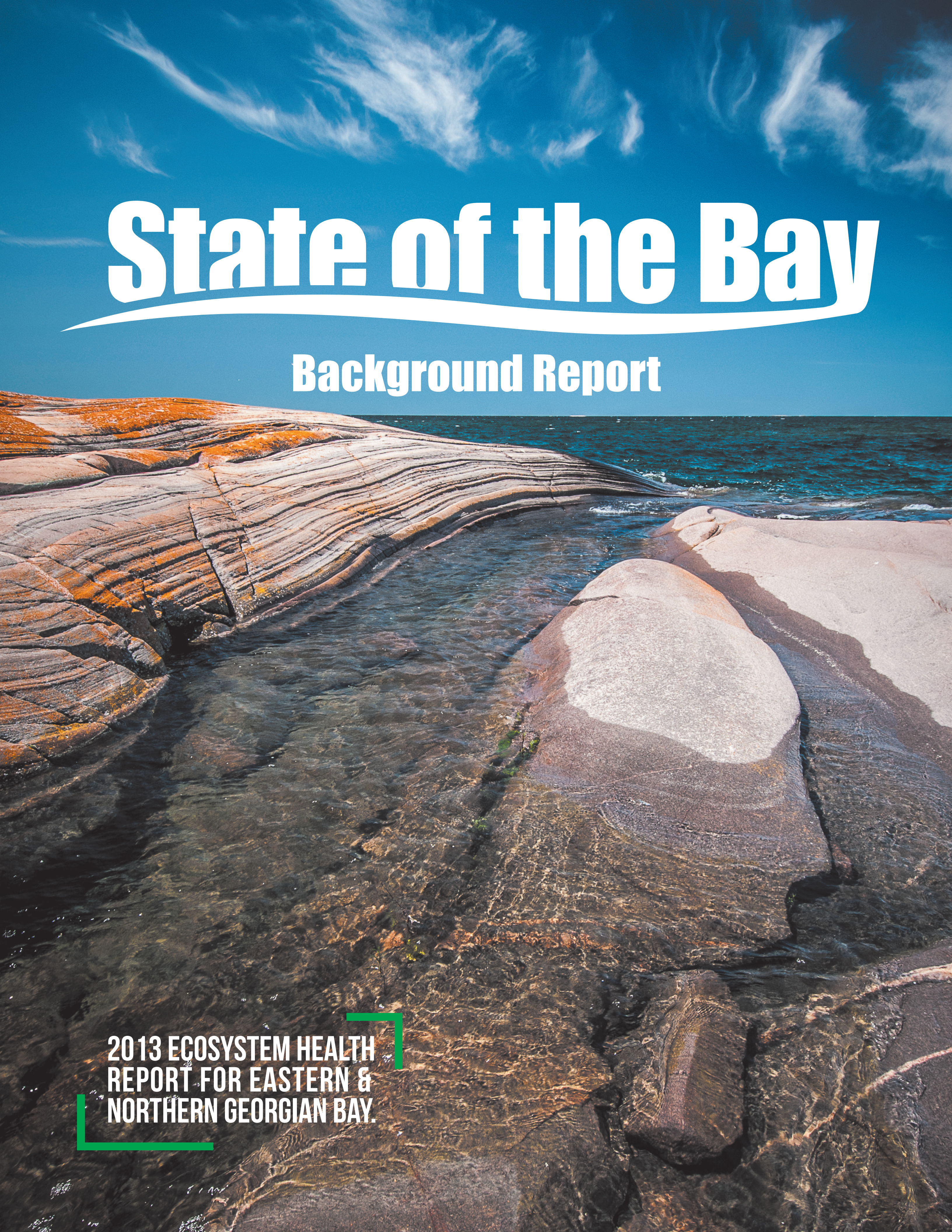
State of the Bay

Background Report



2013 ECOSYSTEM HEALTH
REPORT FOR EASTERN &
NORTHERN GEORGIAN BAY.

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Compiled by the Georgian Bay Biosphere Reserve.

Lead Author: David Bywater.

1 Introduction

When we think about Georgian Bay, images of islands, cobalt blue water, colourful rocks and windswept pines often come to mind, iconic scenes celebrated through the works of many artists including members of the Group of Seven. It's the same natural beauty of Georgian Bay that draws thousands of visitors each year to fish, swim, boat, and just relax along the shorelines. The quality of their experience is linked to the quality of the natural surroundings; hence a healthy environment is essential to our local economy.

How would you respond if asked for your view on the environmental health of Georgian Bay? Your answer is likely influenced by where you live, how long you've been there, and what activities you do. While eastern and northern Georgian Bay are considered to be in good condition compared to the other Great Lakes, they are still subject to pressures from invasive species, water levels, development and other human impacts. To help monitor these changes the Georgian Bay Biosphere Reserve (GBBR) and its partner organizations initiated the *State of the Bay* project.

Project partners came together in 2010 to begin discussions on the need for raising awareness about "the state of Georgian Bay" – by selecting key indicators that summarize the ecosystem health of the Bay. Beyond the science, the report is intended to highlight ongoing conservation and stewardship projects and how you can become more involved. *State of the Bay* project partners include:

1. The Georgian Bay Association – www.georgianbayassociation.com
2. The Georgian Bay Biosphere Reserve – www.gbbr.ca
3. Georgian Bay Forever – www.georgianbayforever.org
4. The Georgian Bay Land Trust – www.gblt.org
5. Eastern Georgian Bay Stewardship Council – www.helpourfisheries.com
6. The Muskoka Watershed Council – www.muskokawatershed.org

The *State of the Bay* project has three main components:

1. A 16 page, magazine-style, Public Report Card for eastern and northern Georgian Bay. This report card summarizes the key findings of each indicator and environmental issue.
2. A Background Report (this document) that forms the basis of the public report card and provides details about each indicator, outlines programs and practices to encourage public participation and stewardship (in relation to each indicator and environmental issue), and outlines data gaps and research needs.
3. A *State of the Bay* project website (www.stateofthebay.gbbr.ca) that profiles the Public Report Card, the Background Report, report card maps, and ways to get involved in environmental monitoring programs and stewardship practices.

Following the model of watershed report cards, the *State of the Bay* report presents information about key ecosystem health indicators along Georgian Bay. Key indicators were selected in the areas of water quality, wetlands, fisheries, and landscape in order to provide a science-based snapshot of conditions from Honey Harbour to Killarney-McGregor Bay. The *State of the Bay* project aims to summarize existing scientific reports about the Great Lakes, Lake Huron, and Georgian Bay, and bring it down to smaller regions of the Bay, so readers can learn about environmental conditions and trends in their own backyards.

The whole process of choosing ecosystem health indicators to effectively communicate complex science to the public raised a number of questions:

- Is the indicator a good barometer of ecosystem health?
- Do the indicators tell a meaningful story?
- Is the indicator data available/affordable and will it continue to be available in the future?
- Can the results be "graded" and what is an 'A' score over a 'B'?
- One of the biggest challenges was how to address ecosystem diversity – from nearshore areas to outer islands. How to compare or average these results would be like comparing apples and oranges.
- Another concern was about at what (regional/community) scale the results should be presented? Clearly giving the entire Georgian Bay a single grade would not be meaningful.

The scale for reporting was decided through a public survey. Over 250 people responded to questions about how they would like the report card presented. Not surprisingly, the overwhelming response was at the scale of a "community or neighbourhood"; this reflects a strong sense of people's place and attachment to their cottage associations or waterfront towns. Because of this connection, and because the data available can be analyzed at a regional level, the report card shows results for ten regions (Figure 1).

The overall boundaries for the *State of the Bay* report card were determined by the project's Steering Committee (list of Steering Committee members is provided in Section 9). The report card generally follows the UNESCO GBBR boundaries (visit www.gbbr.ca to learn more about GBBR boundaries), with the exception of the addition of the McGregor Bay and Killarney areas. The boundary for these areas roughly follows the Great Lakes Heritage Coast project boundary, which is also the basis for the GBBR boundaries. As noted above, public consultation helped to inform the designation of the report card 'regions.' The boundaries between regions predominately uses sub-watershed boundaries. The total area of the *State of the Bay* report card is 474,071 hectares.

Figure 1: *State of the Bay* report card regions

A number of factors informed the selection process for the ecosystem health indicators, including: public consultation, advice and guidance from scientists, an ecosystem health workshop, and a literature review. After selecting the six ecosystem health indicators, background research was carried out in order to identify available data sources, benchmarks, and information relevant to Georgian Bay. However, there are certain instances where data does not exist. In other words, it has not been collected through government, university, or community research and monitoring programs. Data gaps are considered to be an important outcome of the report card project. By flagging these data needs, hopefully they will be strategically filled and inform future report cards. Effective monitoring programs, such as the Lake Partner Program, provide long-term data that help establish trends. The reporting cycle for showing changes is typically 4-5 years and the project partners are hopeful that these gaps will be met in that timeframe through partnerships, community monitoring, and more research.

The six ecosystem health indicators selected for the 2013 *State of the Bay* report card are:

1. Phosphorus as an indicator of water quality (Section 2.1);
2. Fish community health (Section 2.2);
3. Percentage of natural cover (terrestrial) (Section 2.3);
4. Percentage of large natural areas (water and landscape) (Section 2.4);
5. Percentage of coastal wetland cover (Section 2.6); and
6. Wetland macrophyte (plants) as an indicator of wetland quality (Section 2.7).

Each of these ecosystem health indicators has been described, measured, and reviewed by experts. Together they provide a snapshot of the health of Georgian Bay and provide a baseline for future years.

Table 1 presents the *State of the Bay* 2013 report card results for the 10 regions, as well as an average for eastern and northern Georgian Bay. You will see that for some ecosystem health indicators, not enough data was available. In some cases more science is needed to define what should be measured.

Table 1: *State of the Bay* 2013 report card results

Region	Total Phosphorus (Average µg/L)	Fish Community Health (No grade available)	Coastal Wetland Cover (Percent wetland area)	Wetland Macrophyte Index (Average WMI score)	Natural Cover (Percent natural cover)	Large Natural Areas (Research required)
McGregor Bay & Killarney	NG	RR	2.5%	3.3 = C	95.7% = A	RR
French River	8.6 = B	RR	2.4%	3.7 = B	98.4% = A	RR
Britt	6.6 = B	RR	3.3%	3.6 = B	97.7% = A	RR
Pointe au Baril	8.4 = B	RR	5.4%	3.5 = B	98.3% = A	RR
Carling	9.6 = B	RR	3.2%	3.6 = B	95.6% = A	RR
Parry Sound	9.7 = B	RR	2.6%	NG	83.5% = B	RR
Massasauga & Sans Souci	9.8 = B	RR	2.3%	3.5 = B	95.8% = A	RR
Twelve Mile Bay & Go Home Bay	4.8 = A	RR	5.4%	3.7 = B	98.2% = A	RR
Cognashene	6.1 = B	RR	2.7%	3.8 = A	98.1% = A	RR
Honey Harbour	8.1 = B	RR	10.6%	3.3 = C	88.1% = B	RR
State of the Bay 2013 Average	8.0 = B	RR	3.3%	3.6 = B	96.0% = A	RR

NG = No grade available. RR = Research required.

During the process of identifying and selecting the ecosystem health indicators it was decided that the *State of the Bay* 2013 report card should also report on key environmental issues facing Georgian Bay. These three issues are: Water Levels (Section 3); Invasive Species (Section 4); and Species at Risk (Section 5).

Special thanks goes to the Ontario Trillium Foundation, RBC Bluewater, the Canada-Ontario agreement respecting the Great Lakes Basin Ecosystem (COA), the Lake Huron Framework for Community Action, and to the many businesses, municipalities, and organizations who have become sponsors of the program.

Ontario Trillium Foundation
Fondation Trillium de l'Ontario
An agency of the Government of Ontario.
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RBC
RBC Blue Water Project™

Ontario

Lake Huron - Georgian Bay Watershed
A Canadian Framework for Community Action

2 Ecosystem Health Indicators

A total of six ecosystem health indicators have been selected for *State of the Bay* 2013 report card: Total Phosphorus; Fish Community Health; Natural Cover; Large Natural Areas; Coastal Wetland Cover; and Wetland Macrophyte Index. A number of factors informed the selection process for these indicators, including: public consultation, advice and guidance from scientists, an ecosystem health workshop, and a literature review.

During the process of identifying and selecting the ecosystem health indicators it was decided that the *State of the Bay* 2013 report card should also report on key environmental issues facing Georgian Bay. These three issues are: Water Levels; Invasive Species; and Species at Risk.

2.1 Total Phosphorus

2.1.1 What is measured?

Average total phosphorus (TP) concentration of a report card region. Please note that this average phosphorus concentration includes the nearshore waters of eastern Georgian Bay (and does not include data from inland lakes).

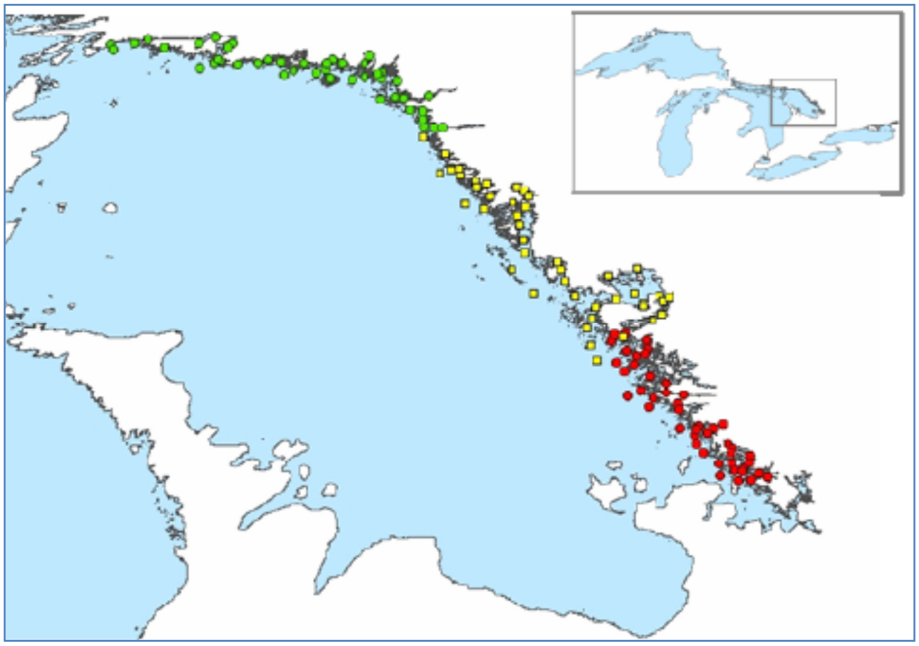
2.1.2 How is it measured?

Phosphorus monitoring is carried out by a number of organizations and various levels of government across eastern Georgian Bay. The *State of the Bay* report card has utilized two existing data sets to report on phosphorus concentrations, these are: the Lake Partner Program (LPP) and the Great Lakes Nearshore Assessment (GLNA). By combining these two data sets we'll have great geographical coverage, long term and short term data trends, seasonally variability, and a mechanism to encourage public monitoring. For the *State of the Bay* report card, TP was calculated by adding the phosphorus values from the GLNA and LPP datasets for each region, and dividing by the number of sampling values.

The Lake Partner Program, operated by the Ministry of Environment (MoE), is a province wide, volunteer-based, water quality monitoring program. Volunteers collect TP samples and make monthly water clarity observations on their lakes. MOE staff also sample lakes on the Canadian Shield for TP once per year during the month of May (MoE, 2005b). TP analyses are conducted at the Dorset Environmental Science Centre's low-level laboratory. The LPP data was screened for outliers using two procedures. The first procedure used a "bad split" test to identify large differences between duplicate samples. The second procedure used "Dixon's test" to identify outliers between duplicate pairs and within a site over time.

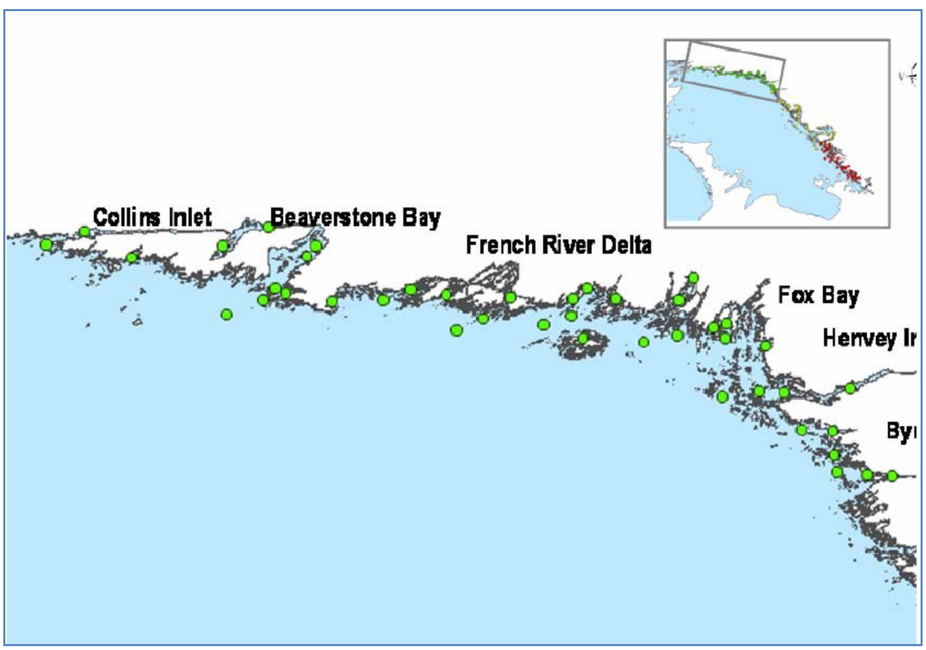
To detect a trend in phosphorus concentrations, the Lake Partner Program recommends analysis of a minimum of three years of data. It is anticipated that *State of the Bay* report cards will occur on a four-to-five year reporting cycle and therefore LPP data used for this 2013 report card includes 2009 to 2012. However, four years of data does not allow for the examination of long-term trends. The LPP encourages monitors to examine the long-term trends from their dataset to identify outliers, discern seasonal patterns, and gain a sense of average phosphorus levels for their particular water-body.

The Great Lakes Nearshore Assessment was conducted by the Environmental Monitoring and Reporting Branch of the MoE. The objective of the GLNA was to document ambient water quality conditions in the coastal areas of eastern Georgian Bay across a spectrum of physical environments; to assess variability in water quality over the region; and to examine the factor(s) responsible for observed patterns of variability. Water quality conditions were characterized between 2003 and 2005 across a spectrum of environments along a north to south gradient, from Killarney to Honey Harbour. Figure 2 presents an overview map of all the sampling stations: the green dots were sampled in 2003 (Figure 3); the yellow dots were sampled in 2004 (Figure 4); and the red dots were sampled in 2005 (Figure 5). Embayments, coastal nearshore and open-water locations were sampled three times to capture spring, summer and fall water quality conditions. This study conducted monitoring on a range of water quality parameters, including conductivity, alkalinity, chloride, pH, dissolved organic carbon, TP, nitrogen, chlorophyll A, silicates, optical properties, and hypolimnetic (hypolimnion = deep cold zone of water) water quality. TP analyses were conducted at the Dorset Environmental Science Centre's low-level laboratory (Diep et al., 2007). The GLNA was conducted over a three year period due to the large scope of the assessment in terms of spatial coverage (i.e. eastern Georgian Bay), seasonal variability, and a wide range of parameters. The GLNA data used for the *State of the Bay* report card was screened for outliers by the GLNA team.



Source: Diep et al., 2007.

Figure 2: GLNA sampling stations



Henvey I = Henvey Inlet

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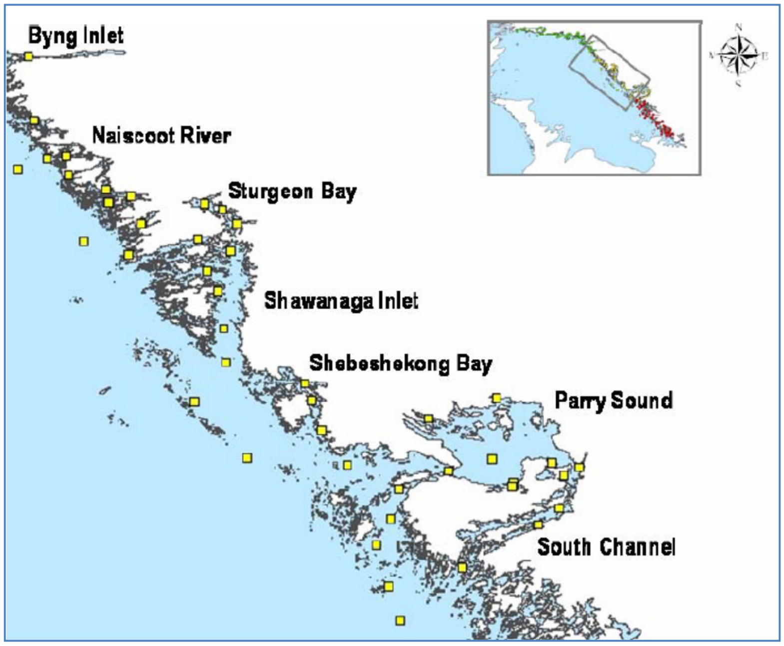
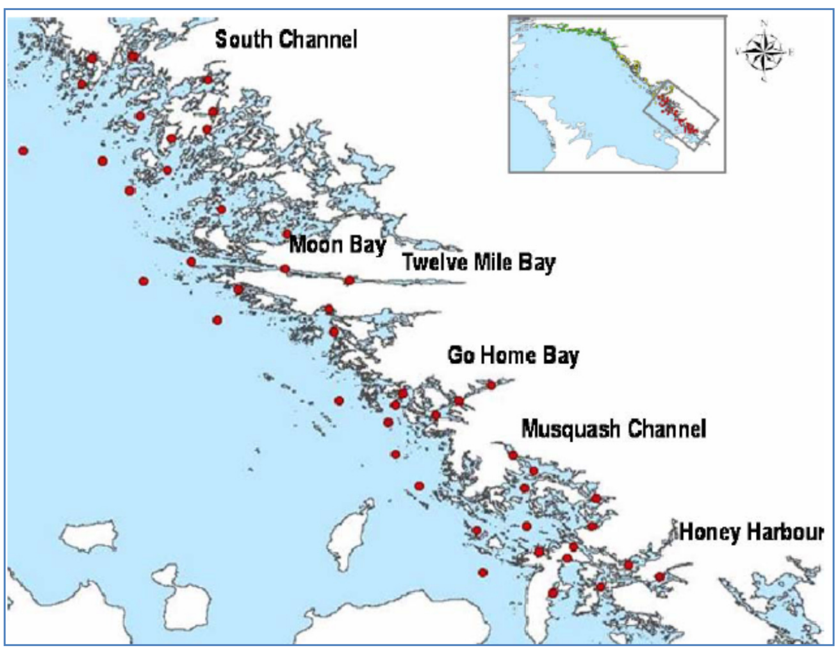
Source: Diep et al., 2007.

Figure 3: Water quality stations sampled in 2003 from Killarney to Byng Inlet



Source: Diep et al., 2007.

Figure 4: Water quality stations sampled in 2004 from Byng Inlet to Parry Sound

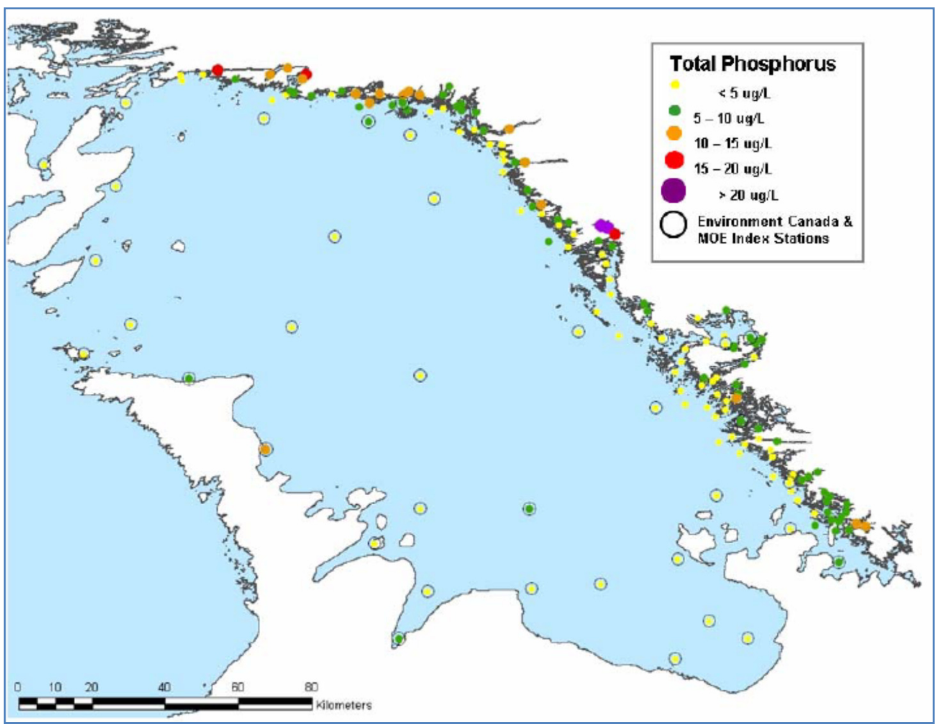


Source: Diep et al., 2007.

Figure 5: Water quality stations sampled in 2005 from Parry Sound to Honey Harbour

Many limnologists place lakes into three broad categories with respect to nutrient status. Lakes with less than 10 µg/L TP are considered oligotrophic. These are dilute, unproductive (in terms of aquatic life) lakes that rarely experience nuisance algal blooms. However there are exceptions to this general trend with areas of the Great Lakes experiencing nuisance levels of algal with reference levels less than 10 µg/L. Lakes with TP between 10 and 20 µg/L are termed mesotrophic and are in the middle with respect to trophic status. These lakes show a broad range of characteristics and can be clear and unproductive at the bottom end of the scale or susceptible to moderate algal blooms at concentrations near 20 µg/L. Lakes over 20 µg/L are classed as eutrophic and may exhibit persistent, nuisance algal blooms (MoE, 2005a).

Georgian Bay is oligotrophic with the GLNA reporting a phosphorus concentration below 5 µg/L across the coastal waters of eastern Georgian Bay. However, TP concentrations varied widely across sampling locations (Figure 6) with concentrations between 1 – 31 µg/L and with trophic status ranging from oligotrophic to meso-eutrophic. Higher TP levels were observed at embayment locations and lower concentrations were observed at the open water locations. Seasonal variability in phosphorus levels were also evident with maximum TP concentrations observed in the spring. A spring TP median of 6.4 µg/L suggests seasonal influx of higher nutrient waters to the eastern shores of Georgian Bay. Phosphorus levels diminish in the summer and fall, with lower variability and lower seasonal averages, likely due to either reduced inputs from the watershed or to biological uptake by phytoplankton (Diep et al., 2007).



Source: Diep et al., 2007.

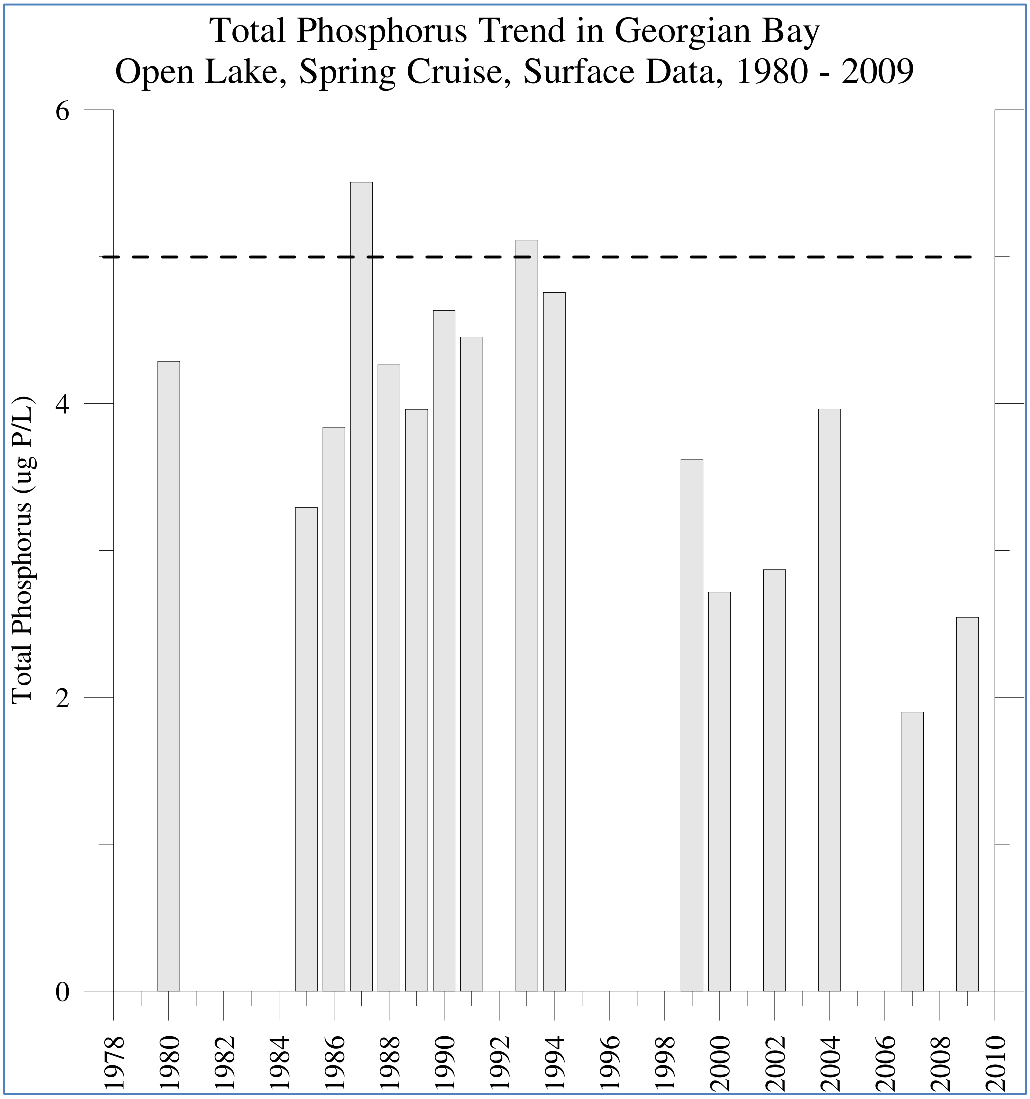
Figure 6: TP concentrations for 2005-2007 at stations in the Great Lakes Nearshore Reference and Index Station Network

TP levels have been decreasing in Georgian Bay (Figure 7). This decline is due to both a reduction in nutrient loading and a change in biological processing of phosphorus.

Dolan and Chapra (2012) conducted modelling and data analysis to evaluate whether target loads of phosphorus established by the Great Lakes Water Quality Agreement (GLWQA) have been and are currently being met. Historically, the Lake Huron load was occasionally above its target of 4360 metric tonnes per annum (MTA) through 1985. The analysis determined that main Lake Huron never exceeded its target load during the study period (1994 to 2008), although the major embayments, and in particular Saginaw Bay, occasionally exceeded their targets.

Georgian Bay's target load was set at 600 MTA in 1976 and the estimated load at this point in time was 630 MTA. Georgian Bay's target load has been exceeded only once since 1994, with a load of 658 MTA in 2000. The average target load for Georgian Bay during the 15 year study period (1994 to 2008) was 420 MTA Dolan and Chapra (2012). The reduction in nutrient loading since the 1970s is due significant restrictions on point sources of TP loading to the Great Lakes basin (discussed in Section 2.1.3.2). Remedial Action Plans (RAP) were developed and implemented for areas of concerns, which are areas that experienced environmental degradation. Within eastern Georgian Bay, Severn Sound was identified as an area of concern. Their RAP (Sherman, 2002) highlighted improvements to sewage plants and called for application of agricultural best management practices (BMPs) for important watersheds. Overall, the BMPs resulted in the loss of less sediment and sediment bound phosphorus via creeks. The most widely practiced BMP was stream fencing to keep livestock away from the stream banks (EC, 2013).

The decline in phosphorus may also be connected to the ongoing spread of quagga mussels (*Dreissena bugensis*) whose populations have increased by a factor of 5 between 2003 and 2006 (EC, 2013). Dreissenid mussel invasions (which include zebra mussels) have often been associated with dramatic changes in the physical, chemical, and biological properties of the affected habitats, including shifts in primary production and energy transfer from pelagic to benthic pathways. Mussels are known to filter nutrients from circulating water and cause a deposition of nutrients in nearshore areas and advection (horizontal movement of water) to deep sediment areas. Nearshore areas of Lakes Huron exhibited significant decreases in phytoplankton, P, chlorophyll, and chlorophyll to phosphorus ratios coincident with establishment of dreissenids, indicating that the filtering impact of the mussels has an appreciable effect on the nearshore water column (Hecky et al., 2004).



Source: Environment Canada, 2009.

Figure 7: TP trend in Georgian Bay

2.1.3 Why is it important?

Phosphorus is a natural essential nutrient, required by phytoplankton and the quantity of phosphorus is generally a good indicator of the productivity or trophic status of an aquatic system. Phosphorus is an essential nutrient for the plants and animals that make up the aquatic food web. Phytoplankton, photosynthetic organisms at the base of the food web, require phosphorus for growth and temperate freshwater ecosystems are generally phosphorus limited (Diep et al, 2007).

Phosphorus exists in different forms in water. It can be dissolved, bound to particles of soil and other materials, or contained within living or decaying plants. Dissolved phosphorus is most readily used by plants and algae, and is typically found in low concentrations in unpolluted water bodies (MoE, 2011). TP is a measure of both inorganic and organic forms of phosphorus.

TP is also an indirect indicator of recreational water quality, as changes to water quality affect recreational pursuits such as swimming, boating, fishing and aesthetic enjoyment. Good water quality and healthy aquatic ecosystems are generally the most important concerns expressed by those living on or using recreational lakes and rivers in Ontario. Without clean and safe water, many of our favoured summer recreational activities are jeopardized and our sense of enjoyment of being in a natural and relatively pristine environment is quickly lost (Schiefer, 2009).

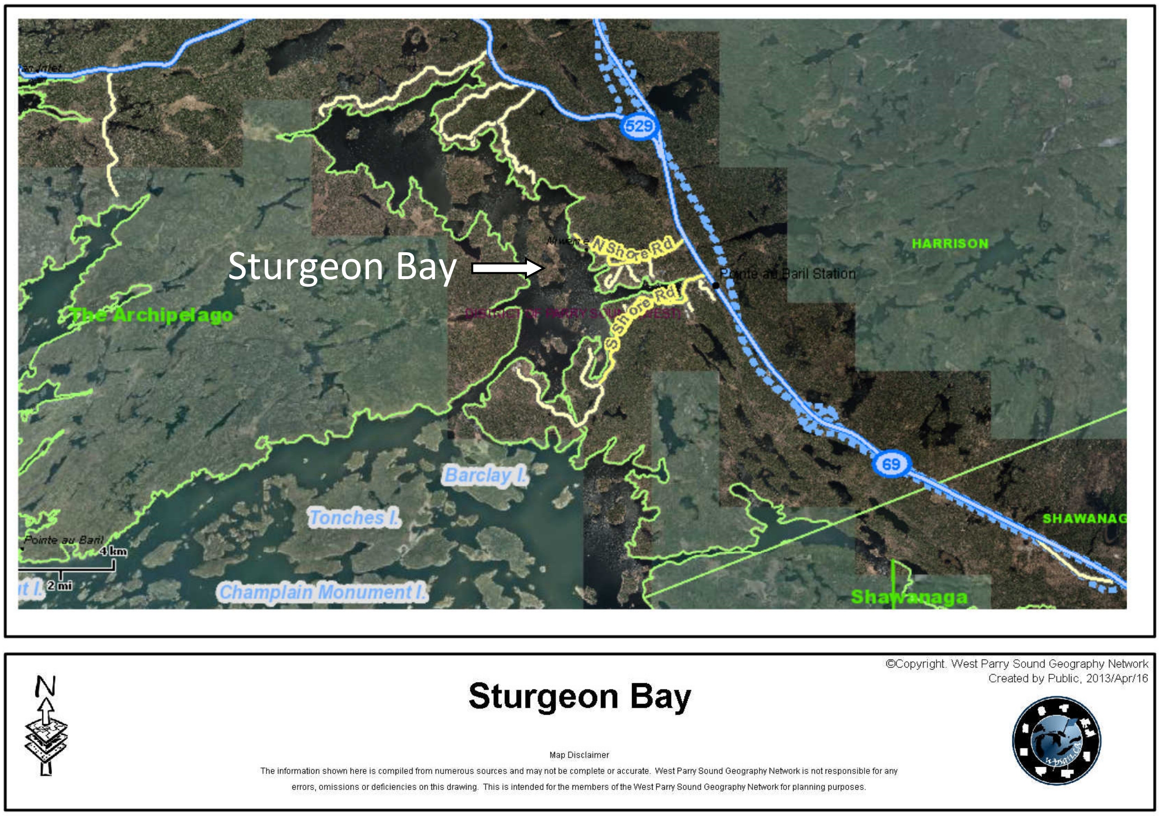
2.1.3.1 Sources of phosphorus

Phosphorus sources come from both natural processes (watershed run-off and atmospheric deposition) and human activities (septic systems and land disturbance). For the purposes of discussion potential sources of phosphorus are presented below using the above categories.

Sturgeon Bay is an interesting case study as this embayment has been extensively monitored and studied due to re-occurring high levels of phosphorus, often resulting in blue-green algae blooms. Sturgeon Bay is a relatively large embayment (690 ha – including islands) with two distinct basins extending approximately 15 km inland from the northeast shoreline of Georgian Bay (Figure 8). Sturgeon Bay is hydrologically connected to Georgian Bay via a narrow channel, but is largely isolated from major hydrological and limnological processes operating in the open water of Georgian Bay (Schiefer, 2003). As such, the chemical characteristics of Sturgeon Bay are distinct from those of Georgian Bay with higher nutrient concentrations and lower pH and conductivity that reflect stronger watershed influences (Diep et al., 2007) and the generally shallow nature of the Bay (Figure 9).

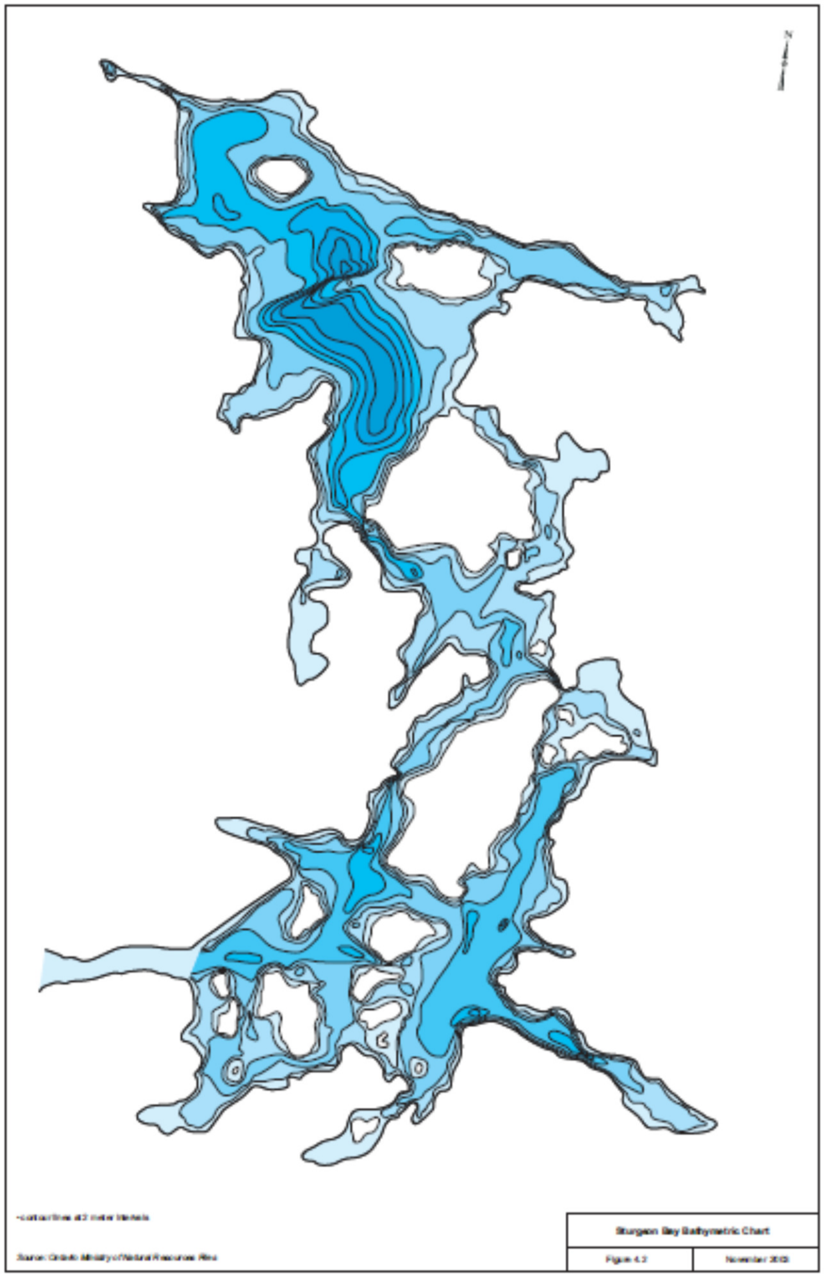
Sturgeon Bay is a major access node and service area for the large water-access cottage community in this region of Georgian Bay. Approximately 70% of the developed lots on Sturgeon Bay have road access, with the remainder being water access. These factors have resulted in a significant amount of lakeshore cottage development. Sturgeon Bay also has a village of year-round residents at Pointe au Baril Station, several large tourist resorts, a number of large marinas, a water-access commercial service area at Pointe au Baril Station, and a provincial park with camping and beach use at the northeastern extremity of the bay (Sturgeon Bay Provincial Park).

Other areas of Georgian Bay have also experienced elevated phosphorus levels, and in some cases algae blooms, including: French River, Honey Harbour, Cognashene Lake, Twelve Mile Bay, Go-Home Bay, Port Severn, and inland bays in Parry Sound. These elevated TP levels have often been detected with monitoring completed by consultants and environmental associations. However, the monitoring data are insufficient in most cases to determine if anything has, or is changing, and the science to determine the cause of the problems and what to do about them have not been done (EC, 2013).



Source: West Parry Sound Geography Network.

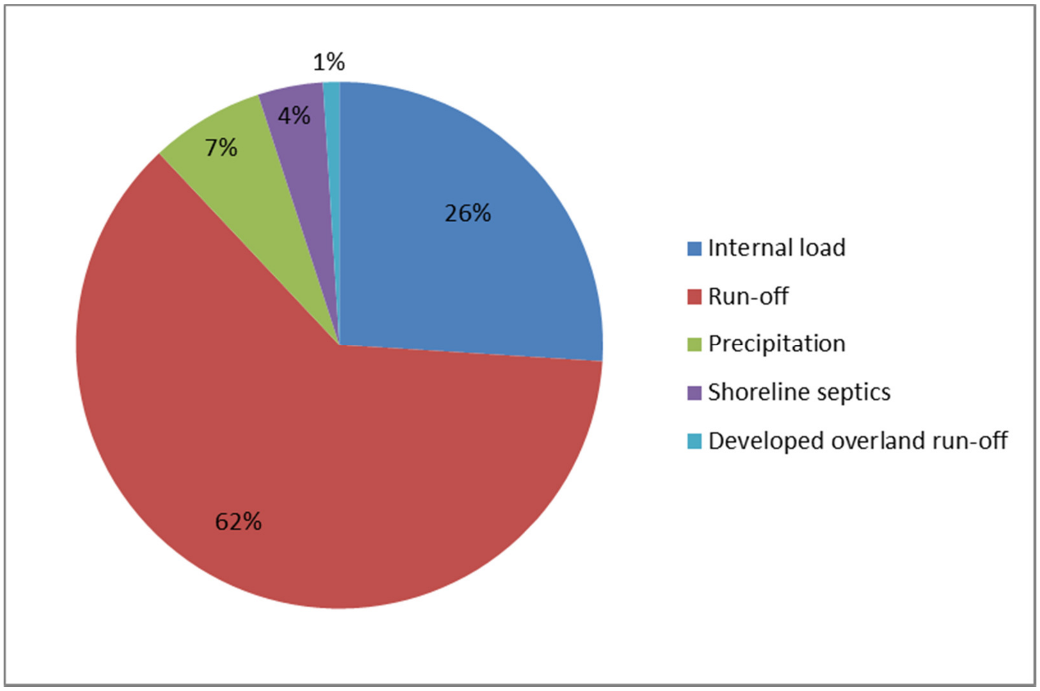
Figure 8: Aerial view of Sturgeon Bay



Source: Schiefer, 2003.

Figure 9: Sturgeon Bay bathymetric chart

Gartner Lee (2008b) conducted modelling to predict TP concentrations by estimating hydrologic and phosphorus loading from natural and human sources and linking them together with an understanding of lake dynamics to predict TP concentrations in lakes. The contribution of phosphorus sources in Sturgeon Bay is illustrated in Figure 10 and discussed below in order to provide an example of the influence of each source. However, the contribution of sources to the TP 'budget' will vary for each water-body, due to differences between watershed, morphometry, usage of the shoreline, and extent of exchange with open water.



Source: Gartner Lee, 2008b.

Figure 10: Relative phosphorus loads to Sturgeon Bay from external and internal sources

Natural Processes

<u>Run-off from Undeveloped Land</u>

Georgian Bay receives hydrologic and nutrient loadings from all upstream sources in its watershed. Tributaries (such as rivers and streams) typically provide the water-based transport mechanism for phosphorus sources flowing into Georgian Bay from upstream watersheds. Due to the differences in landscape and land-use of the watersheds along eastern and northern Georgian Bay, it is not possible to generalize about the influence of tributaries as a source of phosphorus. Instead, the extent to which a tributary is a source of phosphorus (to a particular area of the Bay) needs to be evaluated on a case by case basis. Furthermore the influence of tributaries changes over the year due to the seasonal changes in flow rates (with the largest influence occurring during spring).

Gartner Lee (2008b) concluded that overland run-off from undeveloped watershed areas is the largest source of phosphorus to Sturgeon Bay with loads representing 62% of the total load. This high run-off load is due to the relatively large undeveloped surrounding area which includes abundant wetlands.

Wetlands (such as bogs, marshes, fens, and beaver ponds) are thought to provide a significant source of natural phosphorus as they typically have a higher level of organic material (from decaying plants).

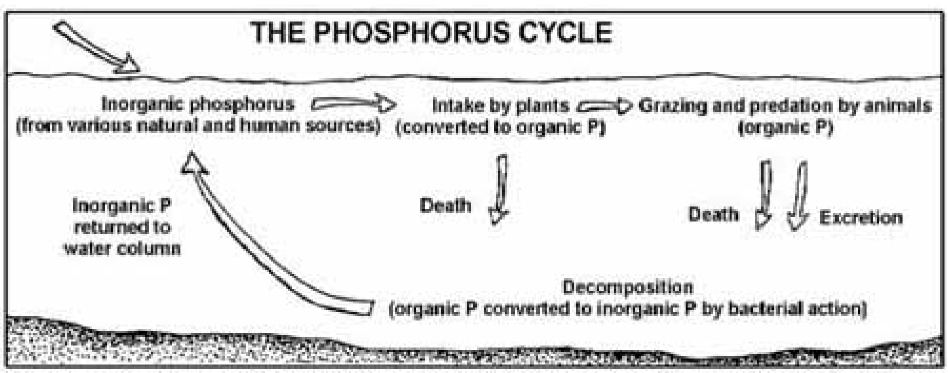
In a study of 33 coastal marshes, DeCatanzaro and Chow-Fraser (2011) found the phosphorus concentrations averaged 16 µg/L with a range of 9 to 34 µg/L. These studies found that the season variability was considerable. It should be noted that these values do not represent discharge to bays, but rather indicate the range of concentrations available in nearby water.

Atmospheric Deposition

Atmospheric transport of phosphorus usually occurs in a particulate form adhering to other materials and is often calculated as the amount of precipitation to the lake surface. In the case of Sturgeon Bay, Gartner Lee (2008b) determined that atmospheric deposition represents 7% of the TP load.

Internal Phosphorus Cycling

Internal phosphorus loading refers to the release of phosphorus contained in bottom sediments to the overlying water (Figure 11), which, in some water bodies, can contribute to a significant amount of the total phosphorus load (Figure 10). A combination of chemical and biological factors control internal loading, but the most important factor is the amount of dissolved oxygen (DO) in waters near the sediment-water interface. Under anoxic (absence of oxygen) conditions, phosphorus is readily mobilized in a dissolved form that is biologically available for algal growth. Under oxygenated conditions, phosphorus is mineralized but more slowly (than in anoxic conditions) (Gartner Lee 2008a).



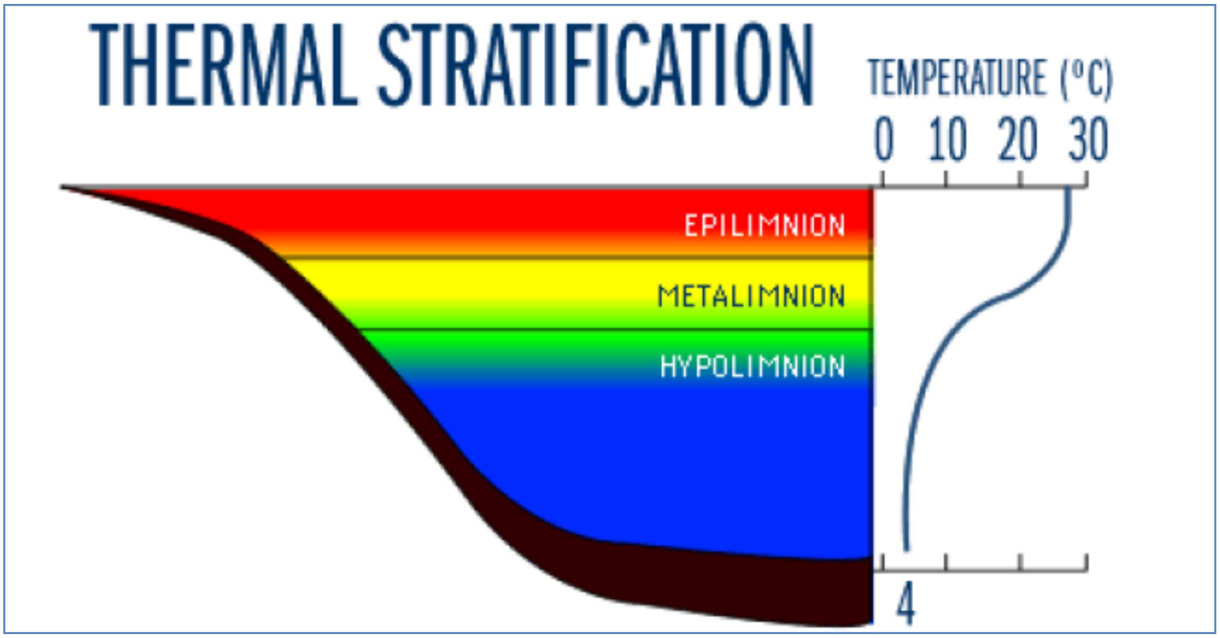
Source: http://water.epa.gov/type/rsl/monitoring/vms56.cfm

Figure 11: Internal phosphorus cycling

Anoxia can develop in water bodies that undergo thermal stratification (Figure 12), a process whereby layering occurs in the water column due to temperature-dependent density gradients. In sufficiently deep temperate lakes, the surface waters warm over the course of the open-water season creating a warmer, less dense layer (the epilimnion) of water that overlies a colder denser layer (the hypolimnion). Between these two layers is a third layer (the metalimnion) where the strongest vertical differences (gradients) in temperature, and therefore density, prevail (the thermocline). All temperate lakes deeper than ~10 m will stratify but the onset and intensity of stratification depends on a number of factors including the shape and depth of the basin, the amount of wind, and the orientation of the lake with respect to dominate wind directions. For example, in the absence of rain or snowmelt, an injection of nutrients may occur simply from high winds that mix a portion of the nutrient-enriched upper waters of the hypolimnion into the epilimnion. (Gartner Lee 2008a).

For those interested in learning more about lake ecology, the Environmental Protection Agency (USA) has a great primer:

- http://cfpub.epa.gov/watertrain/pdf/limnology.pdf



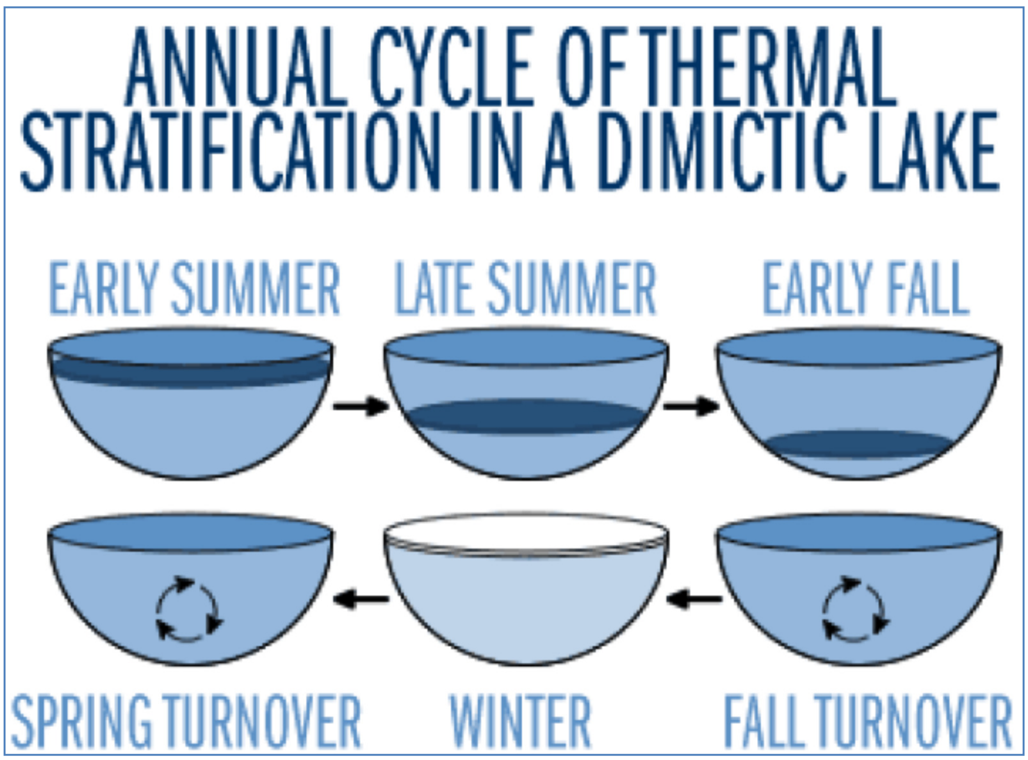
Source: http://cfpub.epa.gov/watertrain/pdf/limnology.pdf

Figure 12: Thermal stratification

The DO concentration in the epilimnion remains high throughout the summer because of photosynthesis and diffusion from the atmosphere. Concentrations of phosphorus typically decrease in the epilimnion during summer stratification as nutrients are taken up by algae and eventually transported to the hypolimnion when the algae die and settle out. During this period, any "new" input of nutrients into the upper water may trigger a "bloom" of algae (EPA, Date unknown).

However, conditions in the hypolimnion vary with trophic status. In eutrophic (more productive) lakes, hypolimnetic DO declines during the summer because it is cut-off from all sources of oxygen, while organisms continue to respire and consume oxygen. The bottom layer of the lake and even the entire hypolimnion may eventually become anoxic, that is, totally devoid of oxygen. In oligotrophic lakes, low algal biomass allows deeper light penetration and less decomposition. Algae are able to grow relatively deeper in the water column and less oxygen is consumed by decomposition. The DO concentrations may therefore increase with depth below the thermocline where colder water is "carrying" higher DO leftover from spring mixing (recall that oxygen is more soluble in colder water). In extremely deep, unproductive lakes, such as Lake Superior, DO may persist at high concentrations, near 100% saturation, throughout the water column all year. These differences between eutrophic and oligotrophic lakes tend to disappear with fall turnover (EPA, Date unknown).

In the winter, oligotrophic lakes generally have uniform conditions. Ice-covered eutrophic lakes, however, may develop a winter stratification of DO. If there is little or no snow cover to block sunlight, phytoplankton and some macrophytes may continue to photosynthesize, resulting in a small increase in DO just below the ice. But as microorganisms continue to decompose material in the lower water column and in the sediments, they consume oxygen, and the DO is depleted. No oxygen input from the air occurs because of the ice cover, and, if snow covers the ice, it becomes too dark for photosynthesis. This condition can cause high fish mortality during the winter, known as "winter kill." Low DO in the water overlying the sediments can exacerbate water quality deterioration; because when the DO level drops below 1 mg O_2/L chemical processes at the sediment-water interface frequently cause release of phosphorus from the sediments into the water. When a lake mixes in the spring, this new phosphorus that has built up in the bottom water fuels increased algal growth (EPA, Date unknown). Figure 13 illustrates the annual cycle of thermal stratification in a dimictic lake (lakes with a pattern of two mixing periods are referred to as dimictic).



Source: http://cfpub.epa.gov/watertrain/pdf/limnology.pdf

Figure 13: Annual cycle of thermal stratification in a dimictic Lake

The exposure of the coastline also influences internal phosphorus cycling. Even in areas that are not susceptible to anoxic bottom waters, there is a gradient in the amount of fine particles and organic material that will accumulate on the lake bed depending on exposure and re-suspension by wave action. For example, shallow areas of open coastline typically have a lakebed composed of hard material, often of bedrock, with little buildup of fine sediment and organic material. In a comparative sense, these areas are less likely to experience phosphorus buildup on sediment particles and in bottom dwelling organisms than in embayments and more protected areas, where fines sediments accumulate and bottom dwelling organisms are typically more numerous and internal cycling of phosphorus is likely greater.

In the case of Sturgeon Bay, Gartner Lee (2008b) determined that the internal load represents 26% of the TP load and is the second largest source (after run-off from undeveloped watershed areas).

Human Activities

Human activities that take place upstream in watersheds also contribute to phosphorus entering into tributaries: discharges from sewage treatment plants and septic systems; storm water runoff from developed areas; and erosion and runoff from agricultural lands that have been treated with phosphorus containing fertilizers or manures or both (MoE, 2011).

Phosphorus can enter a water-body from land-use activities near and/or adjacent to Georgian Bay. The quantification of phosphorus loadings from septic systems, lawn fertilizers, soap and detergent use, stormwater runoff from developed areas, and other human activities is difficult to quantify without complex measurement and modelling. For example, a shoreline development activity (towards new lots or existing properties) raises potential concerns about impacts on water quality. The amount of phosphorus generated by a shoreline residence will depend on the usage of that residence; the number of people using it and the amount of time they spend there, as well as their overall environmental practices (that can be assessed using GBBR's Life on the Bay guide). Year-round occupancy will generate more phosphorus contribution to a septic system and hence more potential for phosphorus to migrate to the water-body.

Septic systems are often perceived to be a significant source of nutrients, especially where systems are old and do not meet the building code. Gartner Lee (2008b) noted that recent scientific studies have shown that much of the septic phosphorus load is reduced by acidic and mineral-rich soils found in the Precambrian shield. The mineralization of phosphate occurs with the iron and aluminum in the soil. The mineralization reactions appear to be favoured in acidic and mineral rich groundwater in Precambrian Shield settings, such that over 90% of septic phosphorus may be immobilized (Gartner Lee, 2008b). These reactions appear to be permanent. It should be noted that these studies are based on performance, and that when septic systems are poorly installed, or have breakthroughs, there is the risk of nutrients entering the local water-body. Septic system maintenance tips are outlined in Section 2.1.6.

Given the strong scientific evidence supporting the reduction of septic phosphorus by soils, recent water quality models typically assume some reduction of septic phosphorus with distance from the lake, but there is no clear guidance on how much phosphorus is reduced by soils. Gartner Lee (2008b) assumed that 26% (as an input for their modelling) of the septic phosphorus moves to the lake, based on the findings of Dillon et al. (1994) that studied phosphorus loading from septic systems around Harp Lake in Muskoka.

Furthermore, landscape features influence the movement of phosphorus from sources such as septic systems, fertilizers, and stormwater run-off. Hardened surfaces, such as pavement or rock, have an increased ability (compared to natural surfaces) to convey particulate material of phosphorus to a water-body. Waterfront homeowners and businesses should consider the water quality benefits of a more natural landscaping, including the use of native plants and shrubs. The use of vegetative buffer strips slows down run-off, capture sediments and increase infiltration and phosphorus uptake rates. A case study presented in the Environmental Protection Agency's Understanding Lake Ecology (date unknown) compared different phosphorus export coefficients and determined that eleven years of phosphorus loading from a forested area can be deposited within a year from urbanized areas.

In the case of Sturgeon Bay, the Gartner Lee (2008b) modelling determined that septic systems do not have a large effect on the embayment. They reported that shoreline and the Provincial Park septic systems account for only 4% of the total load. The run-off from developed areas accounts for 1% of the total load.

Despite these low percentages of external sources of phosphorus in Sturgeon Bay, the concerns regarding the long-term effect of storing human waste in the shoreline decade after decade persist. Environment Canada's (2013) Science Synthesis report recommends a correlative study to examine the relationship between cottage development and water quality by comparing bays and lakes of equal size and depth.

2.1.3.2 Eutrophication and algae blooms – when phosphorus levels become too high

TP concentrations are ideally used to interpret nutrient status since phosphorus is the element that controls the growth of algae in most Ontario lakes. Excessive inputs of phosphorus to water bodies can disrupt the natural processes of a water system and its inhabitants. When a water-body experiences excessive loading of nutrients it is called nutrient enrichment or eutrophication (Figure 14).

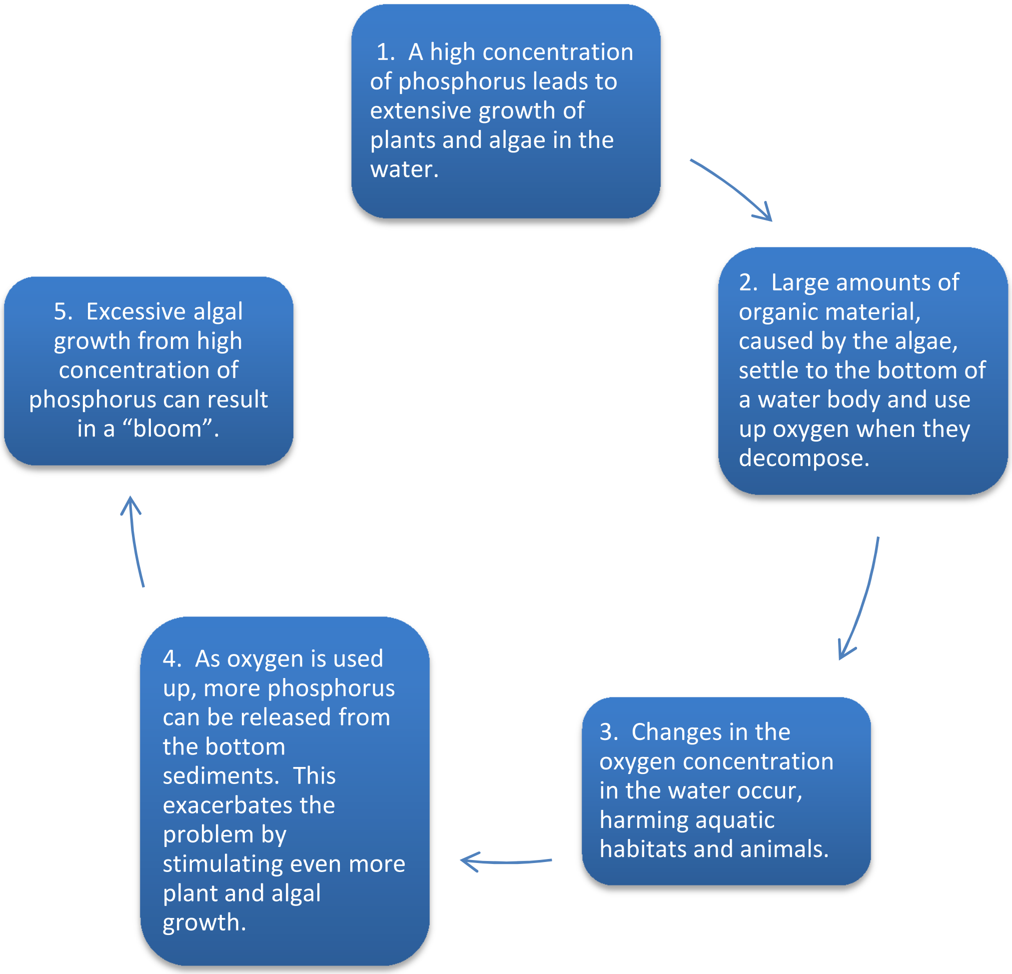


Figure 14: Phosphorus enrichment cycle

Eutrophication is the process by which a body of water acquires a high concentration of nutrients, especially phosphorus and nitrogen. These typically promote excessive growth of algae. As the algae die and decompose, oxidation of this organic matter and respiration by the decomposing organisms can deplete the water of available oxygen, causing the death of other organisms, such as fish. Most focus is on visible blue-green algae blooms caused by toxic cyanobacteria. However green algae like Cladophora can also create large blooms, but they do not produce harmful algal toxins.

In extreme cases, blue-green algae blooms will affect the aesthetics of the lake and/or cause taste and odour problems in the water. Blue-green algae, known scientifically as cyanobacteria, are primitive microscopic plants commonly found in freshwater. Not only are these blooms unappealing in appearance and smell but when the algae die they may release toxins, and if ingested these toxins can cause health issues in humans, pets, livestock, and wildlife.

History of Cladophora in the Great Lakes

By the early 1960s, Cladophora blooms occurred in all five of the Great Lakes. Cladophora blooms were identified as a significant problem in the lower Great Lakes (Erie, Michigan, Ontario) from the 1950s through the 1970s by the International Joint Commission and were recognized in the Great Lakes Water Quality Agreement (1978) between Canada and the United States (Higgins et al., 2008).

Numerous studies were conducted during the 1970s and early 1980s to better understand the ecology of C. glomerata and provide the information necessary for successful management. These studies identified the role of temperature, light, macronutrients (C, N, P), and micronutrients in constraining Cladophora growth rates and biomass accrual. They provided a scientific consensus that elevated concentrations of soluble phosphorus associated with cultural eutrophication were ultimately responsible for the bloom occurrences (Higgins et al., 2008).

Reductions in TP concentrations in the lower Great Lakes from the 1970s to the mid-1990s, brought about through significant restrictions on point sources of TP loading to the Great Lakes basin, were primarily designed to reduce eutrophication in the offshore waters of the lakes and deep-water anoxia in Lake Erie. These reductions in loading and ambient TP concentrations, however, also reduced Cladophora biomass. During the time period 1984–1993, few incidents of beach fouling by Cladophora were reported (Higgins et al., 2008).

Nuisance growth of the attached, green alga Cladophora was considered to have been abated by phosphorus management programs mandated under the GLWQA. The return of widespread Cladophora blooms in the lower Great Lakes from 1995 to 2006 was not associated with increased TP loading or ambient TP concentrations. The notable increase in shoreline fouling by Cladophora in the lower Great Lakes was, however, coincident with the establishment of dense communities of invasive zebra and quagga mussels (*Dreissena polymorpha* and *D. bugensis*, respectively), which occurred during the early to mid-1990s (Higgins et al., 2008). The impact of these mussels on water quality is provided in Section 2.1.2.

2.1.3.3 Phosphorus concerns in Georgian Bay

The GLNA reported an annual median of 5.5 µg/L, which indicates that the majority of eastern Georgian Bay is oligotrophic (nutrient poor water). However, there are areas of the Bay that have phosphorus concerns and problems. Since at least 2001, extensive algal blooms have developed annually in Sturgeon Bay beginning in late summer. Visible blooms and surface scums have been most prominent in the north end of Sturgeon Bay as seen in Figure 15 (Gartner Lee, 2008a). As noted above in Section 2.1.3.1, other areas of Georgian Bay have also experienced elevated phosphorus levels, and in some cases algae blooms.

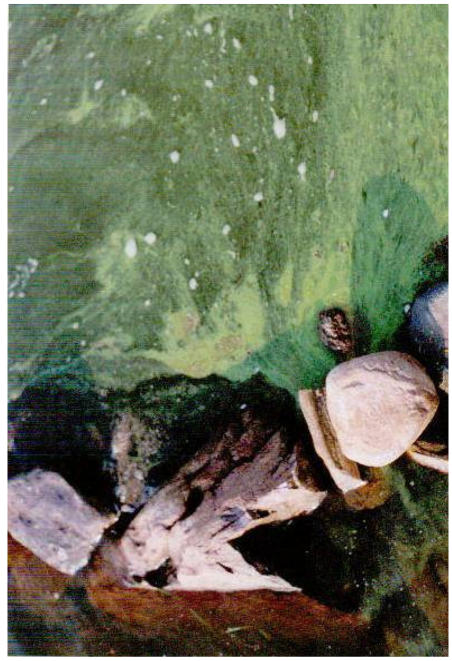



Figure 15: Algae bloom in Sturgeon Bay

Environment Canada's Science Synthesis report (2013) reviewed phosphorus monitoring along eastern Georgian Bay and noted that most of the embayments or lakes experiencing elevated levels of TP have low DO concentrations in the summer. Low DO can exclude fish from the bottom layer and allow some release of phosphorus from the sediments. The report noted that the degree of oxygen depletion seems high compared to the relatively low phosphorus concentrations in surface water and hypothesized that these areas may begin the season with abnormally low oxygen. The report suggests that monitoring from early spring through the season could show whether the water column ever achieves equilibrium with the atmosphere. The report also notes that it is important to determine how to prevent the production of more organic matter in these bays and to determine whether there is any unexpected shore or watershed sources of organic matter that may decay to exacerbate the oxygen depletion.

However, it should be noted that low oxygen concentrations in the summer do not necessarily mean that a water-body will have elevated phosphorus levels. Many water bodies will naturally experience oxygen reduction in the bottom layer due to physical structure/bathymetry.

There are further factors involved in this complex system. Iron is released from sediment under the same DO conditions which release phosphorus. Some of the iron in solution is an essential nutrient for blue-green algae. Blue-green algae can access this iron by migrating down to assimilate it and then migrating back up to depths where there is more light; the iron may also diffuse upward. It is hypothesized that the blooms do not occur until recycling of the iron during bottom water anoxia allows them to grow and dominate the algal population. This "phosphorus-ferrous eutrophication model" is being tested in Sturgeon Bay (Molot et al. 2010) and may result in new information on the extent of nutrient interaction.

Recently, a new product called Phoslock has become available for phosphorus inactivation. Phoslock is considered a natural, non-toxic product, produced from modified bentonite clay and developed by the Land and Water Division of Australia's Commonwealth Scientific and Industrial Research Organization. The objective of this product is to significantly reduce the amount of filterable reactive phosphorus present in the water column and in the sediment pore water of a water body (Gartner Lee, 2008c). The Township of the Archipelago is leading on the application process to apply Phoslock in Sturgeon Bay and information on the status of the application can be found here:

- www.thearchipelago.on.ca/index.php/residents/water-quality/water-quality

Consideration needs to be given to what phosphorus concentrations are required for algal blooms to occur. Due to the complexity of mechanisms that promote algal blooms, as well as the physical and bathymetric properties of a water-body; there is no magic number at which algal blooms occur. Other areas of the Great Lakes are experiencing algal blooms, in particular Lakes Ontario and Erie; however, given the significant differences between the characteristics of these southern Ontario water bodies (e.g., geological, hydrological, bathymetrical, and surrounding land use patterns), a comparison with Georgian Bay's coastal embayments and lakes is not particularly useful.

Successful management of algal blooms will require an improved understanding of the sources and retention to the littoral zone of both particulate phosphorus (i.e., that can be recycled by dreissenid mussels) and soluble phosphorus, improved monitoring and forecasting of dreissenid population density, improved monitoring of Cladophora populations over a gradient of human and dreissenid influence, and further improvements in our understanding of Cladophora ecology and capacity to model the complete seasonal growth cycle and transport and fate of detached filaments (Higgins et al., 2008). Potential effects on these water bodies from changing water levels and climate change, add further complexity to the research needed.

2.1.4 What do the grades mean?

Selecting a benchmark for eastern Georgian Bay is difficult due to the broad range in phosphorus concentrations across locations and seasons, which highlights the inherent variability in this region and are likely a function of proximity to shore, the magnitude and characteristics of the watershed, and the physical features of the site. These environmental features are key to understanding the nutrient dynamics of the coastal areas of eastern Georgian Bay (Diep et al., 2007).

The GLWQA outlines substance objectives for phosphorus concentrations for the open waters of each Great Lake. These substance objectives are established to facilitate the Parties achieving the Lake Ecosystem Objectives. As a result of the creation of these substance objectives each Party is required to meet phosphorus loading targets and allocations for each Great Lake.

The substance objective for TP concentration in open waters for Lake Huron is 5 µg/L (as represented by spring means). The *State of the Bay* report card has adopted this value as a benchmark and the grades for TP concentration are:

- A < 5.0 µg/L
- B 5.0 – 9.99 µg/L
- C 10.0 – 14.99 µg/L
- D 15.0 – 19.99 µg/L
- F > 20 µg/L

The updated version of the GLWQA (EC, 2012) states that it will develop substance objectives for nearshore waters, including embayments and tributary discharge for each Great Lake. It is recommended that future *State of the Bay* report cards review the updated GLWQA for a Georgian Bay substance objective (to be used as the TP benchmark).

It is recognized that averaging TP values across a report card region does not reflect the environmental features that influence the TP value of a specific area. In other words, potential areas of concern that record higher values, often found at nearshore locations (Figure 16) and in particular embayments, will be artificially lowered by averaging across a region. And of course the opposite is also true in that lower values, often found at open water locations (Figure 17), will be artificially elevated by averaging across a region. However, the report card scale allows for regional representation that provides an indication of the overall condition of a region. We encourage residents and seasonal visitors to compare their local TP values to the grades presented above.

Figure 16: Example of a 'Nearshore' location – Key River

Figure 17: Example of an 'Open Water' location – the Umbrellas

Ideally, a grading system that is based on regional segmentation of environmental features would be preferred. For example, this system would likely have different grading systems for nearshore and open water areas, because as noted above, these areas typically have different TP values. This system would likely produce an index that reflects the ranges in environmental conditions/features within the system for an overall rating/grade. However, the research and data is not currently available to determine this index and overall rating system. The Environmental Monitoring and Reporting Branch (of the MoE) are aware of this data gap and endeavour to include it as part of their survey design in subsequent Georgian Bay nearshore assessments.

Another potential approach for future phosphorus grading systems was suggested by Keith Somers with the DESC. In collaborations with universities, they have proposed a generic method to define normal conditions based on the reference condition approach (as outlined in Kilgour et al., 1998). The variability or distribution of samples from minimally impacted reference areas is used to characterize the normal range of variability and this range can be used to evaluate samples from other areas. This approach would define the normal range for reference areas in Georgian Bay as a means to evaluate samples from embayments that may be experiencing different levels of anthropogenic impacts.

In summary, the current benchmark and grading system takes a regional approach to evaluating TP in order to provide more options in the future as research provides better information. The objective of the *State of the Bay* program is to determine current environmental conditions using existing data and analysis. The program also aims to identify research gaps (Section 2.1.7), such as the need for an improved TP grading system, which can improve future report cards that will be issued on a 4 or 5 year reporting cycle.

2.1.5 What are the results?

Table 2: Grades for Total Phosphorus

Region Name	Average TP Value	Grade
McGregor Bay & Killarney	No data	-
French River	8.6	B
Britt	6.6	B
Pointe au Baril	8.4	B
Carling	9.6	B
Parry Sound	9.7	B
Massasauga & Sans Souci	9.8	B
Twelve Mile Bay & Go Home Bay	4.8	A
Cognashene	6.1	B
Honey Harbour	8.1	B
State of the Bay 2013 Average	8.0	B

2.1.6 What can I do to help?

Join the Lake Partner Program

You can join the Ontario Lake Partner Program by telephone, e-mail or visiting the websites provided below. Consider getting in touch with your Cottage Association to determine if they are already participating in the LPP.

- Dorset Environmental Science Centre's website:
  - http://desc.ca/programs/LPP
- Ministry of the Environment's website:
  - www.ene.gov.on.ca/environment/en/local/lake_partner_program/STDPROD_078989.html

Upon registering, they will mail you a kit that contains the materials necessary to conduct water clarity measurements and take water samples. The Lake Partner kit includes materials and instructions to assemble a Secchi disk. Volunteers need to supply a rope and something to serve as a weight. The kit also contains a sampling bottle, a filter, and phosphorus sample tubes. The tubes are filled according to the instructions provided and returned, postage paid, to Dorset, Ontario for analysis (conducted free of charge).

If you become a Lake Partner volunteer the number of phosphorus samples that you take each year will depend on whether your lake is on the Canadian Shield. Volunteers located on the Canadian Shield take one water sample in the spring and Secchi disc water clarity measurements at least once every two weeks throughout the summer.

Blue Green Algae

What can you do to prevent these blooms from affecting your water-body? Primarily, we need to reduce the amount of phosphorus entering our embayments, lakes, and rivers by:

- Restoring shoreline vegetation.
- Limiting the use of chemical fertilizers, compost and manure on lawns.
- Using phosphate-free soaps and cleaning products.
- Complete self-evaluations of your property and lifestyle practices to identify ways to improve your local water quality:
  - www.gbbr.ca/our-environment/life-on-the-bay-guide/
- Ensuring your septic system functions properly (see below).

Wastewater and Septic System

Overtaxing a septic system can not only reduce its lifespan, but also contribute to the nutrient enrichment of groundwater and the lake (nutrients feed plants like algae). For a fully operating septic system, it is important to minimize water use in order to keep solid sludge settled on the bottom of the tank. Excessive water flowing into the septic tank, from overuse of toilets, laundry, dishwasher, showers, baths, and lawn watering can cause the sludge to be disturbed and allow the solids to pass out of the tank and into your distribution box. These solids can clog your distribution box, your drain-field pipes and even your drain-field. Avoid excess water use; using too much water is the single biggest reason for system malfunction.

Chapter 5 of GBBR's Life on the Bay guide has further tips on how to maintain your septic and wastewater systems in good condition. For example, information on setback distances (shoreline and well) and septic pump-out frequency can be found in this document. It also contains a self-assessment checklist to determine current conditions and practices, which identify potential areas for improvement. It is available online here:

- www.gbbr.ca/our-environment/life-on-the-bay-guide/

2.1.7 Data gaps and research needs

In summary, the data gaps and research needs with respect to the Total Phosphorus indicator are:

1. Grading System
    a) Ideally, a grading system that is based on regional segmentation of environmental features would be preferred. This system would likely produce an index that reflects the ranges in environmental conditions/features within the system for an overall rating. However, the research and data is not currently available to determine this index and overall rating system. The Environmental Monitoring and Reporting Branch (of the MoE) are aware of this data gap and endeavour to include it as part of their survey design in subsequent Georgian Bay nearshore assessments.

    b) Another potential methodology (for future grading systems) was suggested by Keith Somers with the DESC. In their collaborations with universities, they have proposed a generic method to define normal conditions based on the reference condition approach (as outlined in Kilgour et al., 1998). The variability or distribution of samples from minimally impacted reference areas is used to characterize the normal range of variability and this range can be used to evaluate samples from other areas. This approach would define the normal range for reference areas in Georgian Bay as a means to evaluate samples from embayments that may be experiencing different levels of anthropogenic impacts. The idea could be used for any set of measurements including water chemistry, benthos (see Somers et al. 2006), or even the fish community.

2. Environment Canada's Science Synthesis report (2013) reviewed phosphorus monitoring along eastern Georgian Bay in order to identify embayments or lakes experiencing elevated levels of TP. The report notes that monitoring data for water-bodies with known TP concerns are insufficient in most cases to determine if anything has changed, or is changing, and the scientific studies to determine the cause of the problems and what to do about them have

not been done. Monitoring from early spring through the season could show whether the water column ever achieves equilibrium with the atmosphere. The report also notes that it is important to determine how to prevent the production of more organic matter in these bays and whether there is any unexpected shore or watershed sources of organic matter that may decay to exacerbate the oxygen depletion. It is recommended that a robust monitoring protocol is developed and distributed to volunteers in areas with known TP concerns. The Severn Sound Environmental Association's protocol could be considered, as it is robust and adoption would facilitate data comparison (between different regions). Their protocol can be found online here: www.severnsound.ca/ssea_OpenWater.htm

3. Successful management of algal blooms will require an improved understanding of the sources and retention to the littoral zone of both particulate phosphorus (i.e., that can be recycled by dreissenid mussels) and soluble phosphorus; improved monitoring and forecasting of dreissenid population density, improved monitoring of Cladophora populations over a gradient of human and dreissenid influence; and further improvements in our understanding Cladophora ecology and capacity to model the complete seasonal growth cycle and transport and fate of detached filaments (Higgins et al. 2008).

4. The updated version of the GLWQA (EC, 2012) states that it will develop substance objectives (including phosphorus) for nearshore waters, including embayments and tributary discharge for each Great Lake. It is recommended that future *State of the Bay* report cards review the updated GLWQA for a Georgian Bay substance objective (to be used as the TP benchmark).

2.2 Fish Community Health

2.2.1 Foreword

Formulating indicators of fish community health is highly problematic and controversial. Foremost in terms of being problematic is a paucity of historic data relating to the near-shore fishery with which to establish fish community health benchmarks. Prior to the 1970s, there is little or no historic data available. Subsequent data collection (1970s onwards) was largely directed at species of sport fishing interest (primarily walleye) in specific localized areas (French, Severn, Shawanaga and Moon River areas – Figure 18). No effort was made to assess the status of the fish community on a holistic basis in these localized areas – let alone on a wide scale basis. Methods used to collect data from the 1970s to the early 1990s have been highly variable, further confounding legitimate comparisons between studies. Commencing in the mid-1990s the Ministry of Natural Resources (MNR) began adopted standardized sampling methods to address these shortcomings. Even these 'standardized' surveys have been subject to on-going revision and refinement.

Figure 18: Location of standardized (ESTN) fisheries assessment surveys conducted on eastern Georgian Bay

Although this was a welcome advance in fisheries management, difficulties associated with the immense sampling area of Georgian Bay still remain. Ecologically, various areas of the Bay may be quite different from one another and this is reflected in a highly diverse and variable fish community throughout the Bay. Although the best trend-through-time data set is that for the Severn Sound area, it is questionable how representative this is for the remainder of the east and north shores. Another data set exists for the Moon River area which is arguably more representative of the east and north shores, but it is not as complete in a temporal sense.

Another significant challenge is selecting a specific suite of indices or indicators that are truly reflective of the health of the near shore Georgian Bay fishery. Without historic benchmarks or well defined and accepted criteria, allocating a grade for various indices seemed highly subjective and open to legitimate criticism. For example, we wondered if catch rates (fish / net night) for various species as an index of relative abundance would be a good indicator. What would be an appropriate benchmark for a passing or failing grade or to distinguish between an "A, B or C" grade? Although Provincial benchmarks for standard surveys do exist, they are for inland lakes covered by huge geographic areas and one wonders how suitable they are for Georgian Bay?

We were also very concerned that a number of pressing and critical issues facing the eastern shore fishery were not adequately addressed by proposed indicators. These include threats related to low water levels, invasive species and nutrient disruption through the food web.

With these difficulties in mind, we considered it ill-advised to force the adoption of inadequate and/or inappropriate indicators based on insufficient and/or incompatible data. For the fisheries section of this report we have adopted a discussion-oriented approach, which we feel is a more legitimate and appropriate method to assess fish community health at the present time. Admittedly, the lack of robust fish community indicators is a "data gap" that warrants future attention.

2.2.2 Fish community health indicators discussion

Fisheries assessment data collected in the Severn Sound area of eastern Georgian Bay from 1975 to the present (Figure 19) represents the most complete and comprehensive nearshore fish community data set available. Consequently we have used this data set to formulate indicators of fisheries health. We readily acknowledge some unfortunate inadequacies with this approach:

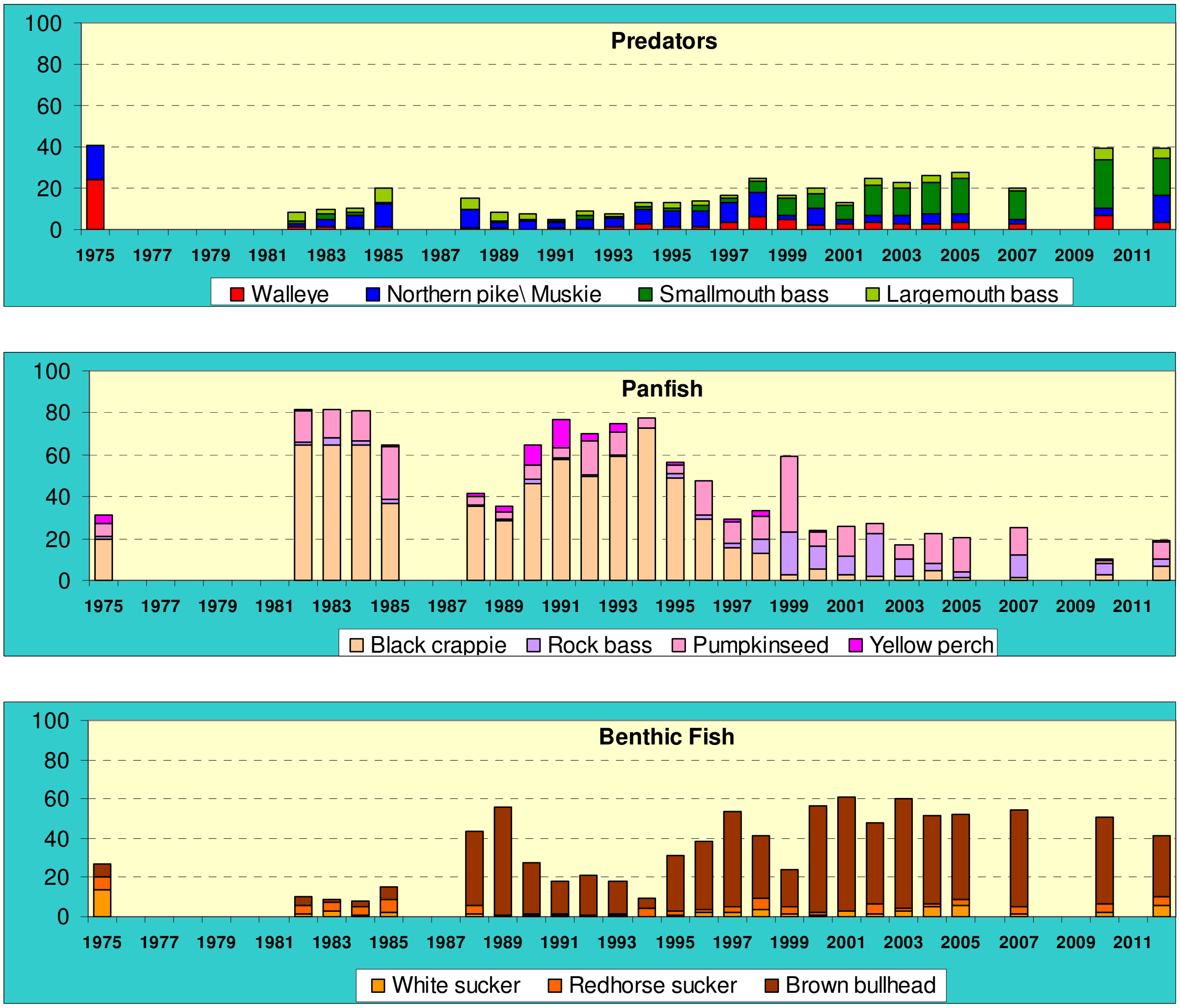
Nearshore fish community structure varies dramatically across Lake Huron and Georgian Bay (Figure 20). Therefore, it is not appropriate to formulate fishery health indicators for Severn Sound and directly extrapolate these indicators to the rest of north and eastern Georgian Bay. Simply put, the fish community structure, habitat and productivity levels in the Severn Sound area are not representative of north and eastern Georgian Bay.

Even with the Severn Sound data set, methodologies have changed over the time series, being most consistent since 1999 (Figure 21), and therefore data is presented in a way that provides broad and descriptive characterizations of the fish community. The Moon River delta area has also been surveyed (Figure 22) using the same methodologies as in Severn Sound, but far less frequently and spanning a shorter time frame. This area may be more representative of fish community diversity and productivity for the rest of the eastern and northern Georgian Bay shoreline. Consideration can be given to include summaries of this data set as more surveys are completed in the future.

Notwithstanding the above points, the data available for Severn Sound (Figure 19) is unquestionably the most complete in terms of spanning a long time frame (1975 to present) and most intensively surveyed. It also offers the best opportunity for continued fisheries assessment into the future.

However as mentioned in the foreword, developing suitable indicators of fisheries health for the nearshore areas of eastern and northern Georgian Bay is a daunting task. This is because:

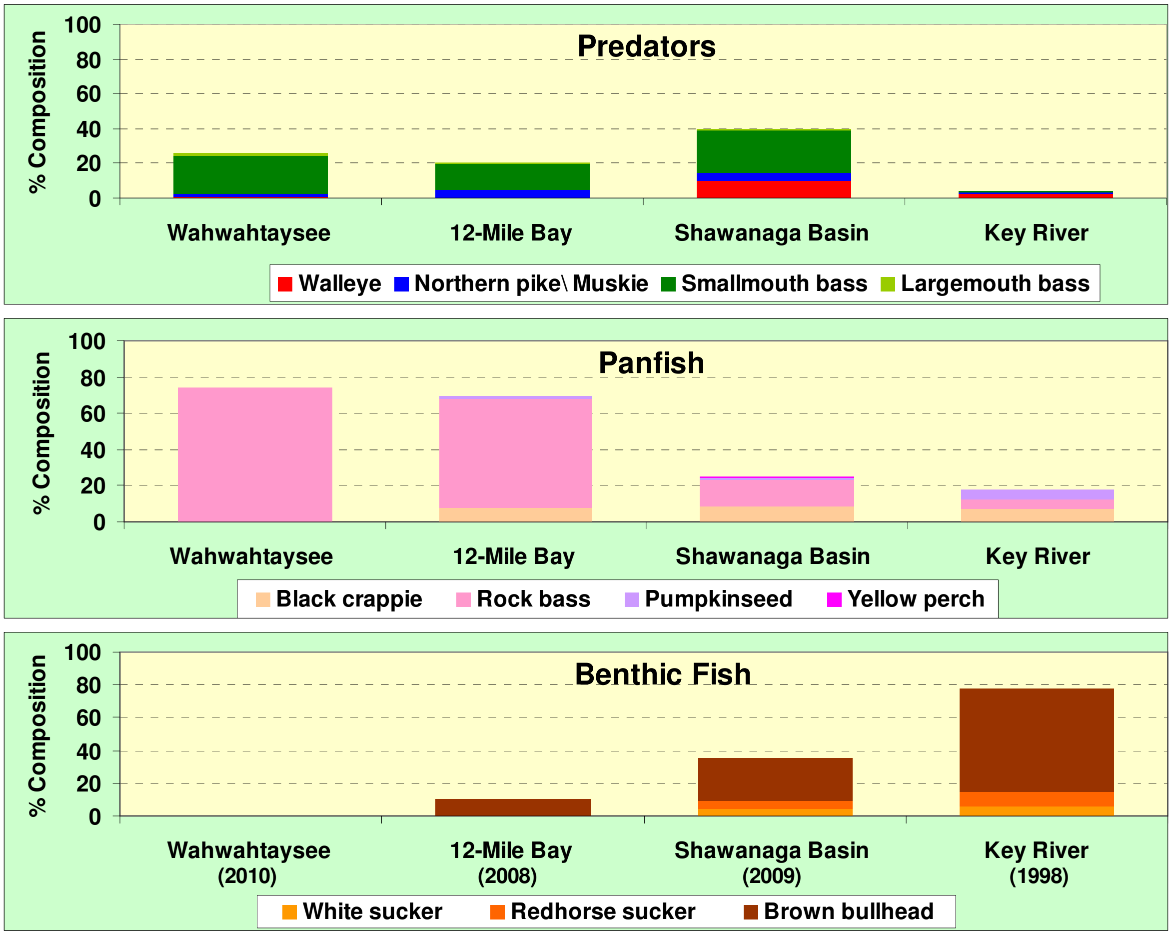
- Fisheries Assessment techniques have been highly variable in methodology and often directed at individual species, not community structure.
- Nearshore areas of north and eastern Georgian Bay encompass an immense area. Assessment has generally targeted specific localized areas (Figure 18).
- As a consequence of the above, there is a paucity of reliable and consistent trend-through-time data for any extensive and/or representative area.
- There has been little opportunity to augment assessment data collected by the MNR with that collected by non-government agencies.



Y-axis: percentage composition of catch

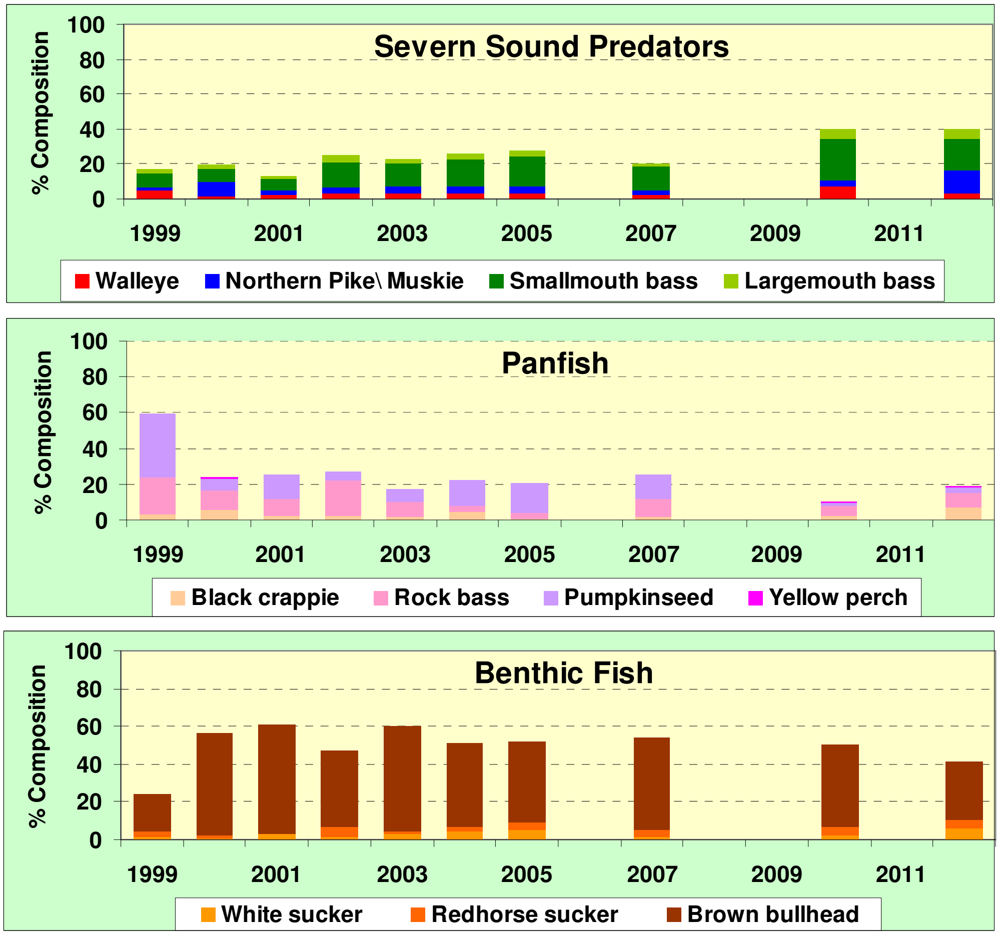
Source: UGLMU, pers. comm., 2013.

Figure 19: Trend-through-time abundance (as measured by % composition of catch) of predator, panfish and benthic fish species captured in fisheries assessment surveys in the Severn Sound area of eastern Georgian Bay, 1975 to the present



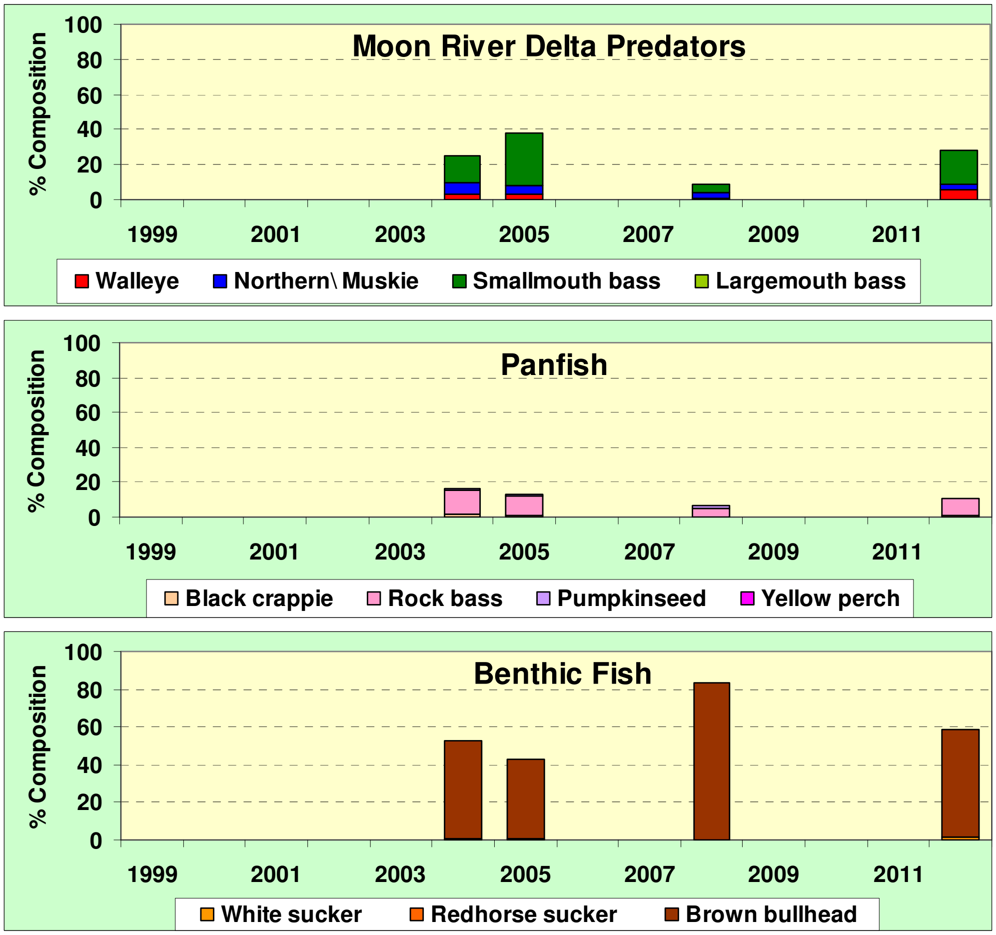
Source: UGLMU, pers. comm., 2013.

Figure 20: Nearshore fish community abundance (as measured by % composition of catch) of predator, panfish and benthic fish species captured in standardized (ESTN) fisheries assessment surveys conducted at various locations and years along eastern Georgian Bay



Source: UGLMU, pers. comm., 2013.

Figure 21: Trend-through-time abundance (as measured by % composition of catch) of predator, panfish and benthic fish species captured in standardized (ESTN) fisheries assessment surveys in the Severn Sound area of eastern Georgian Bay, 1999 to the present



Source: UGLMU, pers. comm., 2013.

Figure 22: Trend-through-time abundance (as measured by % composition of catch) of predator, panfish and benthic fish species captured in standardized (ESTN) fisheries assessment surveys in the Moon River delta area of eastern Georgian Bay, 1999 to the present

2.2.3 Fisheries health indicators

We partitioned fish species into three categories:

1. Predators – consisting of walleye, northern pike, muskellunge, smallmouth bass, and largemouth bass.
2. Panfish – consisting of black crappie, rock bass, pumpkinseed, and yellow perch.
3. Benthic fish – consisting of white sucker, northern redhorse sucker, and brown bullhead.

We then followed the relative abundance (as measured by percentage species composition in the catch of assessment nets) for fish species and categories of fish over time (1975 – present) in the Severn Sound area (Figure 19).

Observations from Figure 19:

- The percentage composition of predator species has seen an over-all, slight increase in abundance from the early 1980s to present day (top chart of Figure 19). Over the past decade and a half, smallmouth bass have increased in abundance and northern pike have decreased. We are unsure how to interpret the high abundance of northern pike and walleye observed in 1975, but note its presence. It should also be noted that efforts to rehabilitate walleye populations in this area have been ongoing since the early 1980s and have met with variable success.
- The percentage composition of panfish has been in general decline since the mid-1990s, reaching an all-time low in 2010 (middle chart of Figure 19). There have been significant changes in the composition of the panfish community over the 35-year data set period. Black crappie, which was the largest component in the panfish category and the most abundant species in the fish community prior to the mid-1990s, have now decreased to their lowest level. Over the past decade, pumpkinseed and rock bass have dominated the panfish community. Prior to the late 1990s, rock bass was almost absent.
- The benthic fish component has been variable in terms of abundance over the 35-year data set, but generally stable (lower chart of Figure 19). There does appear to be a higher abundance of benthic fish since the late 1990s.

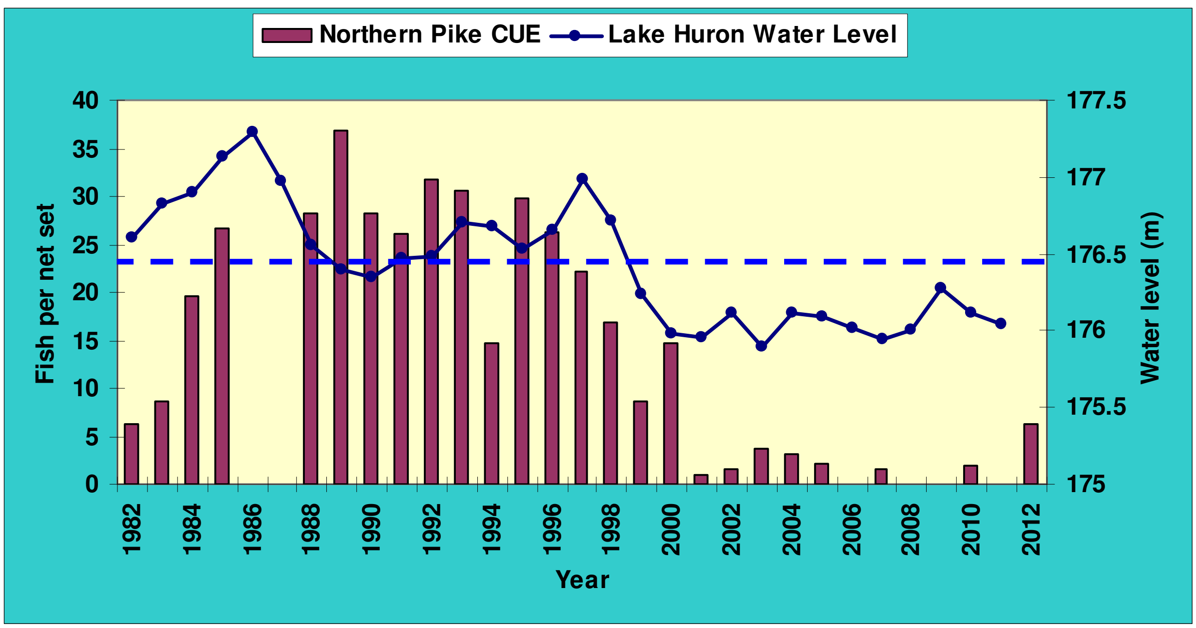
In general, these observations suggest a relatively stable fish community in the Severn Sound area. Perhaps of some concern over the past decade and a half is a trend of increasing abundance of benthic species and decreasing panfish species. This may suggest a slight change in environmental and habitat conditions that may favour low-valued species that feed near the bottom of the food chain. Chronic low water levels may be playing a role in this regard. Consideration also needs to be given to water quality improvements that occurred in Severn Sound subsequent to its listing as an Area of Concern by the International Joint Commission, a Bi-national coordinating body for the Great Lakes.

2.2.4 Threats to fish community health

We feel the above analysis misses some salient points that should be considered in ascertaining the health of the nearshore fishery. Today's fishery faces three significant threats:

1. ***Low Water Levels (see Section 3)***

The eastern shore of Georgian Bay is an archipelago containing some of the most productive wetlands in all of the Great Lakes (as discussed in Section 2.7.3). These wetlands serve as vital spawning and nursery grounds for many fish species (as discussed in Section 2.6.3), as well as supporting the base of the food chain for off-shore predator fish. The decrease in northern pike abundance in the Severn Sound area is highly correlated to low Georgian Bay water levels in the last decade and a half (Figure 23). Chronically low water levels will significantly decrease fish productivity and detrimentally impact the nearshore aquatic environment (as discussed in Sections 2.6.2 and 2.6.3).



Source: UGLMU, pers. comm., 2013.

Figure 23: Abundance of northern pike (fish per net set) correlated with Georgian Bay water levels, 1982 to 2012. Dashed blue line represents average GB water level over the time period. (Note the decrease in northern pike since the late 1990s is coincident with lower water levels)

2. ***Invasive Species (see Section 4)***

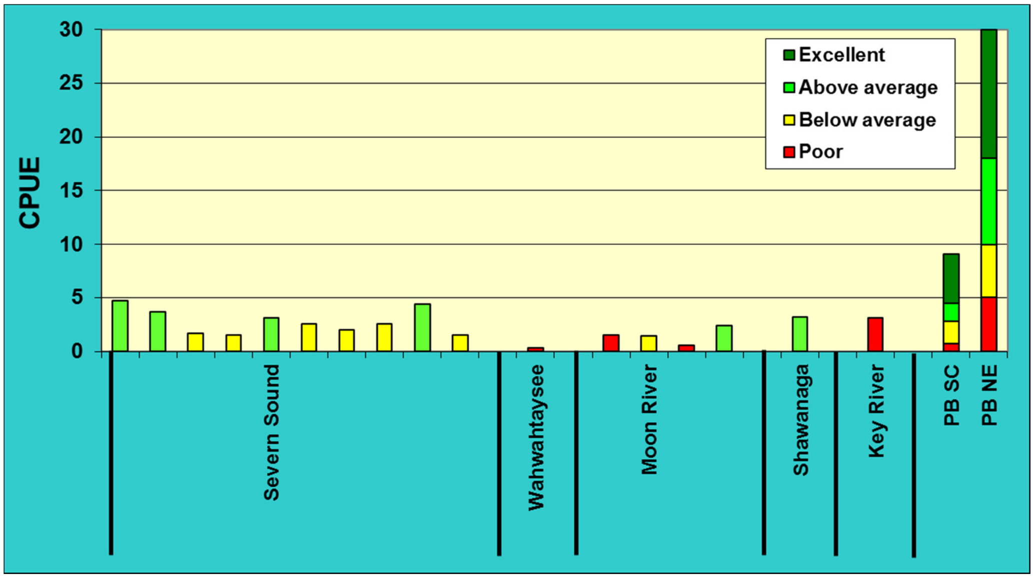
The recent establishment and proliferation of invasive species such as round goby and quagga mussels has injected a high degree of biological uncertainty and instability into the aquatic ecosystem of Georgian Bay. Furthermore, the Great Lakes face the catastrophic threat of Asian carp gaining access to these waters. Invasive species is considered by many to be the greatest threat facing the Great Lakes ecosystem.

3. ***Nutrient Disruption***

   The food web and ecology of Lake Huron and Georgian Bay has undergone significant changes in the past decade primarily driven by the proliferation of invasive species. The offshore waters of Georgian Bay have been characterized as oligotrophic (naturally low nutrient levels), with increasing nutrients in nearshore waters provided by stream and river inputs (and more recently human altered/developed shorelines). The zebra mussel has been implicated in sequestering large amounts of nutrients in the nearshore areas of Georgian Bay, and more recently, a close relative the quagga mussel, has enhanced this effect by extending it to deep, offshore waters as well (as discussed in Section 2.1.3). The loss of nutrients to offshore waters has substantially reduced the abundance of phytoplankton and zooplankton and has made the water much clearer. The cumulative effect is reduced fish productivity (especially reduced forage fish availability in offshore waters), nuisance algal blooms in inshore areas, and the advent of repetitive botulism outbreaks. In synergy with invasive species noted above, these factors are having a highly destabilizing effect on the Georgian Bay aquatic ecosystem and fish community.

2.2.5 The story of the Bay's walleye

Walleye populations throughout Georgian Bay have declined in abundance compared to historical levels due to a combination of over-exploitation, spawning habitat alteration, and declines in water quality (Figure 24). Efforts to rehabilitate this species are ongoing and focus on rehabilitative stocking, habitat restoration and regulations that restrict harvest rates. Monitoring and assessing of walleye populations is accomplished through surveys targeting spawning and post-spawning walleye. The standardized ESTN survey is conducted after walleye have spawned and are beginning their post-spawning recovery and feeding movements. ESTN surveys conducted in different regions of the province provide an opportunity for comparing relative abundance of walleye populations. Of the 17 ESTN surveys conducted in the GBBR area, close to 65% of survey results indicate that walleye are below average in relative abundance compared to southern Ontario walleye populations and all would be considered as poor in relative abundance compared to populations in northeastern Ontario. Generally, efforts are needed to continue with walleye rehabilitation for much of eastern Georgian Bay due to persistent low relative abundance and in some cases the absence of walleye populations where they once existed (UGLMU, pers. comm., 2013).



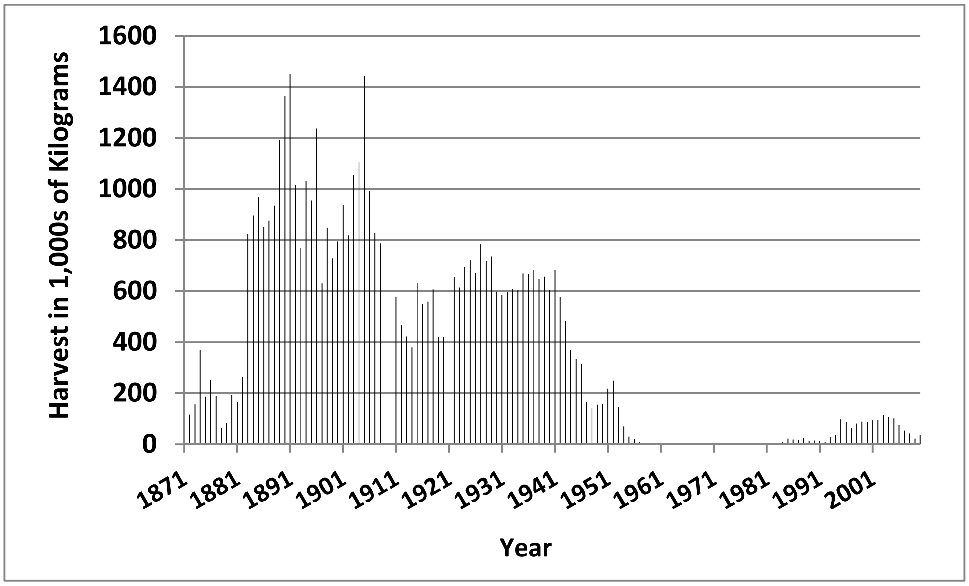
CPUE = Catch per unit effort

Source: UGLMU, pers. comm., 2013.

Figure 24: The relative abundance of walleye from ESTN surveys conducted in the GBBR area of eastern Georgian Bay (bar colours refer to provincial benchmarks of relative abundance established from north-east (NE) and south-central (SC) surveyed lakes)

2.2.6 The story of the Bay's lake trout

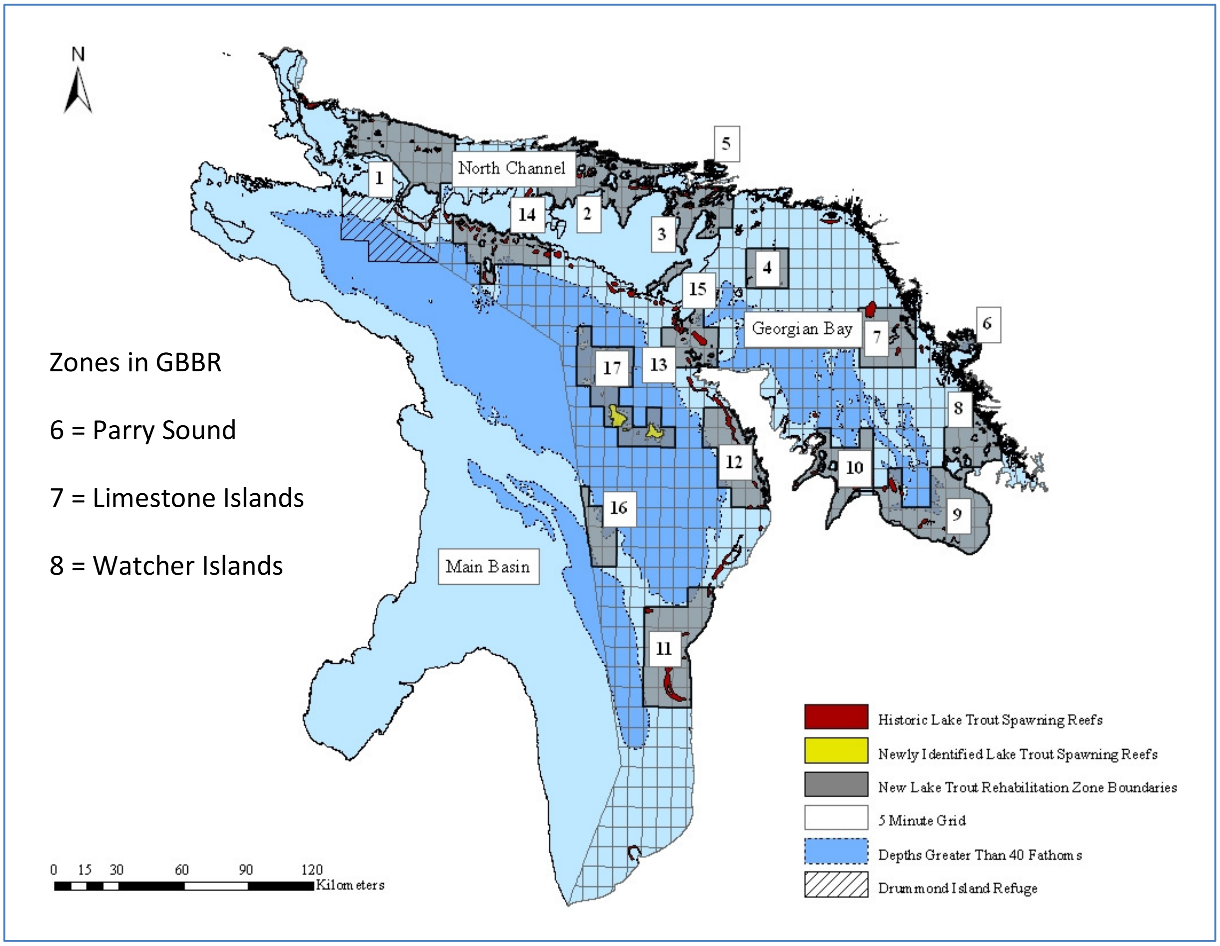
Lake trout were historically the top cold water predator in Lake Huron, including Georgian Bay. The GBBR area supported numerous populations that resided in the deep offshore waters and utilized shallower waters for spawning in the fall and feeding in the spring. The invasion of sea lamprey, in combination with over-exploitation, caused lake trout populations in Lake Huron to collapse (Figure 25) in all but two isolated locations, Iroquois Bay in northern Georgian Bay, and Parry Sound. Efforts to rehabilitate this species have been ongoing since 1969, primarily through sea lamprey control, stocking and restrictions on harvest. In Parry Sound, the persistence of a native, locally adapted strain of lake trout, together with restrictive harvest regulations, establishment of a no-fishing for lake trout sanctuary, and stocking of Parry Sound strain lake trout until 1997, all contributed to the rehabilitation of this lake trout population. Outside of Lake Superior, this is the only population of lake trout to be considered fully rehabilitated across the Great Lakes (UGLMU, pers. comm., 2013).



Source: UGLMU, pers. comm., 2013.

Figure 25: Historical Lake Trout commercial harvest in Georgian Bay

In spite of the success in Parry Sound, lake trout populations have not been established in most locations where they were found historically. A Draft Revised Lake Trout Rehabilitation Plan for Lake Huron (MNR, 2013a) identifies three lake trout rehabilitation zones (including Parry Sound) that are included in the GBBR area (Figure 26). The other two areas are the Limestone Islands and Watcher Islands, which continue to be the focus of lake trout rehabilitation in eastern Georgian Bay. Recent surveys assessing the status of lake trout populations in these areas suggest that although some progress is being made, especially in the Limestone Islands area, the rehabilitation objectives outlined in the revised plan are still not being achieved. With reduced productivity in the offshore waters and other ecosystem changes the prospects for lake trout rehabilitation are less certain.



Source: MNR, 2013a.

Figure 26: Lake Huron Lake Trout rehabilitation zones

2.2.7 What can I do to help?

Listed below are some suggestions and practices you can adopt to help the Bay's fisheries:

1. Support the work of the Eastern Georgian Bay Stewardship Council:
   - www.helpourfisheries.com
2. Plan any work in or near the water carefully to prevent or minimize impacts to fish and fish habitat. Fisheries and Oceans Canada (DFO) has details on their website about the impacts to fish and fish habitat from projects such as dredging, and shoreline stabilization. These resources also include information about controlling aquatic plants and how to plan your project to minimize potential impacts to the aquatic environment.
   - www.dfo-mpo.gc.ca/habitat/habitat-eng.htm
   - www.dfo-mpo.gc.ca/regions/central/pub/factsheets-feuilletsinfos-on/index-eng.htm
3. Complete self-evaluations of your property and lifestyle practices to identify ways to improve your local water quality and fish habitat:
   - www.gbbr.ca/our-environment/life-on-the-bay-guide/

4. Help stop the spread of invasive species:
    - www.invadingspecies.com/stop-the-spread/
5. The LandOwner Resource Centre's extension notes:
    - www.ont-woodlot-assoc.org/info_pub_ext.html
6. The Living By Water Project:
    - www.livingbywater.ca/main.html
7. Fisheries Management Zone 14 Council webpage, for those interested in local fisheries and wondering how they can convey their interests or concerns:
    - www.mnr.gov.on.ca/en/Business/LetsFish/2ColumnSubPage/STDPROD_086386.html
8. The GLFC website has State of Lake Huron reports for more detailed fisheries information:
    - www.glfc.org/lakecom/lhc/lhchome.php#pub
9. When fishing, consider practicing conservation principles and don't catch your limit.

2.2.8 Data gaps and research needs

In summary, the data gaps and research needs with respect to the Fish Community Health indicator are:

1. The lack of robust fish community health indicator is a data gap that warrants future attention. A potential was suggested by Keith Somers with the DESC. In their collaborations with universities, they have proposed a generic method to define normal conditions based on the reference condition approach (as outlined in Kilgour et al., 1998). The variability or distribution of samples from minimally impacted reference areas is used to characterize the normal range of variability and this range can be used to evaluate samples from other areas. The idea could be used for any set of measurements including water chemistry, benthos (see Somers et al., 2006), or even the fish community.

2. In terms of temporal coverage, in order to track trends over time (of nearshore fish community abundance) continued investment in conducting these surveys should be an ongoing priority. In more recent years (2010 onwards), MNR has also collected biomass estimates of fish species captured during the ESTN surveys. Biomass provides a more accurate depiction of the prominence of species in the fish community than numbers. It is recommended that MNR continue to collect the biomass estimates as it may be useful in developing an indicator and for ongoing future data needs.

2.3 Natural Cover

2.3.1 What is measured?

Percentage of each region's terrestrial area (i.e. land) in natural cover. Natural cover is defined as wetlands, forests, rock barrens, and other natural systems (please note: this indicator does not include water features, such as lakes, rivers and Georgian Bay – explanation provided below in Section 2.3.2).

The natural cover analysis has been completed at a fairly high level and does not consider the fragmentation created by roads, railways and other forms of linear development (the impact of these features are discussed in the large natural areas indicator – Section 2.4). This landscape level indicator provides a good understanding of the overall health and function of the landscape.

2.3.2 How is it measured?

In this part of Ontario natural features are maintained and updated in the Ministry of Natural Resources' (MNR) Forest Resources Inventory (FRI) dataset. FRI is a product that provides description of all areas within a forest management unit and provides a snapshot in time of the characteristics of water and land base geography. An FRI is created when the area within a forest management unit is delineated and classified, based on its geographic features and characteristics, into homogeneous water and land types called polygons. FRI information is used to support various forest management planning and land-use planning decisions over a wide range of geographic areas (MNR, 2009).

The FRI program is currently evolving from a 20-25 year production rotation cycle to a 10 year cycle, and from a periodic inventory to a continuous inventory that is ecologically based. The FRI dataset used for the *State of the Bay* report card was updated and issued in 2009, but uses data collected in 2008. MNR are currently working on a new dataset that will be available in the fall of 2013 and therefore it was not available for the report card analysis.

Percentage natural cover has been calculated using GIS spatial analysis. More specifically, the vector analysis method merged the FRI and regional (report card regions) datasets together and produce a summary of FRI polytype (habitat/land use classification) and ownership attributes. The FRI polytype features that are deemed to have natural cover attributes are presented in Table 3. The total area of these FRI polytype features equals the natural cover area for a given region. The FRI polytype features that are not deemed to have natural cover attributes (i.e. anthropogenic polytypes) are presented in Table 4.

Table 3: FRI polytype features that are deemed to have Natural Cover attributes

Habitat / Land Use	Description
Brush and alder	Areas covered with "non-commercial" tree species or shrubs. These areas are normally associated with wetlands or water features, and must not be confused with productive forest areas of similar brush or bush cover which have developed as a result of forest management operations (e.g., areas that have been recently depleted or areas that are below silvicultural standards such as former "barren and scattered" areas).
Open wetland	Wet areas of mosses, grasses, sedges, and small herbaceous plants, often interspersed with small areas of open water.
Productive forest	Areas that are capable of producing tress and can support tree growth. These areas may or may not be capable of supporting the harvesting of timber on a sustained yield basis. Some areas may have physical and/or biological characteristics which effect land use. Thus this polygon type includes both production and protection forest areas.
Rock	Areas of barren or exposed rock (e.g., bedrock, cliff face, talus slope) which may support a few scattered trees, but is less than 25% stocked.
Small island	Islands less than 8 hectares in size, down to a lower limit of 0.0025 hectares or 25 square metres in size (e.g., 5 metres x 5 metres) are recorded during the inventory production process, but are not interpreted/typed for practicality and cost considerations. Only islands 8 hectares and larger are interpreted and assigned an appropriate polytype code, such as productive forest or brush and alder.
Treed wetland	Areas of dry or wet muskeg on which stunted trees occur as widely spaced individuals or in small groups.

Source: MNR, 2009.

Table 4: FRI polytype features that are not deemed to have Natural Cover attributes

Habitat / Land Use	Description
Buffered linear feature	This includes all linear features except water, such as roads, railroads, communication lines, hydro lines, and transmission lines / pipelines used for natural gas, water or other/unknown purposes.
Developed agricultural land	Lands which are cultivated for growing crops, orchards, floral gardens, etc. These areas may include abandoned agricultural lands.
Grass and meadow	Farm areas devoted to pasture for domesticated animals. These areas may also include abandoned grass and meadows, but are not part of the productive forest land base and do not include "barren and scattered" areas. These areas are similar to barren and scattered, but are located near developed agriculture land or unclassified areas and are usually fenced.
Unclassified	Non-forested areas which were created for specific uses other than timber production, such as roads, railroads, logging camps, mines, utility corridors, logging camps, gravel pits, airports, etc. Most of these areas have been cleared of trees.

Source: MNR, 2009.

Water features were not included in the analysis of the natural cover indicator. The main threats and/or pressures to the natural cover indicator (discussed in Section 2.3.3) are predominately due to the modification and/or development of land. Therefore omitting the water features would allow for this indicator to be more sensitive to tracking these threats and pressures.

2.3.3 Why is it important?

An ecological survey of eastern Georgian Bay (Jalava et al., 2005), conducted by the Nature Conservancy of Canada (NCC), recorded approximately 150 different vegetation community types, using standard ecological land-classification methods. The extensive treed and untreed granite rock barrens that are distinctive of much of the coast are the largest of their kind in the Great Lakes basin, and a wide diversity of rock-and-water ecosystems distinguish both the island shores and the mainland's many wetland shores. White Pine (*Pinus strobus*), Red Oak (*Quercus rubra*), Red Maple (*Acer rubrum*), and Trembling Aspen (*Populus tremuloides*) dominate both the rock barrens and the forests, and Jack Pine (*Pinus banksiana*) barrens form matrix communities at a number of northern sites. A diversity of wetland bog and fen vegetation is frequent along the coast, but much less common elsewhere in Ontario. Relatively little agricultural land conversion has taken place in the area and the native ecosystems remain relatively unfragmented by roads or agricultural lands. These natural communities are habitat for approximately 984 vascular plant taxa (840 of them native), 44 mammal species, 170 breeding bird species, and 34 reptile and amphibian taxa. The Georgian Bay region sustains the highest diversity of reptile and amphibian species in Canada.

The inherent mobility of animals, and of birds in particular, allows most species to make use a range of habitats. Among birds, some may nest in a very specific habitat but forage more widely in search of food. For example, Common and Caspian Terns nest exclusively on small bedrock islands but hunt for fish and other aquatic fauna over a wide range of lakes, rivers and marshes; these birds rely on a variety of habitats during the breeding season. Nevertheless, most vertebrates of the eastern Georgian Bay area are clearly associated with certain general habitat types. For the most part, breeding birds are tied less to landform features than to the specific vegetation communities (i.e., habitats) that occur on them, with the exception of a few species such as Prairie Warbler, which breeds exclusively on coastal barrens (Jalava et al., 2005).

Other species, such as reptiles, amphibians, and mammals, also require a mix of habitats along the coast. Georgian Bay Islands National Park (2006) has created an ecosystem model (Figure 2) that illustrates the different habitat types and their related connectivity. The movement of wildlife from the mainland to the islands, and among the islands is critical for maintaining healthy ecosystems throughout the greater park ecosystem. The ecosystem model notes that it is important to ensure that shoreline development does not eliminate these connections.

In summary, in order to maintain the high diversity of species found along the coast a mix of habitats is required. Therefore the different types of habitat are included in the GIS analysis and the background report will report on and track changes to land use (Section 1.4).

Source: GBINP, 2006.

Figure 27: GBINP ecosystem model

The NCC (Jalava et al., 2005) study concluded that every part of the eastern and northern Georgian Bay area is distinguished by its own unique combination of environmental conditions, and dramatic differences are apparent even within individual sites. Along the north shore of the Severn River warm prairie-like openings occur next to rich, clay-based Basswood forests, and the nearby embayments of the river support a rich aquatic flora. The differences are even more pronounced between different sites. The barren bedrock islands off Cognashene contrast sharply with the dark Eastern Hemlock forests along the Moon River. In July and August, the white-flowering bur-reed meadows on the mudflats of the Musquash River bear little resemblance, besides low relief, to the vast sand beaches of Sandy Island with their display of the golden-yellow blooms of Horned Bladderwort. The lush aquatic beds of the narrow channels of Franklin Island are starkly different habitat from the dry Jack Pine barrens of the North Georgian Bay Shoreline and Islands Conservation Reserve.

The NCC (Jalava et al., 2005) study notes that large tracts of eastern and northern Georgian Bay continue to show little obvious evidence of human disturbance. The diversity of native vegetation and herpetofauna in particular, despite the small and localized populations of non-native species, are indicators of a greater ecosystem that has integrity. Approximately one-third of the eastern Georgian Bay area is regulated in parks and conservation reserves. Northern Georgian Bay is also regulated with an almost continuous series of parks, conservation reserves and First Nation lands along the Georgian Bay coast to Killarney Provincial Park. Another 600 ha are protected as private nature reserves and conservation easements. Regardless of ownership or level of protection, large areas of the landscape should remain in natural cover in order to support the provisioning, regulating, cultural and supporting ecosystem functions.

Although the eastern and northern Georgian Bay area boasts one of the most extensive networks of protected areas in eastern Canada, its terrestrial ecosystems continue to face pressure from human activities. Cottage, marina and resort development, and associated roads and utility corridors, are among the most significant modern stressors in the region today. Waterfront development almost inevitably results in disturbance to sensitive shoreline habitat, alteration of native plant communities and the introduction of invasive species. Dense cottage developments may impede the natural movement of species or be avoided altogether by species that are sensitive to human activity. Utility corridors and access roads that service these areas reduce the extent of interior habitat by bisecting forest and wetland communities, limiting the availability of habitat for fauna requiring large undisturbed natural areas. Mitigating factors may be that the majority of roads are for summer-only and weekend-mainly access, but even these patterns of traditional second-home use are shifting, to more full-time occupation (Jalava et al., 2005). In summary, the main pressure to the natural cover indicator is the development of shoreline and natural areas. Therefore the different types of land use are included in the GIS analysis and the background report will report on and track changes to land use (Section 2.3.5).

Generally, landscapes with a higher percentage of natural cover are better able to provide a healthier environment in which plants and animals can thrive and contribute toward environmental health. For example, studies in the Severn Sound area indicate that total forest cover is the primary factor determining the number of interior birds expected to occur (EC, 2006a). Also, a greater percentage of natural cover in a given region provides more opportunity for larger, connected tracts of natural areas (a discussion of the benefits of large natural areas is provided in Section 2.4.3). This higher percentage (of natural cover) in a region results in more wildlife habitat and an ecosystem that is more robust.

2.3.4 What do the grades mean?

The benchmark for natural cover reflects the naturally higher percentage of natural features in eastern Georgian Bay compared to southern Ontario. If the *State of the Bay* report card were to adopt Conservation Ontario's guideline for forest cover of 25.6% (Conservation Ontario, 2003), or Environment Canada's (2006a) guideline of 30%, there would be considerable loss of natural habitat and significant loss of ecological function across the watershed. Additional research is required on the optimum level of natural cover required to sustain the ecosystems of eastern and northern Georgian Bay. A conservative approach to evaluating natural cover has been taken in order to provide more options in the future as research provides better information. The 'A' grade was determined using the 2013 *State of the Bay* report card average as the benchmark. The grades for natural cover are:

- A > 90%
- B 75 – 89.9%
- C 60 – 74.9%
- D 50 – 59.9%
- F < 50%

2.3.5 What are the results?

Table 5: Grades for Natural Cover

Region Name	Natural Cover %	Grade
McGregor Bay & Killarney	95.7	A
French River	98.4	A
Britt	97.7	A
Pointe au Baril	98.3	A
Carling	95.6	A
Parry Sound	83.5	B
Massasauga & Sans Souci	95.8	A
Twelve Mile Bay & Go Home Bay	98.2	A
Cognashene	98.1	A
Honey Harbour	88.1	B

State of the Bay 2013 Average	96.0	A

In order to track changes in habitat, land use, and ownership over time, the *State of the Bay* background report will also report on the FRI polytype features (described in Table 3 and Table 4). Using GIS analysis, the percentage of each FRI polytype and ownership was determined for each region (Table 6). The ownership attribute contains the traditional FRI ownership information as assigned by the Office of the Surveyor General. The breakdown of FRI polytype and ownership (Table 7) will provide a better understanding of changes over time and the impact on natural areas.

Table 6: Summary of FRI polytype by region and ownership

Region Name	FRI Polytype	Percentage Cover (FRI Polytype ÷ Region Area)	Ownership	Percentage Cover (Area of Ownership ÷ Region Area)
McGregor Bay & Killarney	Brush and alder	0.7	Crown	40.0
	Buffered linear feature	0.2	Federal	0.6
	Developed agricultural land	0.0	First Nation	11.4
	Grass and meadow	0.1	Park	45.8
	Open wetland	2.4	Private	2.2
	Productive forest	55.1		
	Rock	14.8		
	Small island	0.01		
	Treed wetland	0.6		
	Unclassified	3.0		
	Water	23.0		
French River	Brush and alder	0.7	Crown	50.4
	Buffered linear feature	0.1	Federal	0.0
	Developed agricultural land	0.0	First Nation	7.4
	Grass and meadow	0.0	Park	41.8
	Open wetland	3.0	Private	0.3
	Productive forest	39.9		
	Rock	6.0		
	Small island	0.0		
	Treed wetland	0.9		
	Unclassified	0.8		
	Water	48.7		
Britt	Brush and alder	4.0	Crown	40.5
	Buffered linear feature	0.3	Federal	0.1
	Developed agricultural land	0.4	First Nation	17.9
	Grass and meadow	0.4	Park	37.7
	Open wetland	2.7	Private	3.7

Region Name	FRI Polytype	Percentage Cover (FRI Polytype ÷ Region Area)	Ownership	Percentage Cover (Area of Ownership ÷ Region Area)
	Productive forest	27.4		
	Rock	30.0		
	Small island	0.0		
	Treed wetland	1.5		
	Unclassified	0.5		
	Water	33.0		
Pointe au Baril	Brush and alder	2.7	Crown	57.1
	Buffered linear feature	0.6	Federal	0.005
	Developed agricultural land	0.0	First Nation	9.2
	Grass and meadow	0.3	Park	27.8
	Open wetland	2.8	Private	5.9
	Productive forest	25.8		
	Rock	24.8		
	Small island	0.0		
	Treed wetland	1.0		
	Unclassified	0.1		
	Water	41.8		
Carling	Brush and alder	1.3	Crown	66.4
	Buffered linear feature	0.7	Federal	0.007
	Developed agricultural land	0.3	First Nation	8.2
	Grass and meadow	0.5	Park	9.8
	Open wetland	3.0	Private	15.6
	Productive forest	24.8		
	Rock	11.5		
	Small island	0.0		
	Treed wetland	2.0		
	Unclassified	0.5		
	Water	55.4		

Region Name	FRI Polytype	Percentage Cover (FRI Polytype ÷ Region Area)	Ownership	Percentage Cover (Area of Ownership ÷ Region Area)
Parry Sound	Brush and alder	0.5	Crown	37.3
	Buffered linear feature	2.9	Federal	0.6
	Developed agricultural land	1.6	First Nation	11.6
	Grass and meadow	1.4	Park	5.8
	Open wetland	1.8	Private	44.7
	Productive forest	43.3		
	Rock	5.9		
	Small island	0.0		
	Treed wetland	1.3		
	Unclassified	4.5		
	Water	36.8		
Massasauga & Sans Souci	Brush and alder	1.3	Crown	54.4
	Buffered linear feature	1.0	Federal	0.0
	Developed agricultural land	0.2	First Nation	0.1
	Grass and meadow	0.8	Park	28.1
	Open wetland	3.2	Private	17.4
	Productive forest	49.5		
	Rock	13.0		
	Small island	0.0		
	Treed wetland	0.8		
	Unclassified	1.0		
	Water	29.4		
Twelve Mile Bay & Go Home Bay	Brush and alder	1.5	Crown	67.1
	Buffered linear feature	0.3	Federal	0.3
	Developed agricultural land	0.0	First Nation	5.0
	Grass and meadow	0.7	Park	12.6
	Open wetland	1.6	Private	15.1
	Productive forest	44.0		
	Rock	10.3		

Region Name	FRI Polytype	Percentage Cover (FRI Polytype ÷ Region Area)	Ownership	Percentage Cover (Area of Ownership ÷ Region Area)
	Small island	0.0		
	Treed wetland	0.9		
	Unclassified	0.04		
	Water	40.7		
Cognashene	Brush and alder	0.7	Crown	68.1
	Buffered linear feature	0.5	Federal	0.5
	Developed agricultural land	0.0	First Nation	2.2
	Grass and meadow	0.0	Park	16.4
	Open wetland	1.2	Private	12,8
	Productive forest	23.7		
	Rock	13.5		
	Small island	0.0		
	Treed wetland	0.1		
	Unclassified	0.2		
	Water	60.0		
Honey Harbour	Brush and alder	1.4	Crown	60.3
	Buffered linear feature	1.7	Federal	10.7
	Developed agricultural land	0.3	First Nation	0.0
	Grass and meadow	2.1	Park	0.2
	Open wetland	0.7	Private	28.9
	Productive forest	19.9		
	Rock	19.1		
	Small island	0.0		
	Treed wetland	0.2		
	Unclassified	1.4		
	Water	53.3		

Region Name	FRI Polytype	Percentage Cover (FRI Polytype ÷ Region Area)	Ownership	Percentage Cover (Area of Ownership ÷ Region Area)
State of the Bay 2013 Average	Brush and alder	1.4	Crown	52.1
	Buffered linear feature	0.6	Federal	0.5
	Developed agricultural land	0.2	First Nation	8.0
	Grass and meadow	0.4	Park	29.2
	Open wetland	2.6	Private	10.3
	Productive forest	38.8		
	Rock	13.6		
	Small island	0.002		
	Treed wetland	1.0		
	Unclassified	1.2		
	Water	40.2		

Table 7: Breakdown of FRI polytype by region and ownership

Region Name	FRI Polytype	Area (ha) by Ownership				
		Crown	Federal	First Nation	Park	Private
McGregor Bay & Killarney	Brush and alder	121	-	123	218	50
	Buffered linear feature	112	3	-	6	36
	Developed agricultural land	-	-	-	-	-
	Grass and meadow	5	-	23	-	12
	Open wetland	440	-	268	962	24
	Productive forest	9,591	135	5,991	22,610	894
	Rock	4,502	140	718	4,890	306
	Small island	-	6	5	-	-
	Treed wetland	84	-	122	231	8
	Unclassified	55	7	185	40	247
	Water	13,570	118	675	3,666	12
	Total	28,479	409	8,110	32,623	1,589
French River	Brush and alder	497	-	141	184	-
	Buffered linear feature	62	-	-	4	1
	Developed agricultural land	-	-	-	-	-
	Grass and meadow	-	-	-	1	-
	Open wetland	731	-	629	2,001	24
	Productive forest	14,359	-	6,674	23,716	216
	Rock	1,908	-	230	4,454	121
	Treed wetland	70	-	309	634	3
	Unclassified	65	-	-	9	16
	Water	39,162	-	355	16,147	-
	Total	56,853	0	8,338	47,149	381
Britt	Brush and alder	52	0.9	950	701	25
	Buffered linear feature	36	-	47	9	47
	Developed agricultural land	2	-	-	1	148
	Grass and meadow	11	-	80	7	53

Region Name	FRI Polytype	Area (ha) by Ownership				
		Crown	Federal	First Nation	Park	Private
	Open wetland	68	-	352	690	45
	Productive forest	2,899	-	4,477	3,940	425
	Rock	1,784	22	1,494	8,862	691
	Treed wetland	17	-	12	567	26
	Unclassified	44	0.1	25	5	135
	Water	12,845	0.6	253	1,409	11
	Total	17,397	23	7,691	16,191	1,607
Pointe au Baril	Brush and alder	271	-	250	638	23
	Buffered linear feature	129	-	49	19	51
	Developed agricultural land	-	-	-	-	-
	Grass and meadow	4	-	45	57	15
	Open wetland	236	-	380	592	21
	Productive forest	4,577	1	2,462	2,937	1,217
	Rock	1,829	1	711	7,042	1,201
	Treed wetland	83	-	16	353	3
	Unclassified	7	-	27	-	21
	Water	17,667	-	36	429	23
	Total	24,805	2	3,976	12,067	2,575
Carling	Brush and alder	175	-	60	214	278
	Buffered linear feature	106	-	48	7	194
	Developed agricultural land	1	-	-	-	148
	Grass and meadow	11	-	36	2	246
	Open wetland	363	-	354	456	442
	Productive forest	3,197	-	3,115	2,351	4,803
	Rock	2,519	4	299	1,553	1,837
	Treed wetland	300	-	397	130	267
	Unclassified	6	-	109	2	114
	Water	29,350	-	16	584	143
	Total	36,027	4	4,433	5,298	8,473

Region Name	FRI Polytype	Area (ha) by Ownership				
		Crown	Federal	First Nation	Park	Private
Parry Sound	Brush and alder	21	-	24	820	86
	Buffered linear feature	23	7	60	75	652
	Developed agricultural land	8	-	-	-	454
	Grass and meadow	2	5	19	-	385
	Open wetland	49	-	110	14	343
	Productive forest	969	-	2,197	-	8,330
	Rock	346	-	142	82	1,108
	Treed wetland	31	-	189	5	131
	Unclassified	34	164	233	2	841
	Water	9,115	-	329	646	361
	Total	10,599	176	3,303	1,644	12,691
Massasauga & Sans Souci	Brush and alder	388	-	-	211	169
	Buffered linear feature	293	-	-	3	342
	Developed agricultural land	-	-	-	-	98
	Grass and meadow	35	-	-	82	372
	Open wetland	1,211	-	-	422	309
	Productive forest	12,456	-	36	10,432	7,362
	Rock	3,748	-	-	3,137	1,048
	Treed wetland	268	-	-	96	120
	Unclassified	340	-	1	3	257
	Water	14,580	-	-	2,839	558
	Total	33,318	0	37	17,225	10,635
Twelve Mile Bay & Go Home Bay	Brush and alder	235	-	27	216	47
	Buffered linear feature	78	-	25	2	8
	Developed agricultural land	-	-	-	-	-
	Grass and meadow	11	-	229	4	11
	Open wetland	300	-	68	140	40
	Productive forest	8,450	2	1,228	2,598	3,027
	Rock	849	92	14	982	1,635

Region Name	FRI Polytype	Area (ha) by Ownership				
		Crown	Federal	First Nation	Park	Private
	Treed wetland	212	-	46	47	-
	Unclassified	-	-	-	-	13
	Water	13,217	-	102	381	480
	Total	23,352	93	1,738	4,370	5,260
Cognashene	Brush and alder	37	-	-	31	4
	Buffered linear feature	55	-	2	3	-
	Developed agricultural land		-	-	-	-
	Grass and meadow		-	-	4	1
	Open wetland	89	-	20	16	13
	Productive forest	1,063	-	204	1,048	305
	Rock	91	60	2	287	1,059
	Treed wetland	3	-	2	4	-
	Unclassified	5	-	-	1	13
	Water	6,191	-	8	416	27
	Total	7,535	60	239	1,811	1,421
Honey Harbour	Brush and alder	84	-	-	-	106
	Buffered linear feature	26	19	-	2	199
	Developed agricultural land	-	-	-	-	46
	Grass and meadow	11	-	-	-	291
	Open wetland	16	-	-	-	82
	Productive forest	752	2	-	13	2,028
	Rock	286	1,460	-	7	934
	Treed wetland	15	-	-	-	6
	Unclassified	26	-	-	-	165
	Water	7,259	23	-	-	208
	Total	8,475	1,503	0	22	4,063

Region Name	FRI Polytype	Area (ha) by Ownership				
		Crown	Federal	First Nation	Park	Private
State of the Bay 2013 Average	Brush and alder	1,811	1	1,575	2,413	786
	Buffered linear feature	921	29	231	129	1,530
	Developed agricultural land	11	-	-	1	894
	Grass and meadow	90	5	433	157	1,340
	Open wetland	3,502	-	2,181	5,293	1,343
	Productive forest	58,313	140	26,384	70,464	28,607
	Rock	17,862	1,778	3,609	20,054	9,940
	Small island	0	6	5	-	-
	Treed wetland	1,085	-	1,092	2,068	565
	Unclassified	581	171	580	73	1,821
	Water	162,595	142	1,773	26,517	3,221
	Total	246,841	2,271	37,864	127,169	50,048

2.4 Large Natural Areas

2.4.1 What is measured?

Ideally, we are interested in measuring percentage of each region in large natural areas. Large natural areas are defined as areas of forest, rock barrens, wetlands, and water features (lakes, rivers and Georgian Bay) with a contiguous area of 200 ha or greater. Unfortunately, the large natural areas analysis is not available for the 2013 *State of the Bay* report card and it is recommended that it is conducted at a later date. A potential methodology for this GIS analysis is outlined below, including key data gaps and research needs that are required to inform the GIS analysis.

2.4.2 How is it measured?

In order to inform the Muskoka Watershed Council's environmental report card a study on large natural areas was conducted by Riverstone Environmental Solutions Inc. (RES) (RES, 2011). The study recommended using roads as a surrogate measure of human impacts on natural areas. The *State of the Bay* report card should consider using this approach, as well as including railway, hydro corridors, and trails in the analysis of large natural areas. Considering the coastal and archipelago landscape of eastern and northern Georgian Bay, it is recommended to include boat channels in the analysis of large natural areas. Further research is require to determine the types of boat channels to include, such as, main boat channels, side channels, and canoe routes.

Using Georgian Bay's road network to delineate and define natural areas is logical for several reasons. First, roads are typically reflective of development patterns (i.e., more roads usually equals more development); thus, it is an effective measure to gauge the extent of human encroachment into an area. Second, the development of roads is inherently related to a variety of negative impacts on otherwise natural conditions (discussed in Section 2.4.3). Third, because it has been amply demonstrated that roads have numerous adverse effects on a multitude of species, it is logical that roads will form part of the boundaries of what would be considered large natural areas in the majority of cases (RES, 2011).

Large natural areas without roads have been shown to be important for maintaining population distributions and for facilitating adequate levels of space used by many species. Additionally, areas farther from roads and human development are known to have higher water quality, provide high quality wildlife habitat, and support diverse ecological communities (Desbonnet et al., 1994). Relative to other digital datasets, the road 'layers' available are regularly updated.

As noted above, the analysis for large natural areas should also include railway, hydro corridors, trails, and boat channels. These linear features also impact natural areas and conditions. Railways contribute to habitat fragmentation, create barriers to wildlife movement, and passing trains also pose threats to wildlife by injury and mortality (MHF, 2007). Hydro corridors impact natural areas directly and influences adjacent natural areas. The creation and maintenance of hydro corridors destroys habitat, fragments the landscape, produces noise, introduces herbicides, creates barriers to wildlife movements, and increases access to areas that were once sheltered from predators and humans (MHF, 2007). Trails result in anthropogenic disturbances that affect animal and plant communities (MHF, 2007).

Although there is limited research on the effects of boat channels/traffic on natural areas, anecdotal evidence suggests that boat traffic can result in species mortality, disturbance to wildlife, water quality concerns, introduction of invasive species, degradation of the aquatic habitat, and human encroachment.

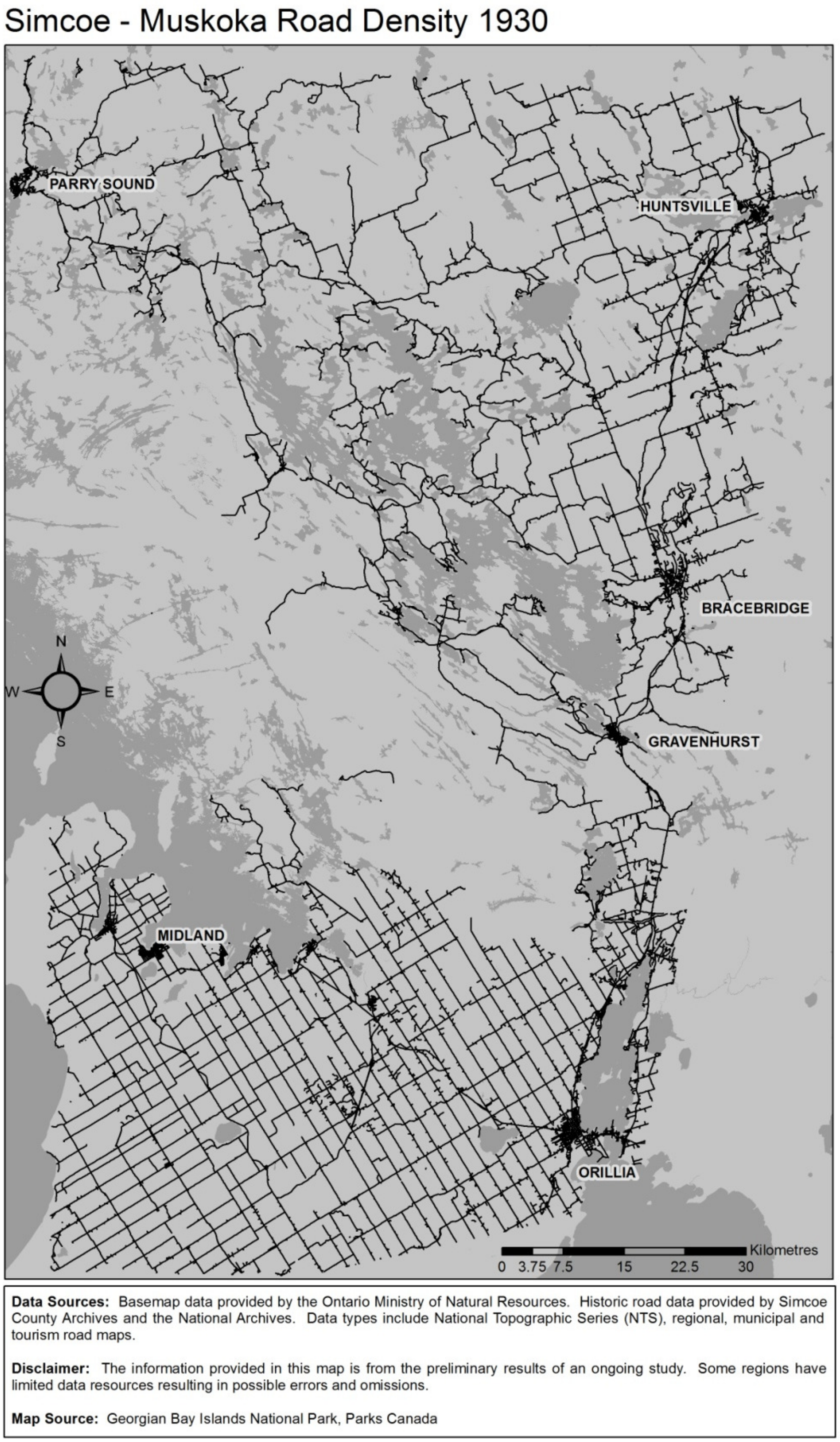
The Riverstone study (RES, 2011) recommends delineating and defining the natural areas by using buffers from the roads (i.e., select a distance from a road to be excluded). Obviously not all roads will have the same impact due to differences in use/traffic and speed. Similarly, the other linear features have different intensity of impacts on natural areas. These differences, in terms of potential impacts on natural areas, are reflected by assigning different buffer distances. Recommended buffer distances for the large natural areas analysis have been taken from the Muskoka Watershed Inventory (MHF, 2007) and are as follows:

- Roads
  - Primary roads – 400 m. A road constructed, maintained and used as part of the main all-weather road system. Primary roads are essentially permanent roads, regularly maintained, with a life in excess of 15 years.
  - Secondary roads – 400 m. A road which is essentially a branch off a primary road. These roads are not considered permanent and are not normally maintained beyond the five to 15 year period of their use.
  - Tertiary roads – 200 m. A road which is built for short-term use (i.e. up to five years) for harvest and subsequent renewal operations. Tertiary roads may be un-surfaced or thinly surfaced and are not maintained beyond the period of their use. They are often reforested.
- Railway – 200 m.
- Hydro corridors – 200 m.
- Trails – 200 m.
- Boat channels – further research is required to determine what types of boat channels to include in the GIS analysis, as well as applicable buffers.

2.4.3 Why is it important?

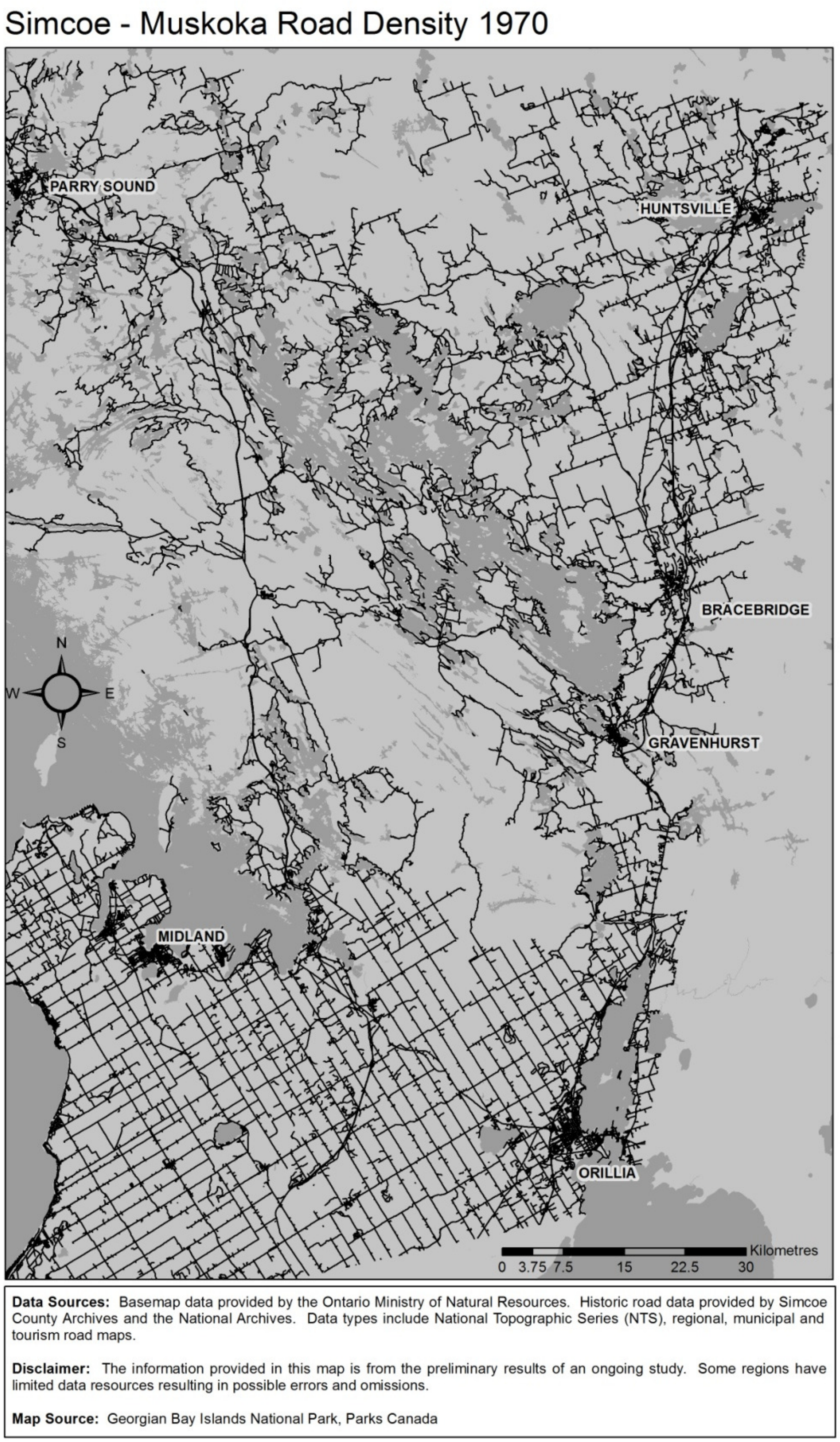
The scientific literature clearly outlines the ecological value of large natural areas. The benefits and values associated with large natural areas are: protection of biodiversity; ecosystem stability; preservation of water quality; and human values. This section of the report borrows heavily from Riverstone Environmental Solutions Inc.'s report (RES, 2011) on large natural areas prepared for the Muskoka Watershed Council, which recommended using roads as a surrogate measure of human impacts on natural areas.

The following Figures (Figure 28, Figure 29, and Figure 30) have been presented to provide an illustration of road development over time. These figures have been prepared by Georgian Bay Islands National Park. The information provided in these maps is from the preliminary results of an ongoing study and therefore some regions have limited data resources, which could result in possible errors or omissions. However, they provide a general trend of road development over time, from 1930 to 2000, in southern Georgian Bay.



Source: GBINP, 2013.

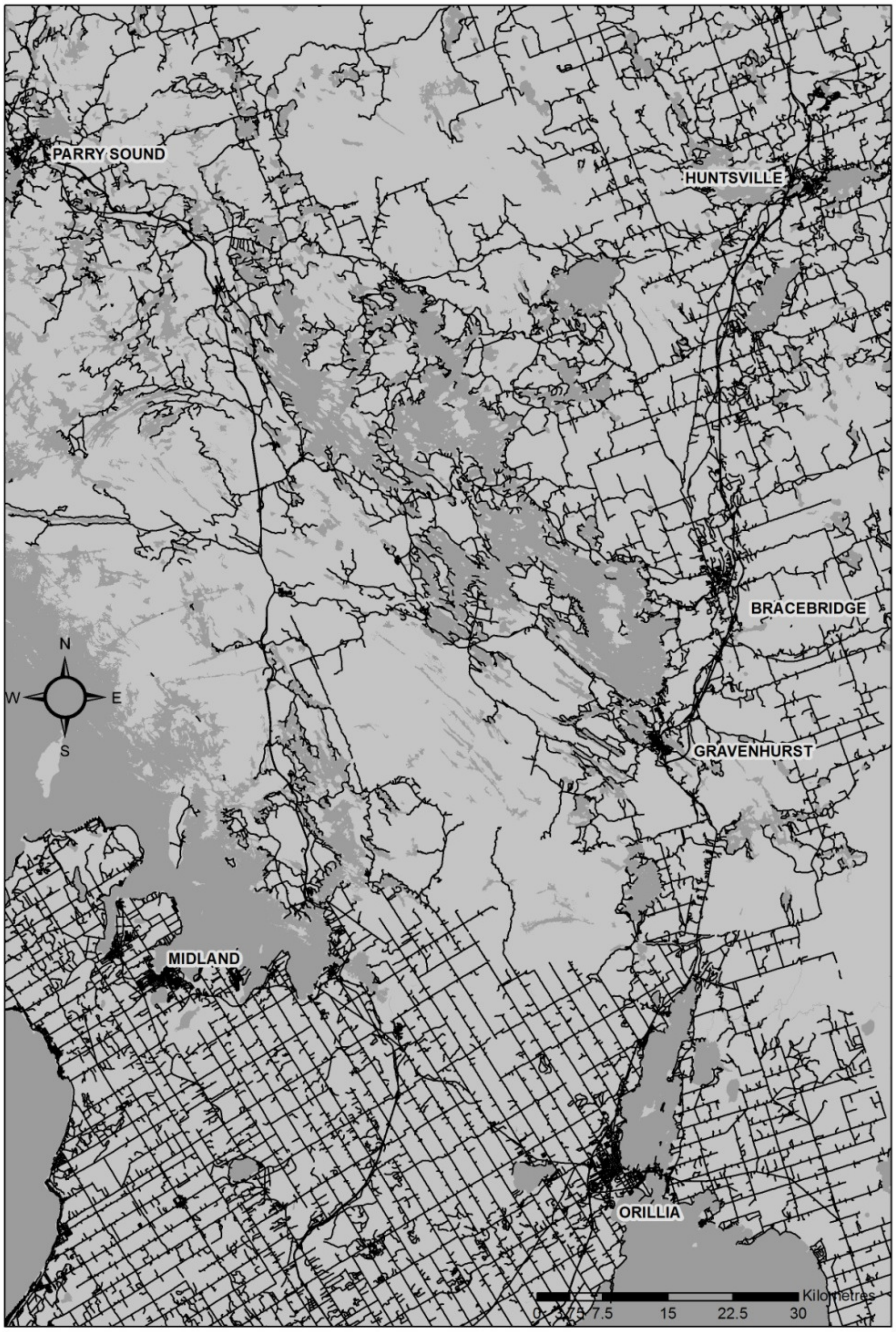
Figure 28: Road density in Simcoe-Muskoka in 1930



Source: GBINP, 2013.

Figure 29: Road density in Simcoe-Muskoka in 1970

Simcoe - Muskoka Road Density 2000



Data Sources: Basemap data provided by the Ontario Ministry of Natural Resources. Historic road data provided by Simcoe County Archives and the National Archives. Data types include National Topographic Series (NTS), regional, municipal and tourism road maps.

Disclaimer: The information provided in this map is from the preliminary results of an ongoing study. Some regions have limited data resources resulting in possible errors and omissions.

Map Source: Georgian Bay Islands National Park, Parks Canada

Source: GBINP, 2013.

Figure 30: Road density in Simcoe-Muskoka in 2000

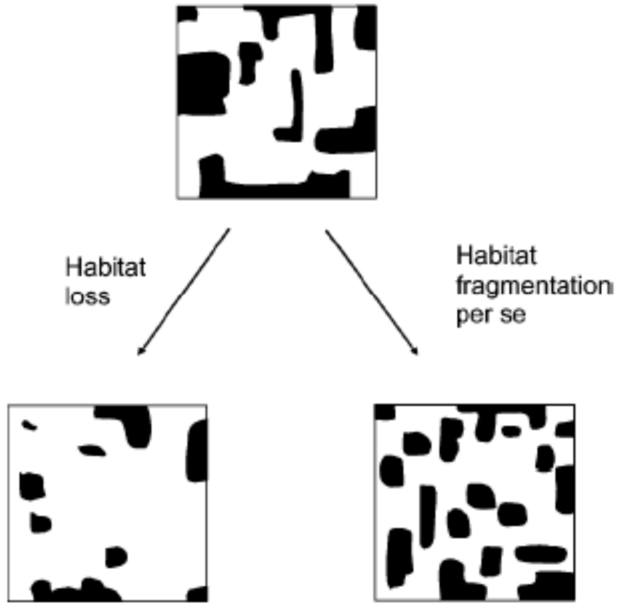
Protection of Biodiversity

One of the most recognized approaches to conserving biodiversity focuses on the establishment and preservation of large natural areas (Timonen et al., 2011). Biodiversity refers to the variety of species and ecosystems in a given area and includes the ecological processes of which these organisms are a part. The three most commonly accepted components of biodiversity are ecosystem, species, and genetic diversity (RES, 2011).

Benefits of biodiversity in a general sense are numerous. It is an essential part of healthy ecosystems, human health, prosperity, security, and wellbeing. Diversity of natural landscapes and species is also a source of emotional, artistic, and spiritual inspiration and cultural identity in Canada (Government of Canada, 2003). Many Canadians recognize that biodiversity is the foundation for Canada's natural resource sectors and the key to continued growth in other sectors such as ecotourism and recreation (Government of Canada, 2003). Many ecologically important regions of the world have hundreds of vertebrate species and tens of thousands of insect and plant species (Holloway et al. 2004), as such, a species-by-species approach to the conservation of biodiversity is nearly impossible (MNR, 2010c).

Natural land cover functions as habitat for species, and it is known that habitat loss is the single most important factor contributing to the global biodiversity crisis (Pimm et al., 1995; Fahrig, 1999). Furthermore, there is a positive relationship between species richness and area for nearly every taxon. Considerable evidence has been collected that shows that the amount of habitat in an area has a much greater effect on biodiversity than the configuration of this habitat (Andren, 1999; Fahrig, 2001; Fahrig, 2003).

The loss of natural areas is often viewed in terms of habitat loss (Figure 31); the largest factor contributing to species declines and extinctions (Fahrig, 1999). Recent increases in habitat loss can be traced primarily to the growth of the human population leading to expansion of human activities into formerly natural areas (Sisk et al., 1994). The effects of losing habitat are often obvious, with individual species that rely on the habitat within the landscape becoming displaced, resulting in a population decline or loss (Bender et al., 1998). Habitat loss usually occurs in small increments (Fahrig, 2003); which is more problematic because losses often occur continuously, thereby making it difficult to stop. In the case of many wildlife populations, large portions of contiguous habitat must be preserved to avoid drastic population declines or massive species loss (Rompre et al., 2010).



Source: RES, 2011.

Figure 31: Visual representation of the difference between habitat loss and habitat fragmentation

Large natural areas help to ensure connectivity between habitats and thereby help to preserve biodiversity. Connectivity is best thought of as the opposite of fragmentation (Figure 31): it is the linkage of habitats, ecological communities, and ecological processes at multiple spatial and temporal scales. Key biodiversity processes such as population persistence and recovery after disturbance are strongly influenced by connectivity in a landscape (Lamberson et al., 1994). Additional processes, such as the exchange of individuals and genes within a population (Saccheri et al., 1998), and the occupancy of habitat patches (Villard and Taylor, 1994) are affected by the levels of connectivity present in a system.

Two of the key land uses that disrupt connectivity in natural systems are roads and urbanization. The number of studies that demonstrate adverse effects of roads on wildlife is considerable. For example, adverse effects of roads have been demonstrated for amphibians (Fahrig et al., 1995; Eigenbrod et al., 2008), turtles (Steen et al., 2006), small mammals (Oxley et al., 1974), bobcats and coyotes (Riley et al., 2006), deer (Kuehn et al., 2007) and grizzly bears (Mace et al., 1996). Although terrestrial taxa are most affected, roads can also disrupt connectivity of aquatic habitats for fish, i.e., when culverts are not appropriately sized or placed, and birds that are killed by motor vehicles. The negative effects of urbanization on biodiversity are also well documented (Trzcinski et al., 1999; Gagne and Fahrig, 2007). For example, the urbanized areas within Canada were more than double in 1996 as compared to 1971 (Canadian Biodiversity Information Network, 2004).

Ecosystem Stability

Large natural areas support higher levels of biodiversity than smaller areas. The insurance hypothesis suggests that ecosystems with higher biodiversity are more stable (Tilman, 1999; Yachi and Loreau, 1999; Leary and Petchey, 2009). This increased stability is based on the idea that if an event resulting in a negative impact were to occur, not all species within an ecosystem would be affected in the same way. In an ecosystem with high species richness, a change in the population level of an individual species is not as likely to result in overall negative impacts on the entire ecosystem (Yachi and Loreau, 1999; Caldeira et al., 2005; Leary and Petchey, 2009). This is because high species diversity increases the likelihood that another species already found within the ecosystem is capable of filling the function of the declining species (Tilman, 1999). In this way, an ecosystem can be said to exhibit resistance and resilience. The insurance hypothesis brings together two key ideas: Ecosystem Resistance and Ecosystem Resilience. Ecosystem resistance is the ability of a given ecosystem to withstand negative impacts, while ecosystem resilience is the ability of the ecosystem to recover from negative impacts.

Studies have demonstrated a positive relationship between high species diversity (and therefore high biodiversity) and ecosystem resistance. It has also been demonstrated that increased species richness (the number of different species) within a given area increases the stability and resiliency of ecosystem functions (Peterson et al., 1998).

Furthermore, studies have demonstrated that larger natural areas are more resilient to change, that is they have greater capacity to accommodate change or absorb disturbance. Climate change represents one of the major perceived long-term disturbances within natural ecosystems. There is now considerable evidence that changes in climate are occurring at higher rates than background levels. As previously mentioned, large natural areas have a greater capacity to resist change and are more resilient to negative impacts of disturbances. Therefore, large natural areas are more likely to be able to maintain ecosystem services and functionality in the face of climate change. Maps presenting potential climate change scenarios, in relation to temperature and precipitation, are presented in Section 3.4.3.

Preservation of Water Quality

Large natural areas aid in the maintenance of water quality. Reductions in the amount of natural land cover adjacent to water bodies have been linked to reductions in water quality (Huntington, 2006). Traditionally, intact vegetated areas have been suggested as methods for minimizing the impacts of adjacent land uses on water quality. These vegetated buffers are typically recommended to be between 15 and 30m wide (MNR, 2010d).

Human Valuation of Large Natural Areas

The role of biodiversity in natural systems is intrinsically complex and environmental degradation can affect many other components of the ecosystem. The preservation of large natural areas contributes to biodiversity and therefore, the associated beneficial ecosystem services.

Although ecological services are essential to life on earth, there are additional philosophical and social arguments for the value of natural areas. Natural areas are said to have intrinsic value because they currently exist and have existed for a long time (Alho, 2008). Humans have also applied economic, aesthetic and recreational value to natural areas.

Aesthetic value is commonly assigned to natural areas by humans seeking contact with nature. Over the past century, humans have become disengaged from the natural environment (Maller et al., 2009). The foundation of the aesthetic value of natural areas is that they are visually appealing and provide opportunities to escape increasingly polluted, densely populated, human-dominated landscapes. Natural areas have high aesthetic value as they provide numerous opportunities for wilderness recreation and solitude (Ehrlich and Ehrlich, 1992). In fact, the ecotourism industry has emerged to provide opportunities for solitude, health and recreation by allowing individuals to embrace the aesthetic value of natural areas (Maller et al., 2009). In the Georgian Bay area, increases in the popularity of nature-based tourism and the use of parks and large natural can have significant impacts on the local economy.

Size of Large Natural Areas

As noted above, the ecological and human benefits of large natural areas are numerous. The challenge is determining “How large does an area need to be to qualify as a large natural area?”

Although there is limited research on the amount and optimum patch size that should be maintained within a forested environment, work undertaken in eastern and southern Ontario recommends that in areas where conifer and deciduous forests are both naturally occurring, forest tracts of 200 hectares for each forest type be maintained to support all or most native interior bird species (used as an indicator of forest health) (EC, 2006a). No research could be found that provides guidance on the amount of natural areas required to maintain a healthy landscape where the natural cover is not forest, but may be rock barren, large wetland areas, or an archipelago. Furthermore, the reference cited above (EC, 2006a) is based on a largely-forested landscape in rural/agricultural southern Ontario. However, we know that large natural areas are important in eastern Georgian Bay’s unique interior, coastal and archipelago landscape. These large natural areas are needed to facilitate the movement of wildlife from the mainland to the islands, and among the islands, which is critical for maintaining healthy ecosystems (GBINP, 2006).

2.4.4 What do the grades mean?

Unfortunately, there is not a scientifically sound way to give large natural areas a grade because research is needed to determine how much habitat is enough for eastern Georgian Bay. Roads, railways, hydro corridors, trails, and boat channels divide up large natural areas, so these can be analyzed, but we don't know what the results would mean for different species and habitats. More research will help us learn about what matters most for this unique archipelago.

2.4.5 What are the results?

Results for the large natural areas indicator are not available. As noted above, it is recommended that further research is carried out prior to conducting GIS analysis for this indicator.

2.5 Natural Cover and Large Natural Areas

2.5.1 What can I do to help?

Listed below are some suggestions and practices you can adopt to help the Bay's natural features:

1. Support the work of the Georgian Bay Land Trust that seeks to identify and protect areas of high biodiversity and special value:
    - www.gblt.org
2. Complete self-evaluations of your property and lifestyle practices to identify ways to improve your natural neighbourhood:
    - www.gbbr.ca/our-environment/life-on-the-bay-guide/
3. The LandOwner Resource Centre's extension notes:
    - www.ont-woodlot-assoc.org/info_pub_ext.html
4. Plant native species, visit Evergreen's website to identify native species that suit your area and habitat:
    - www.evergreen.ca

2.5.2 Data gaps and research needs

In summary, the data gaps and research needs with respect to the Natural Cover and Large Natural Areas indicators are:

1. Additional research is required on the optimum level of natural cover required to sustain the ecosystems of eastern and northern Georgian Bay (i.e. a natural cover benchmark). Future *State of the Bay* report cards should investigate whether to leave this landscape level indicator as is, or if different measures/surrogates/indexes should be used.
   Based on research completed to date, three potential ideas have been identified for future investigation. The first option is to follow up to Conservation Ontario's northern Conservation Authorities as they are currently preparing report cards and in the process of doing so may identify a 'northern' benchmark for natural cover. The second option is to investigate is using 'biodiversity' as a surrogate. Two approaches could be used for biodiversity; creating an index of habitat types and connectivity, or research on biodiversity sampling tools. Georgian Bay Forever is currently investigating aquatic based biodiversity sampling methods. The final option is to consider using 'ecosystem services and functions' as a surrogate; the Muskoka Watershed Council endeavours to lead on a study for Ecoregion 5E (includes Georgian Bay).

2. Unfortunately, the large natural areas analysis is not available for the 2013 *State of the Bay* report card and it is recommended that it is conducted at a later date. In order to inform the Muskoka Watershed Council's environmental report card a study on large natural areas was conducted by Riverstone Environmental Solutions Inc. (RES) (RES, 2011). The study recommended using roads as a surrogate measure of human impacts on natural areas. The State of the Bay report card should consider using this approach, as well as including railway,

hydro corridors, and trails in the analysis of large natural areas. Considering the coastal and archipelago landscape of eastern and northern Georgian Bay, it is recommended to include boat channels in the analysis of large natural areas. Further research is require to determine the types of boat channels to include, such as, main boat channels, side channels, and canoe routes. This research should investigate the impacts of various boat channels in order to determine appropriate buffers for the GIS analysis.

3. As noted above, research is required on the impact of boat channels on large natural areas, and in particular, to determine if they have the same impact as land based linear features. Thus, the analysis method for boat channels should investigate whether to combine boat channels with the other linear features, or whether they are two distinct measures. For example, the nearshore area could be analysed using land based linear features (i.e. roads, rails, hydro corridors, and trails) and the coastal area is analysed using boat channels. Analysing and presenting the results in this fashion might help to identify the need for protected areas in terms of boat traffic.

4. As previously discussed, the ecological and human benefits of large natural areas are numerous. The challenge is determining "How large does an area need to be to qualify as a large natural area?" The MWC report card reports on natural patch sizes over 200 hectares based on work undertaken by Environment Canada (2006a) in eastern and southern Ontario. This study recommends that in areas where conifer and deciduous forests are both naturally occurring, forest tracts of 200 hectares for each forest type be maintained to support all or most native interior bird species (used as an indicator of forest health). No research could be found that provides guidance on the amount of natural areas required to maintain a healthy landscape where the natural cover is not forest, but may be rock barren, large wetland areas, or an archipelago. Furthermore, the reference cited above (EC, 2006a) is based on a largely-forested landscape in rural/agricultural southern Ontario. However, we know that large natural areas are important in eastern and northern Georgian Bay's unique interior, coastal and archipelago landscape. These large natural areas are needed to facilitate the movement of wildlife from the mainland to the islands, and among the islands, which is critical for maintaining healthy ecosystems (GBINP, 2006).
   Therefore future *State of the Bay* report cards should investigate new benchmarks for large natural areas. It is suggested that this research investigates the possibility of using the habitat and range requirements of a species at risk, such as the eastern foxsnake, as a measure of a large natural area.

5. Future *State of the Bay* report cards should include data on road counts (i.e. traffic volume) in order to track changes over time on the use and impact of roads.

6. Future *State of the Bay* report cards should include data on boat counts (i.e. traffic volume) in order to track changes over time on the use and impact of boat channels.

7. Future *State of the Bay* report cards should consider coordinating with Municipalities to collect data on new and proposed developments. The current analysis uses MNR's dataset, which does not always have the most up to date information on new and proposed developments. Therefore partnering with Municipalities to collect this information will help to ensure that the analysis capture recent changes and is up to date.

2.6 Coastal Wetland Cover

2.6.1 What is measured?

Percentage of each region in coastal wetland cover. Coastal wetlands are operationally defined as wetlands that occur within 2 km of the 1:100 year flood line of the Great Lake/channel shoreline, and include all four wetland types (bog, fen, swamp, and marsh) identified in the Ontario Wetland Evaluation System (MNR, 1993). This landscape level indicator provides a good understanding of the overall integrity and function of the coastal aquatic environment.

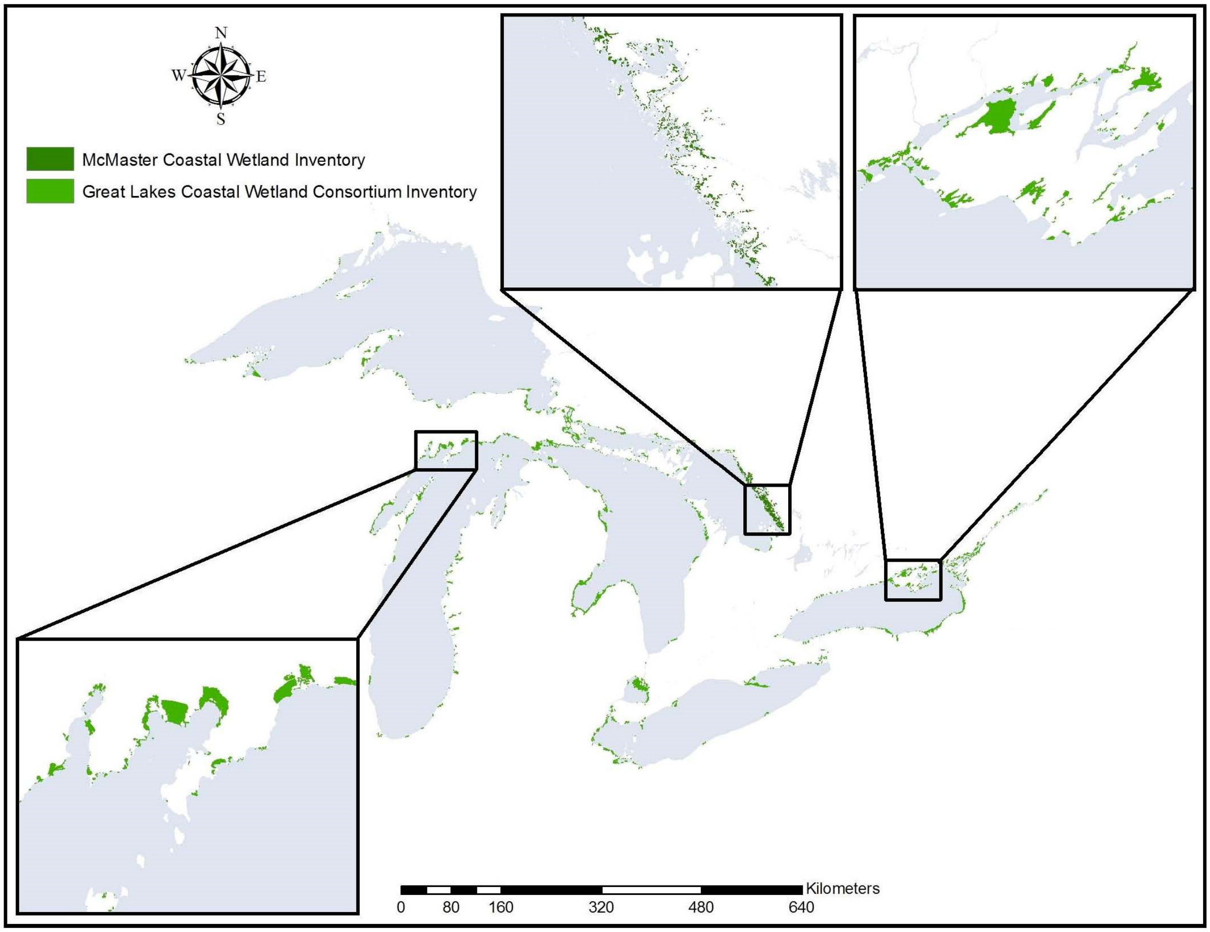
This ecosystem health indicator focuses on coastal wetlands along eastern and northern Georgian Bay, as the focus of the *State of the Bay* 2013 report card is on the coastal environment. Interior wetlands (i.e. wetlands located on in-land lakes and rivers) are also important to the environmental health of Georgian Bay's watershed. Information on the amount of interior wetland cover for each region is summarized in Section 2.3, and in particular Table 6 and Table 7.

2.6.2 How is it measured?

The Great Lakes Coastal Wetland Consortium (GLCWC) initiated a bi-national inventory to map and classify all coastal wetlands on both the U.S. and Canadian shorelines (Ingram et al., 2004). In 2003, the GLCWC assembled existing aerial photographs and satellite images to create a comprehensive wetland inventory. They were successful in putting together comprehensive coverage of coastal wetlands in Lakes Ontario, Erie and Superior; however, they were unable to delineate all coastal wetlands of Lake Huron, especially in Georgian Bay and the North Channel because of scarcity of high-resolution satellite imagery (Midwood, 2012).

In 2007, Georgian Bay Forever (then GBA Foundation) awarded a grant to Dr. Chow-Fraser at McMaster University to create an accurate inventory of the coastal wetlands of eastern and northern Georgian Bay, and this is known as the McMaster Coastal Wetland Inventory (MCWI).

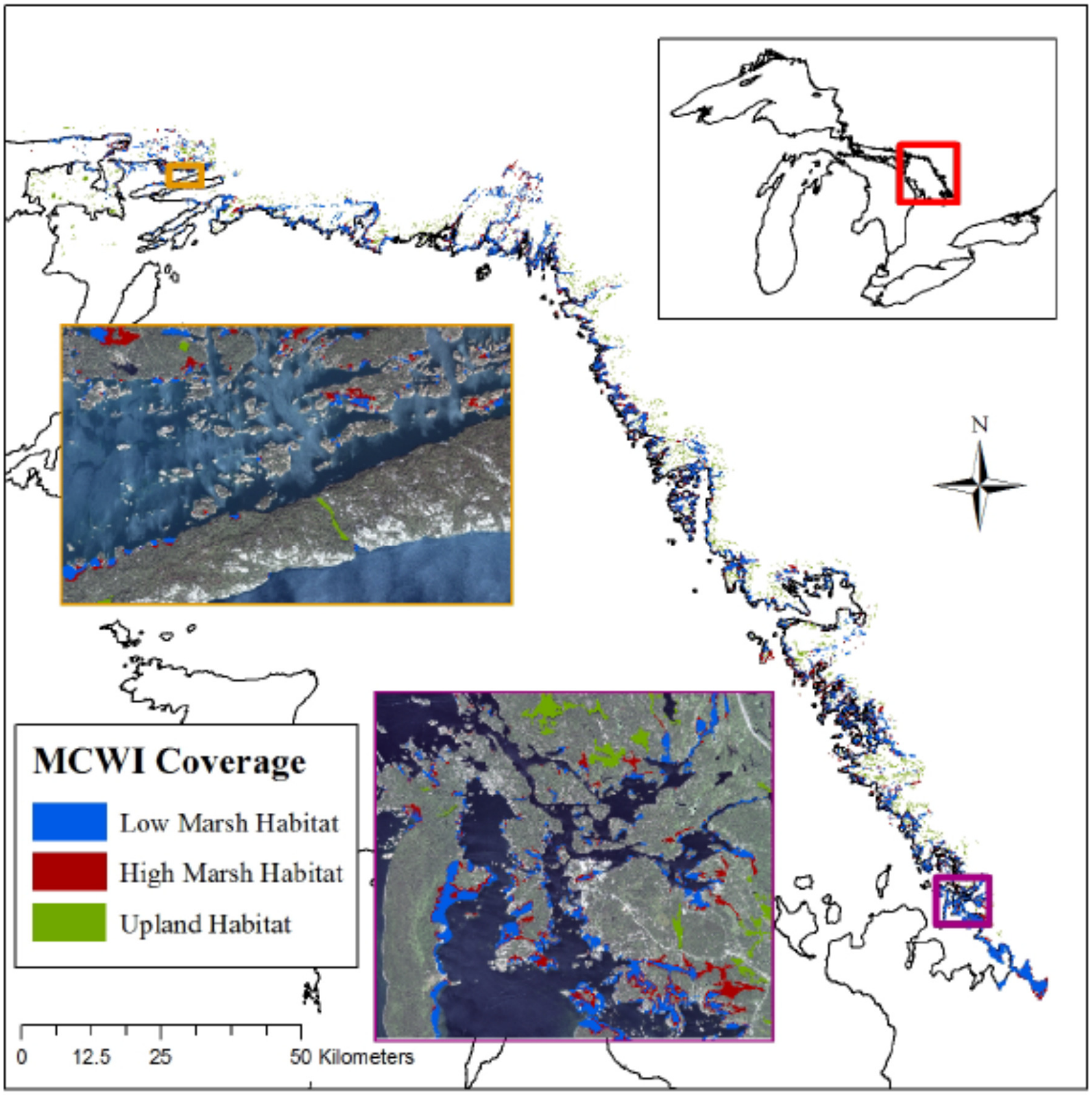
Figure 32 illustrates the distribution of coastal wetlands across the Great Lakes using both the GLCWC and MCWI datasets.



Source: Chow-Fraser, Date unknown.

Figure 32: Distribution of coastal wetlands in the Great Lakes

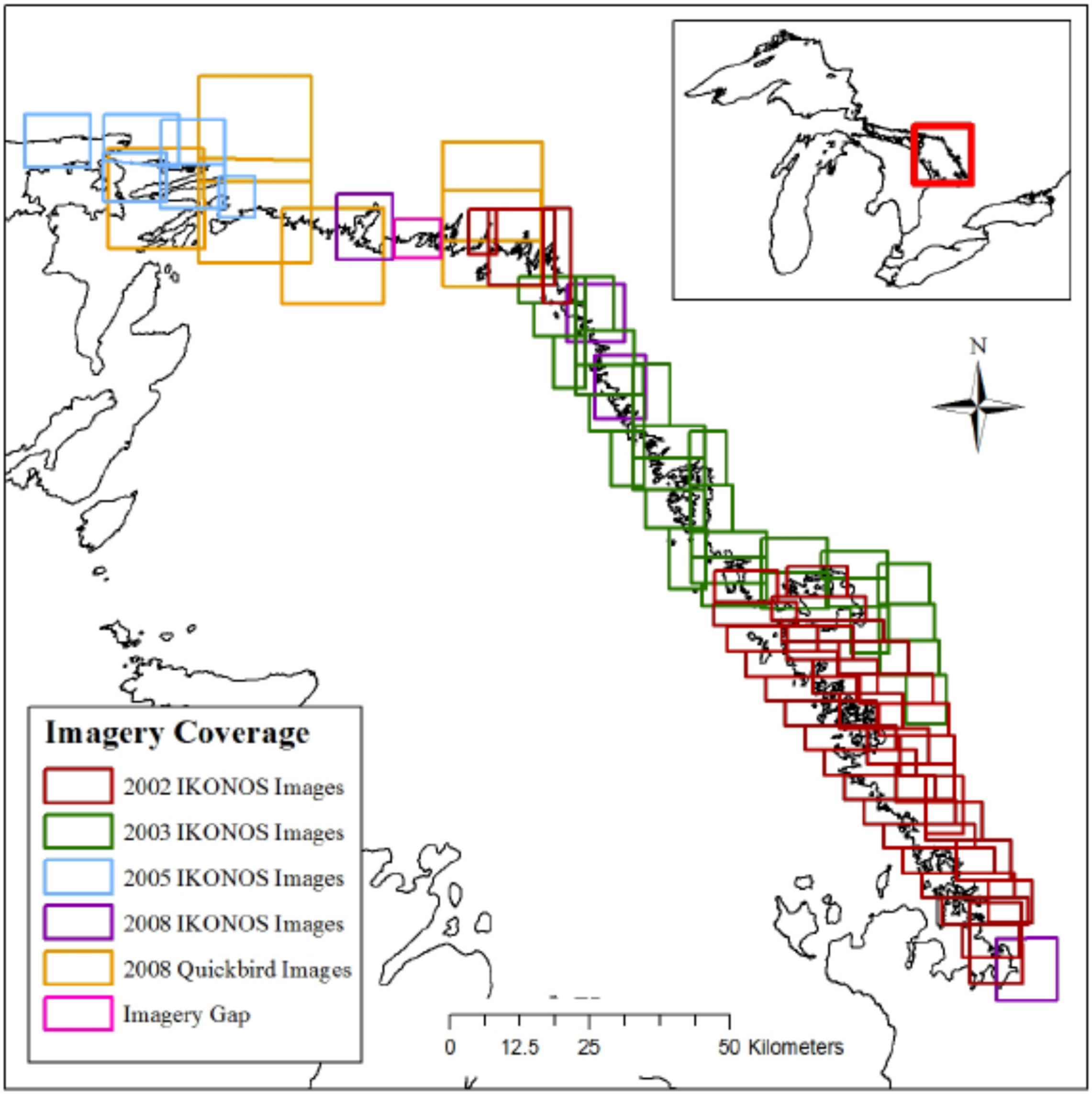
Figure 33 presents an overview map of the MCWI, covering eastern and northern Georgian Bay within 2 km of the shoreline. The two insets provide a close-up of the region near Killarney (top) and Honey Harbour (bottom).



Source: Midwood, 2012.

Figure 33: Overview map of the MCWI

The MCWI consists of manually digitized wetland polygons that were delineated from high-resolution IKONOS (a commercial earth observation satellite) imagery acquired during 2002 to 2008, a period of relatively stable low water levels. Figure 34 shows the boundaries of the IKONOS imagery for eastern and northern Georgian Bay acquired for the MCWI project in 2002, 2003 and 2005. To complete the coverage of southern Georgian Bay, it was necessary to acquire a few additional images in 2008 (indicated in purple). Data gaps still exist along the northern shore of Georgian Bay and are indicated (in pink).



Source: Midwood, 2012.

Figure 34: IKONOS coverage for MCWI project

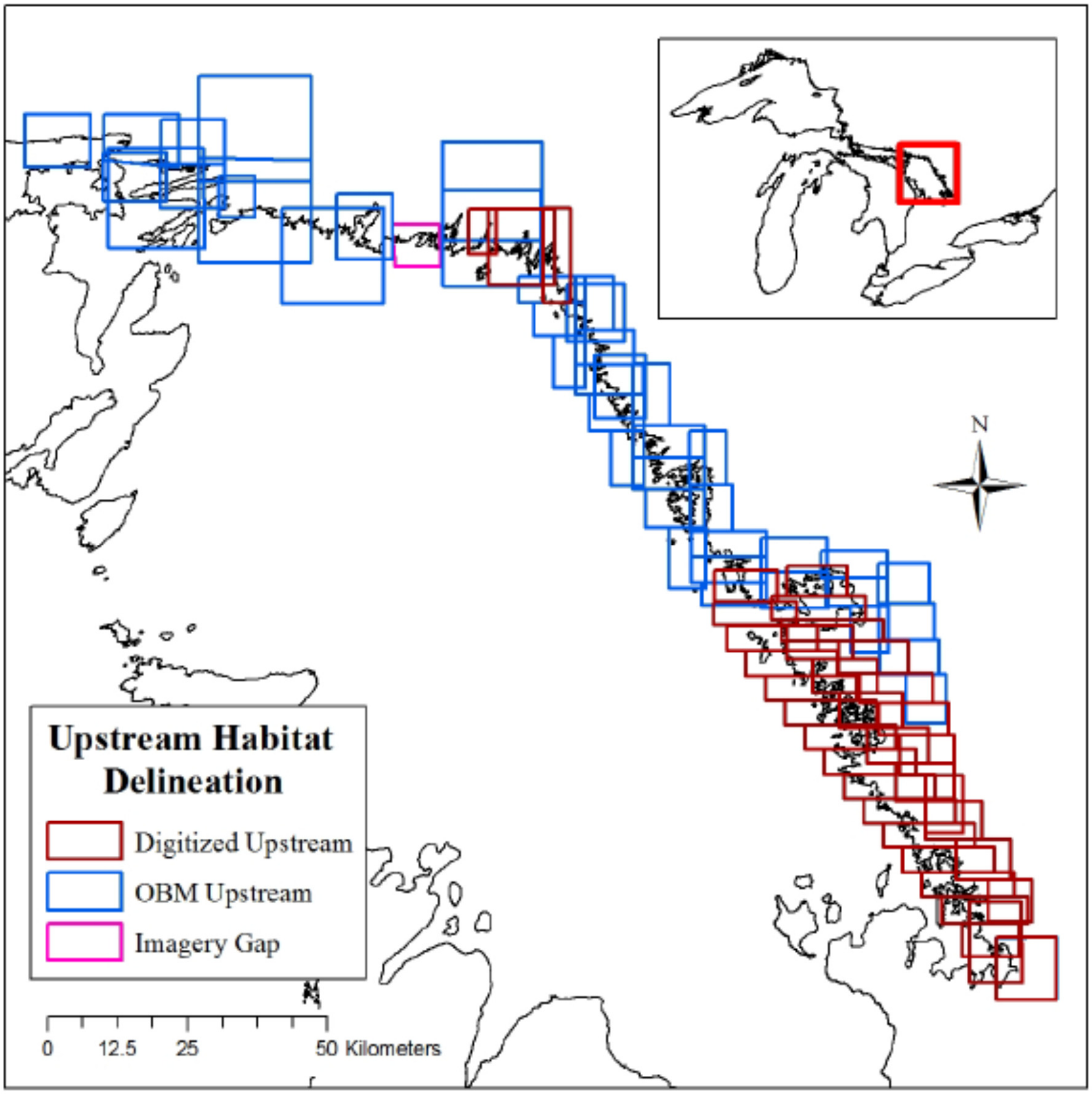
All wetlands delineated within 2 km of the shoreline have been included in a Geographic Information System (GIS), and have been classified into Coastal zone (Coastal) and Upstream wetland (UP) habitat. Habitat within the Coastal zone was further subdivided into Low Marsh (LM; permanently inundated) and High Marsh (HM; seasonally inundated) habitat. Figure 35 illustrates the division of low marsh and high marsh in a coastal wetland. LM habitat extends from the shoreline to a lower limit, operationally defined as 2.5 times the width of the emergent and/or floating vegetation that is visible in the image. This definition is based on field observations and is assumed to be a conservative estimate of the distribution of submersed aquatic vegetation that makes up a large component of LM habitat. HM habitat begins from the water's edge and extends to the upland forest boundary and/or a change in wetland type (e.g. swamp, bog or fen). The UP habitat incorporated all remaining wetlands (of any type) that are hydrologically connected to Georgian Bay via surface water and that occur within the 2 km shoreline buffer (Midwood, 2012).

Source: Midwood et al., 2011.

Figure 35: Division of aquatic (Low Marsh) and meadow (High Marsh) in a costal wetland

It was determined that existing delineations of UP habitat from the MNR's Ontario Base Map (OBM) for the region from Port Severn to Parry Sound were similar to delineations of the same habitat based on IKONOS imagery (Midwood, 2012). To avoid duplicating existing effort and because of time constraints, the wetland layer from the OBM was incorporated without modification into the MCWI as UP habitat for areas north of Parry Sound.

Figure 36 shows the boundaries of imagery that was used to digitize upstream habitat (indicated in red). For all other areas, upstream habitat was obtained from corresponding Ontario Base Maps (obtained from MNR; indicated in blue).



Source: Midwood, 2012.

Figure 36: Upstream habitat delineation of coastal wetlands

Table 8 compares the total amount of wetlands in both the MCWI and the GLCWCI with respect to wetlands greater than 2 hectares. (Please note that the GLCWC aimed to delineate all coastal wetlands along the Great Lakes shoreline that were greater than 2 ha in size).

Table 8: Comparison of the total area of Low Marsh, High Marsh and Upstream wetlands for eastern and northern Georgian Bay identified in the GLCWC and the MCWI

	GLCWC Area (ha)	GLCWC Polygon #	GLCWC Mean Size (ha)	MCWI Area (ha)	MCWI Polygon #	MCWI Mean Size (ha)
Total Low Marsh	298	170	1.8	5,376	3,771	1.4
Total Low Marsh >2 ha	298	170	1.8	4,044	414	9.8
Total High Marsh	587	234	2.5	3,298	6,255	0.5
Total High Marsh >2 ha	587	234	2.5	1,842	289	6.4
Total Upstream	1,762	379	4.7	8,676	2,603	3.3
Total Upstream >2 ha	1,762	379	4.7	7,381	883	8.4
Total Wetland	3,661	696	5.3	17,350	12,629	1.4
Total Wetland >2 ha	3,661	696	5.3	13,267	1,586	8.4

2.6.3 Why is it important?

The term “wetland” refers to a diverse group of ecosystems that are either permanently or seasonally flooded. This report focuses on a specific type of wetland, the coastal marsh. This ecosystem differs from other types of wetlands because it forms along the edges of lakes and large water bodies and is covered by water for most of the year. Consequently, the vegetation within these wetlands can survive and in fact thrives in a flooded state. Coastal wetlands exist at the interface between terrestrial and aquatic habitats. As a transitional environment, they support high levels of biodiversity due to the presence of both aquatic and terrestrial species. A large number of birds, turtles, snakes, frogs, fish, insects and mammals all use coastal wetlands at some point in their life cycle (Midwood et al., 2011). Georgian Bay’s coastal wetlands are dominated by large lake processes, including water level fluctuations, wave action, and wind tides or seiches. Periodic inundation during high lake levels re-sets succession and maintains habitat complexity and these highly productive ecosystems.

Coastal Wetlands of the Great Lakes

Eastern Georgian Bay is fortunate to have a high percentage of coastal wetlands compared to other areas of the Great Lakes (Table 9). The GLCWC coastal wetland inventory (Ingram et al., 2004) reported that Lake Huron had the highest percentage of coastal wetlands (compared to the other Great Lakes), which was expected due to its size, geology, morphology and lesser degree of urban encroachment than the lower Great Lakes of Erie and Ontario.

During the past two centuries, over two-thirds of southern Ontario’s original wetland area has been lost. That number reaches 90 % and higher in areas such as Ontario’s southwest. Wetlands located in coastal areas of the Great Lakes are especially at risk due to high development pressure in urban areas, and stresses such as lake-wide water level regulation (EC, 2002). The lower Great Lakes (Erie and Ontario) have experienced significant coastal wetland losses since European settlement. About

35% of the wetlands along the Canadian shorelines of Lakes St. Clair, Erie and Ontario have been lost (McCullough, 1985).

While a small fraction of pre-settlement wetlands remain in most areas of Lake Huron (Krieger et al., 1992), no comprehensive estimate of wetland loss is available for the Canadian and U.S. sides (of Lake Huron). Large scale wetland loss has not occurred in northern Lake Huron and Georgian Bay because of its sparse population and highly irregular, and in some cases remote, shoreline. Coastal wetlands naturally form in shallow, protected embayments. These areas are also ideal for building marinas and historically for the establishment of settlements (Midwood et al., 2011). Cottage, marina, and subdivision development continue to pressure wetlands.

Table 9 presents the coastal wetland distribution of the main areas and tributaries of the Great Lakes (this calculation includes both the GLCWC and MCWI data sets).

Table 9: Coastal wetland distribution in the Great Lakes by area and percentage

Lake / River	Area (ha)	Percentage
Lake Superior	26,626	11.8%
St Mary's River	10,790	4.8%
Lake Huron	54,141	23.9%
Eastern and northern Georgian Bay*	17,350	7.7%
Lake Michigan	44,516	19.6%
St Clair River	13,642	6.0%
Lake St Clair	2,217	0.9%
Detroit River	592	0.3%
Lake Erie	25,127	11.1%
Niagara River	196	0.09%
Lake Ontario	22,925	10.1%
Upper St Lawrence River	8,454	3.7%
Total	**226,576**	**100.0%**

*as per MCWI

Source: Chow-Fraser, Date unknown.

Eastern Georgian Bay's Costal Wetlands

Along the eastern and northern shores of Georgian Bay, there are a total of 37 quaternary watersheds ranging in size from 564 ha (Giants Tomb) to 126,103 ha (French River). The largest amount of wetland habitat (2,394 ha) was found in the Moon-Musquash watershed. When sorted by different type of habitat, however, the MCWI found that the Coldwater watershed was associated with the greatest amount of LM habitat (49 units with a total area of 797 ha). It was surprising that this LM habitat only accounted for 3.7% of the total Coldwater watershed area, when the LM habitat in Beausoleil-Severn Island accounted for 25.6 % of the total watershed area; Islands in Beausoleil-Severn were also associated with the highest percentage of HM habitat (8.7%). The Eastern Coast Islands watershed contained 1,035 units of HM, for a total area of 404 ha. The Moon-Musquash

River watershed contained the greatest amount of UP habitat, with 159 units and a total area of 1,708 ha, while the McGregor-Sampson Islands watershed had the highest percentage of UP habitat (8.6%) of all 37 quaternary watersheds (Midwood, 2012).

Eastern Georgian Bay is one of the world's largest freshwater archipelagos and wetland habitat is prevalent along the highly complex shoreline. This region is host to a disproportionately large number of pristine wetlands, with high biodiversity of plants and animals (Chow-Fraser 2006; Croft and Chow-Fraser 2007; Seilheimer and Chow-Fraser 2006). Due to the rocky nature of the region Georgian Bay coastal wetlands are better described from a functional perspective as wetland complexes, where many smaller units spread across the landscape act in concert (Midwood, 2012). The MCWI identified 12,629 wetland units along the eastern and northern coast adding up to 17,350 hectares. However, these numbers are not fixed as coastal wetlands are sensitive to changes in water levels. When water levels fluctuate, it will primarily affect the HM and LM. The HM will constitute a smaller proportion of the total wetland (i.e. UP, HM and LM) when water levels are high, and a much larger proportion when water levels are low (i.e. 2013 – current conditions). The LM area will also change with water levels as its upper boundary is defined by the water's edge and the shoreward boundary is an estimate of where the lower limit of colonization of submersed aquatic vegetation (SAV) occurs (which is difficult to estimate without bathymetric data).

A study conducted by Ingram et al. (2004) on coastal wetlands over 2 hectares in size reveals that the average size of eastern Georgian Bay's wetlands is small (8.4 ha) compared with wetlands in Lake Erie (15.9 ha) and Lake Superior (39.2 ha) (Ingram et al. 2004). However, if the results from the MCWI are used to determine average wetland size the value drops to 1.4 ha (unfortunately values for the other Great Lakes taking into consideration wetlands under 2 hectares is not available for comparison).

Wetlands of a wide range of sizes can be important for local or regional biodiversity. For example, a small (<0.5 ha) seasonal ephemeral pond may be an important habitat feature for Blanding's and/or spotted turtles. These temporary wetlands are also likely to support a unique group of species (Snodgrass et al., 2000), hence increasing the diversity of assemblages of species in an area. These animals and invertebrates often respond to the short hydroperiod (length of time the wetland has standing water) and the absence of predatory or competing fish.

For marshes, even small units (e.g., 0.01 ha) may be important for breeding amphibians or as waterfowl habitat, in the latter case especially for springtime pairing and feeding where a series of small wetlands exist in an area (EC, 2006a). In addition, some species of wildlife have adapted to exploit a complex of wetlands in the landscape and will readily move between them to forage (e.g., eastern foxsnake, massasauga rattlesnake, northern harrier, and herons). This is the reason that the OWES recognizes the concept of wetland complexes.

Large swamps tend to have greater habitat heterogeneity (that is, the habitat is more varied within them), which in turn tends to support more species of wildlife (Golet et al., 2001). This effect can also be seen in marshes, and is often termed "interspersion" or the juxtaposition of different marsh communities (e.g., submerged versus emergent vegetation). High levels of habitat interspersion (i.e., open water/submerged vegetation, emergent vegetation and in some cases shrubs) within a marsh provide higher quality habitat for a wider variety of species than, for example, a narrow band of cattails around a shoreline. It must be emphasized that marshes are very dynamic systems, so the ratio of open water/submerged vegetation to emergent vegetation and the interspersion pattern, may vary considerably from year to year (EC, 2006a).

Coastal wetlands provide critical spawning and foraging habitat for fishes. Midwood (2012) notes that complex aquatic habitats support the highest levels of fish diversity and that this habitat structure is provided by aquatic macrophytes. Aquatic vegetation supports a variety of fish functions, including: spawning and nursery habitat, refuge from predators, shade and cooler temperatures, and as a substrate to support food sources (Midwood, 2012).

Midwood (2012) determined that while the vast majority of fishes remain in a single wetland throughout the year, northern pike use multiple wetlands over relatively large areas during the active season. Northern pike that frequented wetland areas tended to be young (2-5 years) and small (<600 mm). On average, these smaller northern pike moved among wetlands that were 1.4 km apart, although some moved as far as 3.9 km.

Since coastal marshes are directly connected to open water of lakes, wetland vegetation responds rapidly to changes in water level and water quality (Lougheed et al. 2001; Hudon, 2004; Chow-Fraser 2006). Expansion and contraction of floating and emergent vegetation due to fluctuating water levels has a direct impact on the amount of critical fish habitat in the coastal marshes of Georgian Bay. Between 1999 and 2008, water levels in Georgian Bay fluctuated at approximately 50 cm below the long-term average, and this has led to major shifts in the wetland plant community, from emergent and floating vegetation to increased meadow vegetation (Midwood and Chow-Fraser, 2012).

Ecosystem Services

Coastal wetlands have important ecological, economic and social functions and values. Those connected with the lake and tributary system perform important functions for Georgian Bay through their contributions to hydrology, deposition of sediments, particle entrapment, nutrient retention, storage and exchange to recipient waters. These wetland functions provide crucial societal values: water quality improvement, flood attenuation, shoreline protection, human food and recreational use, landscape diversity and carbon storage (Loftus et al., 2004).

A study on ecosystem services conducted by Constanza et al. (1997) estimated the global annual valuation of wetland ecosystem services to be $4.9 trillion dollars. Comparatively, the valuation for forests was $4.7 trillion and when we consider that forests are estimated to cover 26% of the Earth's terrestrial surface and wetlands as an entire group cover less than 1%, it becomes apparent that wetlands provide a disproportionally large number of ecosystem services.

Coastal wetland productivity is a source of nutrients and organic material for the lake food web. These wetlands sustain large numbers of common or regionally rare bird, mammal, herptile and invertebrate species, including many land-based species that feed in the highly productive marshes. A rich variety of amphibians and reptiles require these wetlands for breeding, development, foraging, hibernation and refuge (Hecnar et al., 2002). Important staging and nesting areas are provided for waterfowl and other avian species during the reproductive and migration seasons.

Many Great Lakes fish species depend upon coastal wetlands for some portion of their life cycles. Estimates on the number of fish species utilizing coastal wetlands for spawning, nurseries and food sources vary from 59 (Jude and Pappas, 1992) to over 90% of the approximately 200 fish species in the Great Lakes (Liskauskas et al., 2004).

2.6.4 What do the grades mean?

Although we can measure coastal wetland cover, there is no scientifically sound way to grade each region, because we lack historical data. However, the regional results in this report create a baseline for monitoring changes to coastal wetland cover in future report cards.

Some factors to consider when we track the total area of coastal wetlands are:

- How many wetlands did we historically have? How many do we have today?
- When water levels change, so do wetlands, so the results will vary year-to-year.
- It is not yet clear if sustained low water levels will result in a net loss of wetlands.
- Quality, and not just quantity, is important: is the total area of high quality wetlands changing?

It is recommended that future *State of the Bay* report cards develop a quantitative grading system.

2.6.5 What are the results?

Table 10: Coastal Wetland Cover Results

Region Name	Coastal Wetland Habitat Type	%	Total Coastal Wetland Cover %
McGregor Bay & Killarney	High marsh	0.4	2.5
	Low marsh	0.5	
	Upstream wetland	0.1	
	Unclassified	1.3	
French River *	High marsh	0.3	2.4
	Low marsh	0.7	
	Upstream wetland	0.4	
	Unclassified	1.0	
Britt	High marsh	0.6	3.3
	Low marsh	0.7	
	Upstream wetland	2.1	
Pointe au Baril	High marsh	0.9	5.4
	Low marsh	1.4	
	Upstream wetland	3.1	
Carling	High marsh	0.4	3.2
	Low marsh	0.9	
	Upstream wetland	1.9	
Parry Sound	High marsh	0.4	2.6
	Low marsh	0.7	
	Upstream wetland	1.4	
Massasauga & Sans Souci	High marsh	0.4	2.3
	Low marsh	0.9	
	Upstream wetland	1.0	
Twelve Mile Bay & Go Home Bay	High marsh	0.5	5.4
	Low marsh	0.8	
	Upstream wetland	4.0	
Cognashene	High marsh	0.3	2.7
	Low marsh	1.1	
	Upstream wetland	1.3	
Honey Harbour	High marsh	2.8	10.6
	Low marsh	6.5	
	Upstream wetland	1.3	
State of the Bay 2013 Average	High marsh	0.5	3.3
	Low marsh	1.0	
	Upstream wetland	1.7	
	Unclassified	0.1	

* French River values are incomplete (and the total cover percentage is lower than anticipated) due to data gaps in this region (as discussed in Section 2.6.2)

2.7 Wetland Macrophyte Index

2.7.1 What is measured?

The average Wetland Macrophyte Index (WMI) score of each region. This coastal wetland indicator provides a surrogate for wetland water quality and consequently the level of human impact; wetland macrophytes are directly influenced by water quality and impairment in wetland quality can be reflected by taxonomic composition of the aquatic plant community (Croft and Chow-Fraser, 2007).

2.7.2 How is it measured?

The WMI uses aquatic plants as an indicator of water quality. The WMI directly links the presence of certain groups of plants to the degree of human disturbance. Individual species are ranked based on their tolerance to degradation and their niche breadth. Based on the species composition in a wetland, these scores are tallied and an overall WMI score is calculated for a wetland.

The WMI score of a wetland can range from 1 to 5, based on the presence of plants in the various groups. In general, a low score (1 or 2) indicates the presence of certain plant taxa that are tolerant of high levels of human disturbance (i.e. excess nutrients and low water clarity) and a high score (4 or 5) of taxa that are intolerant of human disturbance. Wetlands with WMI scores below 2.5 can be considered impaired (moderately to highly degraded conditions) and may require restoration and other management interventions. Wetlands with WMI scores above 3.5 usually mean that the wetland is in good condition. To date, the maximum WMI score recorded was 4.10. This was found in Tadenac Bay, a fish and wildlife sanctuary in eastern Georgian Bay, which has been managed with minimal human disturbance since the late 1900s (Croft and Chow-Fraser, 2007).

2.7.3 Why is it important?

Aquatic Vegetation

Coastal marshes contain both terrestrial (on shore) and aquatic vegetation, which are plants that thrive in a flooded environment. This latter group is also called aquatic macrophytes and they dominate coastal marshes, providing habitat structure that facilitates many of the ecosystem services discussed above (Section 2.6.3). In aquatic ecosystems, macrophytes, along with algae, are the primary producers. They trap the sun's energy and make it available for other species. Macrophytes have developed special adaptations to living in wetlands that are prone to both draw-down and flooding. Unlike most terrestrial vegetation primarily relies on sexual reproduction, aquatic macrophytes typically reproduce asexually from plant fragments or parts of their rhizomes (Sawada et al. 2003). They also form overwintering buds, called turions, which sink to the bottom when the water freezes, and are capable of surviving droughts and low temperatures before rising again in the spring. Some remain in the wetland until favourable conditions return, and other colonize distant habitats by floating in currents or hitching a ride on boats, birds, and mammals. This is one reason that alien invasive macrophytes are difficult to eradicate once they become established in the Great Lakes (Midwood et al., 2011).

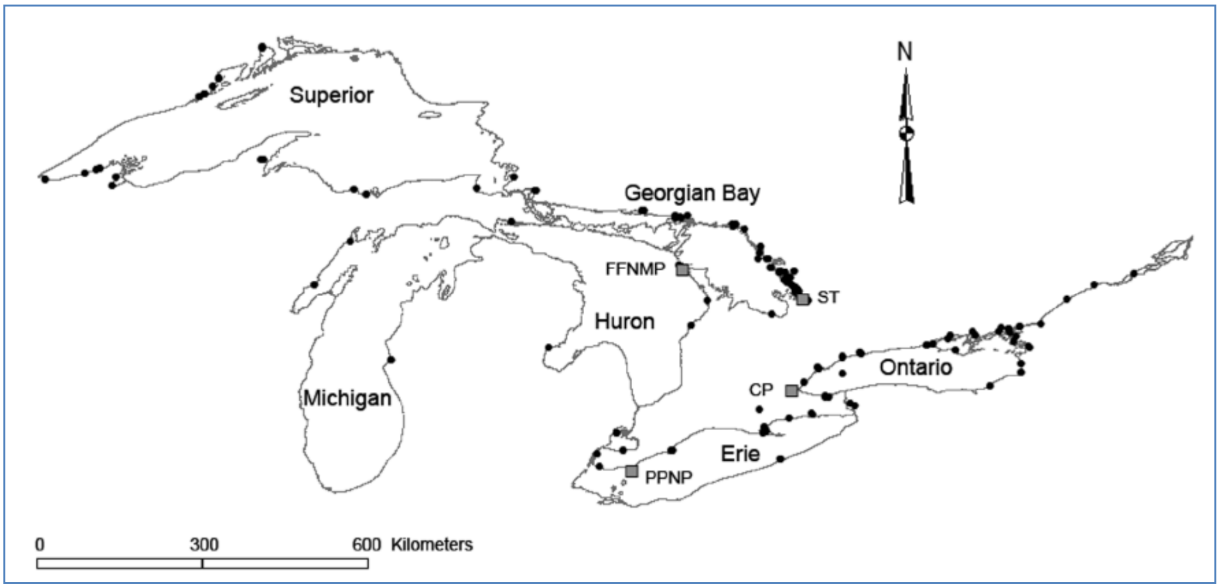
Relationship between the Wetland Quality Index (WQI) and Wetland Macrophyte Index

Wetland degradation in the Great Lakes basin has been attributed to a variety of human disturbances, including increased loading of nutrients and sediment from agricultural and urban development, introduction of invasive species, and shoreline development and recreational activities. The extent to which these factors contribute to marsh degradation depends on the type of wetland. For example, coastal marshes located at the mouth of rivers and estuaries are susceptible to altered land uses in their watersheds, and many in Lakes Ontario and Erie have become turbid, eutrophic systems limiting species composition of submergent macrophytes (Lougheed et al. 2001, McNair and Chow-Fraser 2003). Changes in the submergent community are known to affect communities of zooplankton, benthic invertebrates, and fish. Because water clarity and nutrient levels in coastal marshes have overriding influence on subsequent trophic levels, Chow-Fraser (2006) developed the water quality index (WQI) to measure the degree of degradation attributable to human activities. This index includes six categories that range from highly degraded (index score of –3) to excellent (index score of +3) and has been used successfully to rank 110 wetlands throughout the Great Lakes shoreline according to their degree of water quality impairment (Chow-Fraser, 2006). Cvetkovic and Chow-Fraser (2011) conducted a survey throughout the Great Lakes and found that coastal wetlands in eastern Georgian Bay have the best water-quality conditions, indicating that they have not been negatively impacted by human activities (Figure 39).

Despite the effectiveness of the WQI as a monitoring tool, the effort and costs required to measure all 12 water quality parameters (i.e., physical characteristics, various forms of major nutrients, suspended solids, and chlorophyll concentrations), renders it unlikely to be adopted by most environmental agencies and/or used as a public monitoring protocol (Midwood et al., 2011). Therefore Croft and Chow-Fraser developed the WMI in 2007 to provide a more cost effective and public friendly monitoring tool. Using plants (macrophytes) as a biotic indicator has a number of advantages. First, because wetland plants are essentially non-motile, their distribution can be georeferenced on each sampling occasion and changes in distribution can be tracked over time. Second, compared with fish surveys that require either an electrofishing boat or series of paired fyke nets, plant surveys can be accomplished without specialized and expensive equipment, and with only one or two trained personnel in waders and/or a canoe. Unlike fish and zoobenthos surveys that require overnight traps, most plant surveys can be completed in a day. Additionally, results are available immediately with limited need for further processing such as surveys for macroinvertebrates, zooplankton, or periphyton (Croft and Chow-Fraser, 2007).

The methodology for the development of the WMI is based on previous papers that relate zooplankton and fish to environmental variables using canonical correspondence analysis (CCA). The use of CCA to develop plant indices is prevalent in Europe (e.g., Dodkins et al. 2005), but has not been widely used in North America. The WMI assumes aquatic plants (all species growing obligately in flooded areas but excluding those typically associated with wet meadows) will respond directly (through competition for light and nutrients) or indirectly (through food-web interactions) to changes in water quality conditions. Croft and Chow-Fraser (2007) showed that response to the degree of water quality impairment is reflected in the taxonomic composition of the aquatic plant community. They validated the WMI by choosing two sites that have undergone rehabilitation as part of a Great Lakes remedial action plan (RAP) program (Cootes Paradise Marsh in the Hamilton Harbour RAP and Sturgeon Bay in the Severn Sound RAP, [Hartig 1993]), and for which there exist plant species lists corresponding to conditions before and after RAP initiatives. Two national parks were used as case studies to demonstrate the usefulness of the WMI in routine monitoring (Croft and Chow-Fraser, 2007).

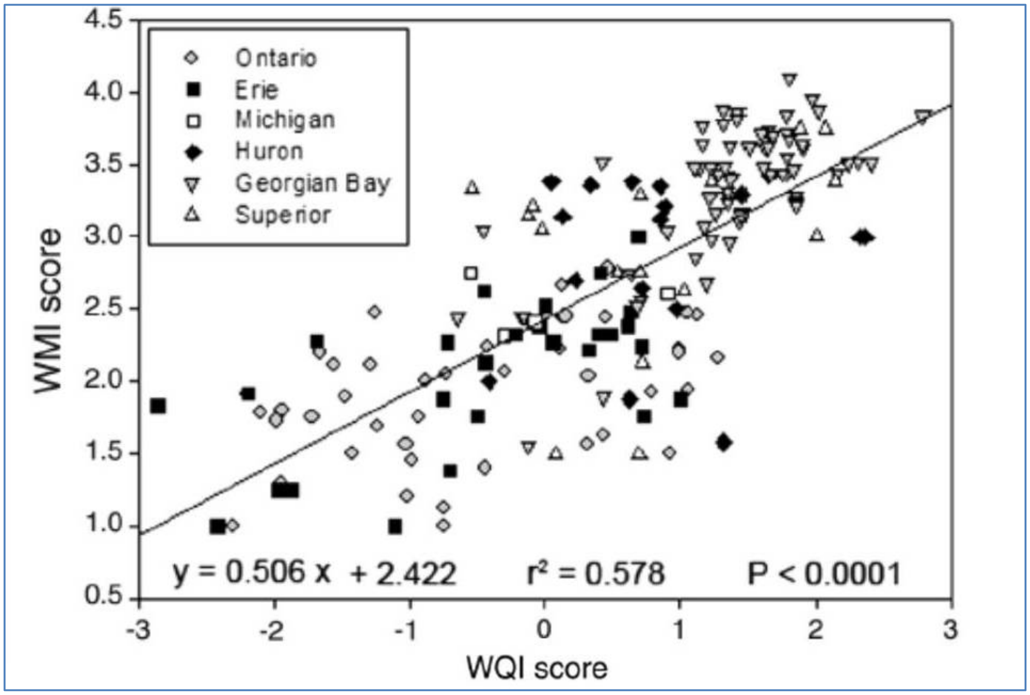
To quantify the extent to which WMI scores accurately reflected water quality conditions, Croft and Chow-Fraser (2007) regressed the WMI scores against corresponding WQI scores for 176 wetland-years (Figure 37) from their large database that had both water quality and plant information (Figure 38). They found a highly significant linear relationship between the two indices ($r2 = 0.57$, $P < 0.01$), indicating good correspondence between the presence/absence of plants and water quality conditions.



Location of the four study sites used for validation of the WMI are indicated by square symbols: FFNMP = Fathom Five National Marine Park, ST = Sturgeon Bay, CP = Cootes Paradise, and PPNP = Point Pelee National Park.

Source: Croft and Chow-Fraser, 2007.

Figure 37: Location of 176 wetland years used in the application of the WMI

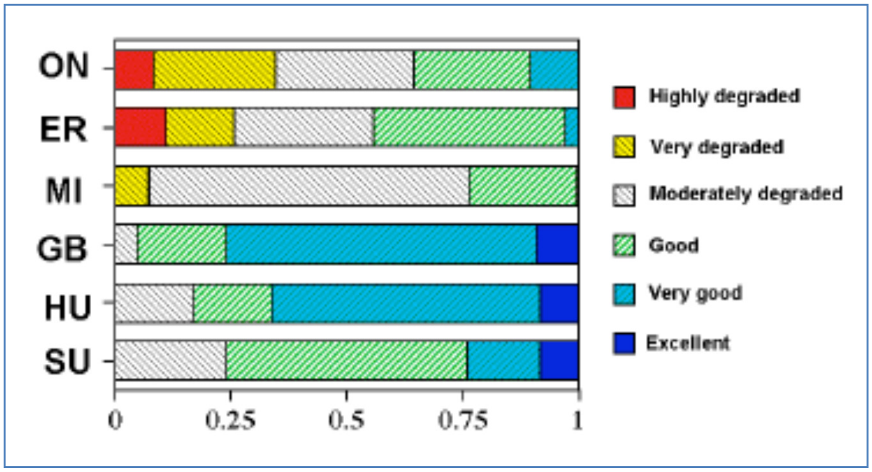


Source: Croft and Chow-Fraser, 2007.

Figure 38: Relationship between the WMI score and WQI score for 176 wetland-years grouped by lake

Factors Influencing Coastal Wetland Quality

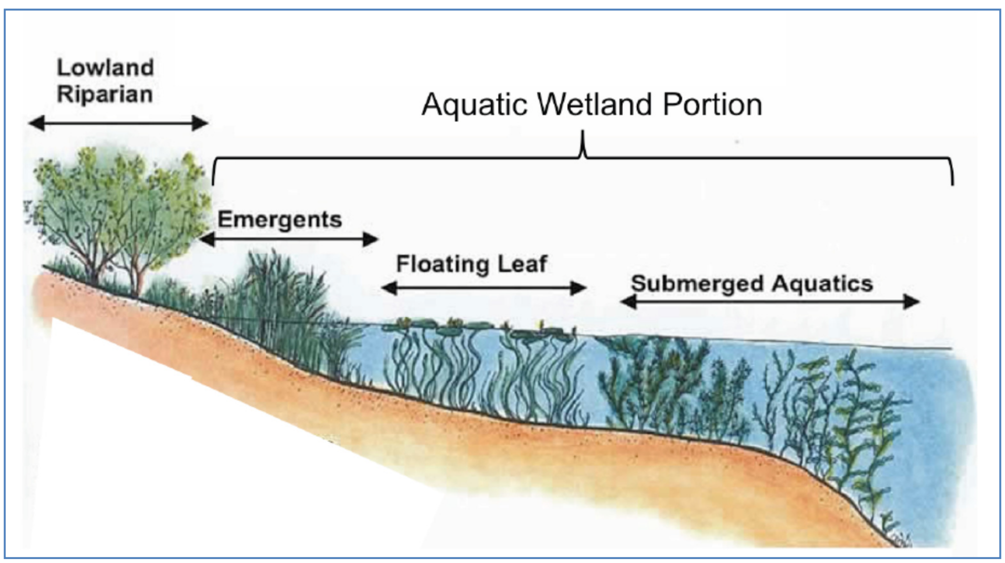
Cvetkovic and Chow-Fraser (2011) found that wetlands in Georgian Bay are some of the most pristine in the entire Great Lakes (Figure 39) and contain some of the greatest diversity of fish (Seilheimer and Chow-Fraser, 2007) and vegetation (Croft and Chow-Fraser 2007). This is largely due to limited human access to the Georgian Bay region and the mainly seasonal, recreational usage. Currently, the major threat to Georgian Bay coastal wetlands is changes to the natural water-level region and the forecasted future continuation of low water levels due to global climate change (Midwood et al., 2011).



Source: Chow-Fraser, Date unknown.

Figure 39: Wetland water quality scores among the Great Lakes

Coastal wetlands are dynamic systems, where a diversity of terrestrial and aquatic biota has alternated their dominance according to the natural 7-10 year cycles of water-level fluctuations in the Great Lakes. In years of high water, terrestrial vegetation dies back, and in years of low water levels, aquatic vegetation disappears (Keddy and Reznicek 1986; Figure 40). Without inter-annual water-level variation, either the aquatic or the terrestrial vegetation would dominate at the expense of the other. Since 1999, water levels in Lake Huron have been low and record lows were recorded in 2012. This stasis in water level has allowed terrestrial vegetation to move into coastal wetlands and there has been a net loss of aquatic habitat (Midwood and Chow-Fraser, 2012).



Source: www.aquatichabitat.ca

Figure 40: Common distribution of wetland plants in a coastal wetland. As water levels change, the plant community will shift in response.

Coastal wetlands of the Great Lakes exist at the interface between the terrestrial and aquatic ecosystems. Hydrologically connected either seasonally or permanently, these shallow marshes have diverse emergent and submergent vegetation that provide important spawning habitat for many species of the Great Lakes fish community (Jude and Pappas 1992).

There is well-documented evidence that land-use alteration in the watersheds of coastal wetlands can negatively affect their habitat quality (Crosbie and Chow-Fraser, 1999; Lougheed et al., 2001; Chow-Fraser, 2006). Agricultural and urban development is generally accompanied by a high nutrient and sediment load to the wetlands, leading to high algal production and increased water turbidity. These changes can cause an overall decrease in macrophyte abundance and diversity (Chow-Fraser et al., 1998). Submergent vegetation is crucial for piscivores (e.g., largemouth bass, *Micropterus salmoides*; northern pike, *Esox lucius*) and forage species (e.g., yellow perch, *Perca flavescens*; sunfish, *Lepomis* sp.; and cyprinids) because it provides structure for spawning, refugia for larvae and juveniles, and habitat for benthic and planktonic prey (Casselman and Lewis, 1996). The plants can also provide shade, reducing local temperature and making it suitable for many cool-water species. Any anthropogenic factor that degrades the overall habitat quality in coastal wetlands can cause a shift in the fishes toward more pollution-tolerant and less desirable assemblages (Brazner and Beals, 1997).

2.7.4 What do the grades mean?

The Wetland Macrophyte Index grades are:

- A > 3.75
- B 3.74 – 3.50
- C 3.49 – 2.50
- D – does not apply
- F < 2.50

The grading system was developed in consultation with Dr Pat Chow-Fraser of McMaster University. As discussed in Section 2.7.2 above, the WMI score of a wetland can range from 1 to 5. Wetlands with WMI scores below 2.5 can be considered impaired (moderately to highly degraded conditions) and may require restoration and other management interventions. Wetlands with WMI scores above 3.5 usually mean that the wetland is in good condition. While a score of 5 is the high end of the scale, a wetland will never record this value given that lower scores are provided for generalist species that are also found in pristine wetlands. To date, the maximum WMI score recorded was 4.10. This was found in Tadenac Bay, a fish and wildlife sanctuary in eastern Georgian Bay, which has been managed with minimal human disturbance since the late 1900s.

2.7.5 What are the results?

Table 11: Grades for WMI

Region Name	Average WMI Score	Grade
McGregor Bay & Killarney	3.27	C
French River	3.65	B
Britt	3.58	B
Pointe au Baril	3.52	B
Carling	3.64	B
Parry Sound	No data	-
Massasauga & Sans Souci	3.54	B
Twelve Mile Bay & Go Home Bay	3.71	B
Cognashene	3.76	A
Honey Harbour	3.34	C
State of the Bay 2013 Average	3.56	B

2.8 Coastal Wetland Cover and Wetland Macrophyte Index

2.8.1 What can I do to help?

Join the Adopt-A-Pond Program

The Adopt-A-Pond wetland conservation program is run by the Toronto Zoo and provides educators, students and community groups with stewardship resources and educational opportunities to protect, restore and conserve wetland habitats and biodiversity. Adopt-A-Pond has five major off-site initiatives. Georgian Bay residents and visitors are encouraged to participate in three initiatives to help protect wetlands and monitor wildlife: Ontario Turtle Tally; Frogwatch Ontario; and the Wetland Guardians Registry.

The purpose of Ontario Turtle Tally is to collect, record and store location and species information on turtles, including species at risk. *Frogwatch Ontario* is a fun, easy amphibian monitoring project for people of all ages. It's a great activity for schools, families, landowners, cottagers, and community and naturalist groups across the province.

By joining the Wetland Guardians Registry, participants can "adopt" a local wetland by entering it into a Canada-wide registry database. The registry is a cumulative account of wetland protection resources for landowners, school and community groups. Participants register a wetland by filling in fields such as wetland description, wetland protection or restoration efforts, methods, results, and funding sources.

Please visit these websites for more information:

- www.torontozoo.com/adoptapond/
- http://adoptapond.wordpress.com/

Join the Volunteer Aquatic Plants Survey (VAPS) Program

Due to the critical role that coastal wetlands play, it is important to monitor these wetlands and watch for major changes that could negatively impact the biotic community. The goal of the VAPS program is to have people in the community take a personal interest in the health of their local wetlands and to make regular reports on the species of aquatic plants they find in these coastal marshes.

The survey is only required once per year, when most aquatic plants have flowered (late July to early September), and it seldom takes more than 3 to 4 hours (usually less than 2 hours) to complete. A thorough survey of a site requires the selection of up to ten quadrants (sampling points) that will be surveyed by canoe or wading. At each location, the participant will survey plants within one meter on either side of the canoe or where they're standing. Participants are encouraged to choose sections that contain a variety of wetland plants: some in deeper open water, some along the shore, and others within the lily pads. Here's what you'll need to conduct a survey:

- Canoe, kayak or rowboat.
- Chest waders or rubber boots.
- VAPS monitoring protocol (available from Dr Pat Chow-Fraser, chowfras@mcmaster.ca).
- Survey data sheet (available from: www.gbbr.ca/about-us/documents).
- A pencil (pen may not write well on wet paper).
- If the water is too deep or murky to identify some plants, you may need a garden rake or pike pole to bring the plants to the surface.

Once the VAPS is completed, participants can either enter it online or send the data via snail mail:

- http://wirenet.mcmaster.ca/indicators/calaculator.php, where you will find a link to the "WMI Form" that is used to enter your data and calculate a score for your wetland.
- Dr Pat Chow-Fraser, McMaster University, 1280 Main St West, LSB 224, Hamilton, ON, L8S 4K1

Please visit these websites for more information:

- http://urbanmonitoring.ca/learn/field-work-prep/wetlands/wetland-plants/
- http://urbanmonitoring.ca/results/

2.8.2 Data gaps and research needs

In summary, the data gaps and research needs with respect to the Coastal Wetland Cover and WMI indicators are:

1. The MCWI was unable to acquire appropriate imagery to fill one small gap in northern Georgian Bay (Figure 34). Based on field experience in this area, the MCWI team know that wetlands exist (in these gaps) and therefore the estimate in this report should be considered a slight underestimate of the actual amount of coastal wetland habitat in northern Georgian Bay. Future efforts should be made to fill this gap with some other satellite media of the same vintage. Relative to the remainder of the shoreline in eastern and northern Georgian Bay, this gap in imagery amounts to only a small fraction of the shoreline and should be relatively easy to update as soon as appropriate imagery has been acquired (Midwood, 2012).

2. The MCWI team are of the opinion that the inventory in its current form provides a useful and comprehensive tool that should be adopted and utilized by conservation managers, but feel that it can be improved with further enrichment. First, wetlands identified by the inventory need to be grouped into ecologically relevant complexes in accordance with the complexing rules outlined in the OWES or with suitable modifications. Secondly, it is recommended that satellite imagery be acquired every five years for a statistically valid subset of the MCWI. This will allow researchers and managers to track general trends in areal wetland coverage change as water levels fluctuate (Midwood, 2012).

3. It is recommended that future *State of the Bay* report cards develop a quantitative grading system for coastal wetland cover. Although we can measure coastal wetland cover, there is no scientifically sound way to "grade" each region, because we lack historical data. However, the regional results in this report create a baseline for monitoring changes to coastal wetland cover in future report cards.
   Some factors to consider when we track the total area of coastal wetlands are:
   - How many wetlands did we historically have? How many do we have today?
   - When water levels change, so do wetlands, so the results will vary year-to-year.
   - It is not yet clear if sustained low water levels will result in a net loss of wetlands.
   - Quality, and not just quantity, is important: is the total area of high quality wetlands changing?

3 Water Levels

3.1 Introduction

Water levels on Lake Huron, which includes Georgian Bay, are always changing and result in dynamic shoreline conditions by influencing natural processes. Natural shoreline habitats, such as coastal wetlands, also change over time in response to fluctuating water levels. Water level changes occur over a variety of times scales including short-term (less than an hour to several days), seasonal (one year), and long-term (multi-year). Seasonal and long-term changes in Lake Huron water levels reflect a balance between the amount of water entering and leaving the lake. Water enters the lake from precipitation falling directly on the Lake Huron surface, inflow from Lake Superior through the St. Marys River, and runoff from the surrounding watershed. Water primarily leaves the lake through evaporation from the Lake Huron surface and outflows through the St. Clair River. The Chicago diversion also makes up a small portion of the water leaving the lake. Natural variability and human-induced changes influence the individual water balance components and contribute to the timing and magnitude of fluctuations in lake levels that are observed.

In January 2013, the monthly average water level on Lake Michigan-Huron established an all-time low level, below the previously recorded all time low recorded in 1964 (based on records beginning in 1918). Seasonal outlooks indicate that water levels may continue to set new record lows. The current record-setting low water levels on Lake Michigan and Huron are thought to be the result of two main factors: 1) climate change impacts leading to a large decrease in water supplies on the upper Great Lakes and increases in overlake evaporation; and 2) post 1960s dredging erosion in the St. Clair River and a minor contribution from glacial isostatic adjustment.

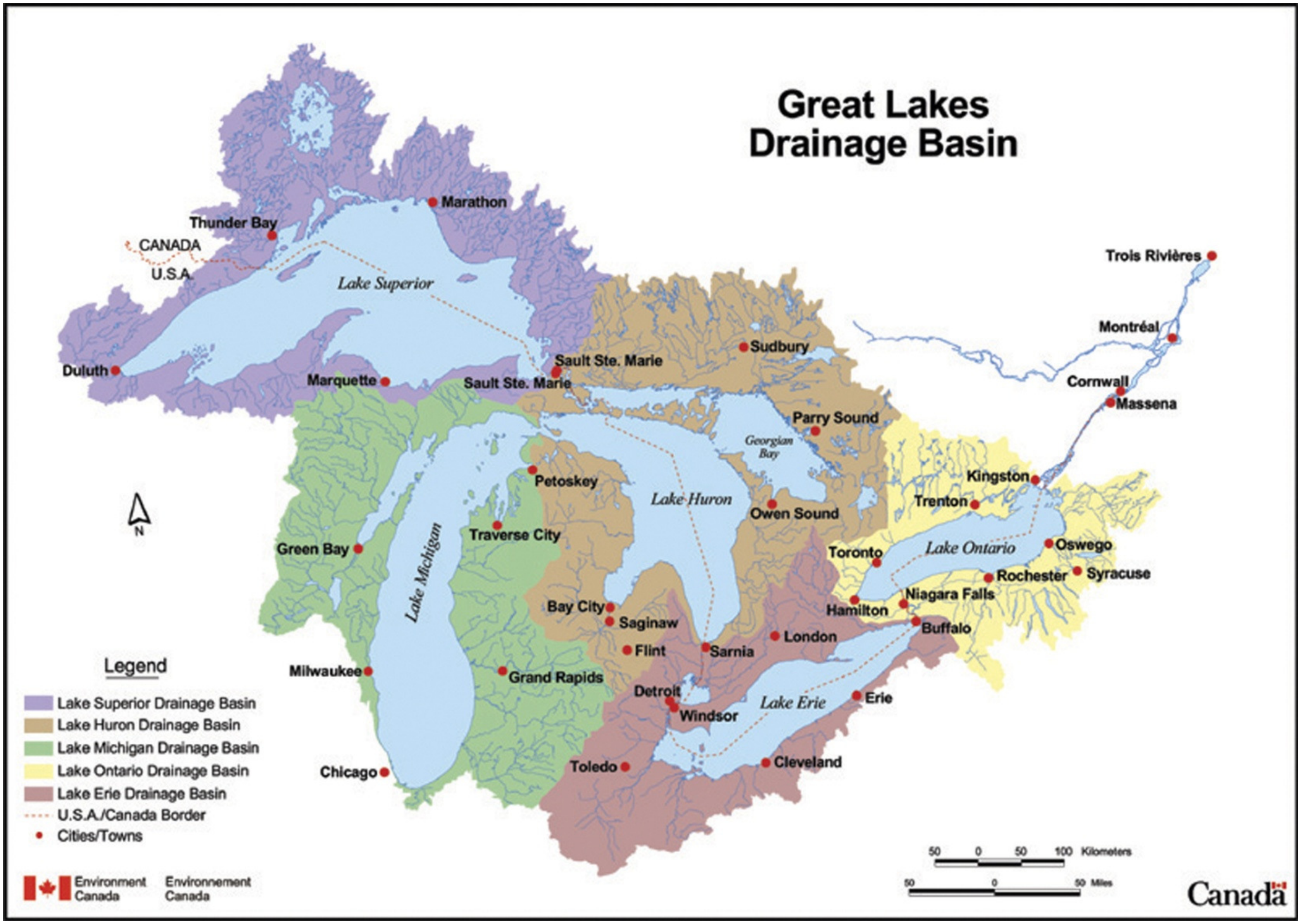
In 2007, the IJC launched a five-year investigation of low water on levels in the upper Great Lakes, which was conducted by the bi-national International Upper Great Lakes Study. The investigation was established to examine a recurring challenge in the upper Great Lakes system: how to manage fluctuating lake levels in the face of uncertainty over future water supplies to the basin while seeking to balance the needs of those interests served by the system. The geographical scope of the Study was the upper Great Lakes basin, from the headwaters of Lake Superior downstream through lakes Michigan, Huron, St. Clair and Erie and the connecting channels (the St. Marys, St. Clair and Detroit rivers, the Straits of Mackinac and the upper Niagara River).

The first phase of the investigation examined the physical processes and possible ongoing changes in the St. Clair River and the effects of such changes on the levels of Lake Michigan-Huron. The second part of the investigation focuses on the formulation and evaluation of options for a new regulation plan for Lake Superior. After reviewing the recommendations made by the International Upper Great Lakes Study Board, the IJC (2013) provided advice to the Governments of Canada and United States. Some of the recommendations include: 1) The Commission recommends that the Governments undertake further investigation of structural options to restore water levels in Lake Michigan-Huron by 13 to 25 cm; 2) The Commission supports the Study Board recommendation that multi-lake regulation not be pursued at this time; and 3) The Commission agrees with the Study Board recommendation to adopt Lake Superior Regulation Plan 2012 to replace Plan 1977A.

3.2 The Great Lakes

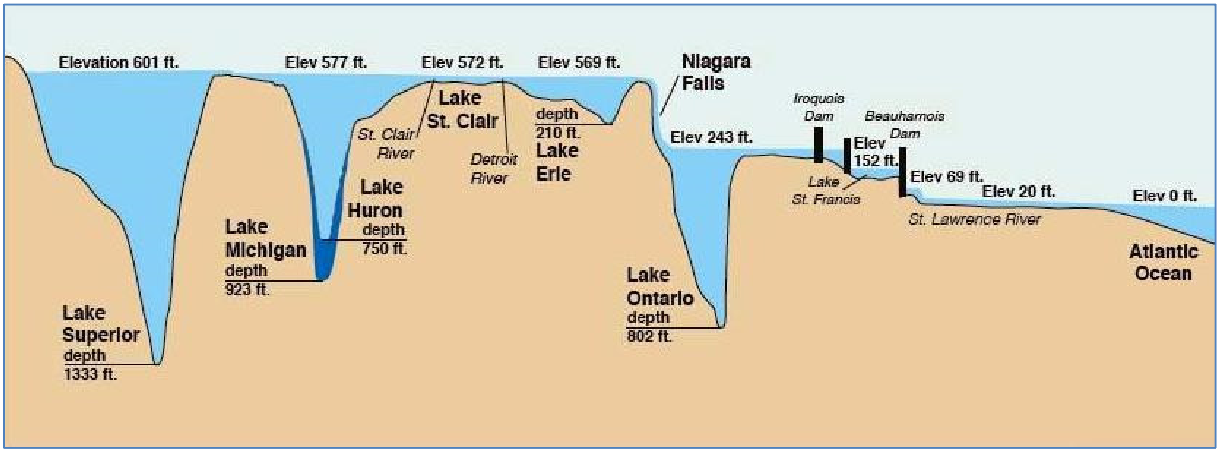
The Great Lakes Basin comprises the watersheds that drain into the Great Lakes and their connecting channels (Figure 41). The Great Lakes basin covers approximately 774,000 km^2. The lakes cover about 32% of the basin and contain about 23,000 km^3 of water (84% of North America's surface fresh water) (EC, 2010).

The Great Lakes-St. Lawrence River System consists of a chain of lakes and outlet channels. The excess waters from one lake drain through its outlet channel into the next lower lake downstream in the system, or, in the case of Lake Ontario, through the St. Lawrence River to the Atlantic Ocean (Figure 42).



Source: www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=03B3F448

Figure 41: Great Lakes drainage basin



Source: http://mff.dsisd.net/Environment/greatlakes.htm

Figure 42: Great Lakes profile

Water level elevations are based on International Great Lakes Datum 1985 (IGLD 1985). IGLD requires updating about every 30 years because the land surface around the Great Lakes is constantly changing in elevation due to the 'bounce back' of the earth's crust following the retreat of the glaciers during the last ice age (also referred to as glacial isostatic adjustment or isostatic rebound). IGLD 1985 was implemented in January 1992 and replaced the previous system, IGLD 1955. The zero for IGLD 1985 is located at Rimouski, Quebec, at the mouth of the St. Lawrence River; water level elevations in the Great Lakes-St. Lawrence River System are measured above mean water level at this site (CHS, 2010c). For an explanation on chart datum please visit:

- www.waterlevels.gc.ca/C&A/datums_e.html

Lake Superior is the uppermost lake, with a chart datum elevation of 183.2 metres, and discharges water through the St. Marys River into Lake Huron. In the upper portion of the river, for the first 22 km, the level of the river falls about 0.1 metre. Through the St. Marys Rapids, a distance of about 1 km, the river falls about 6.5 metres. The remaining fall of about 0.6 metre is on the lower river between the rapids and Lake Huron. A control dam, locks and hydro diversions have regulated the discharge from Lake Superior since 1921 (CHS, 2010b).

Lakes Michigan and Huron are connected by the broad and deep Straits of Mackinac and are treated as one lake for hydrologic and hydraulic considerations. Chart datum on both lakes is 176.0 metres. These lakes discharge through the St. Clair River, which falls 1.6 metres to Lake St. Clair (chart datum of 174.4 metres), and the Detroit River, which falls 0.9 metre to Lake Erie (chart datum of 173.5 metres). The flows on the St. Clair-Detroit River system are dependent on the levels of both the upstream and downstream lakes (CHS, 2010b).

The natural outlet from Lake Erie is through the Niagara River to Lake Ontario, which is about 99 metres lower than Lake Erie. About 95 metres of the elevation drop occurs between the head of the Cascades upstream of Niagara Falls to the Lower Rapids about 10 km downstream of the Falls. A control structure between the Canadian shore and Goat Island is used to maintain the level in the Chippawa Grass Island pool for power generation and to provide the required minimum flow over the Falls. This structure is not used to regulate the level of Lake Erie (CHS, 2010b).

Lake Ontario, with a chart datum of 74.2 metres, is the lowest of the Great Lakes. The outflow from Lake Ontario has been regulated since 1960 with the completion of the control works on the St. Lawrence River for the St. Lawrence Seaway and Power Project. From Lake Ontario, the river drops about 1.7 metres to Lake St. Lawrence, a man-made lake formed behind hydro-electric and control dams upstream of Cornwall. The flows out of Lake Ontario and into Lake St. Lawrence are moderated by the control structure and lock at Iroquois (CHS, 2010b).

The river drops about 26 metres at these dams and the Eisenhower and Snell Locks, then flows into Lake St. Francis which has a chart datum of about 46 metres. Through a series of lakes, navigation channels and locks, the river drops to Montreal, with a chart datum of 5.6 metres at Jetty Number 1. In the 272 km between Montreal and Quebec City, the river fall about 7.5 metres, to a chart datum in Quebec City of -2.0 metres IGLD 1985 (CHS, 2010b).

3.3 Fluctuations in Water Levels

There is a major tendency to think of Great Lakes water levels in terms of extremes rather than of normal conditions. However, more than a century of records in the Great Lakes basin indicate no regular, predictable cycle (Figure 43 to Figure 46). There were record low water levels during the late 1920s and 1930s and again in the mid-1960s. Record high levels were seen in the early 1950s, in 1973, and again in 1985-1986. In the late 1990s, a nearly 30-year period of above-average water level conditions in the upper Great Lakes ended. Over the last 10 years, Lake Michigan-Huron and Lake Superior have experienced lower than average lake level conditions, with Lake Superior establishing record lows in August and September of 2007.

Water levels can also reverse quickly. For example, lake levels dropped from very high to very low levels in a matter of about two years from 1986 to 1988 and again from 1997 to 1998. In 2009, there was a slight recovery of water levels on Lake Michigan-Huron and Lake Superior, though they remained well below long-term averages.

Data for water level measurements on the Great Lakes are available only since about 1860, though there are questions about the reliability and comparability of some older data, given the various types of measurement used over the years. Therefore the majority of historic water level charts have a start date of 1918, when water level data was collected following a standardized protocol (thus facilitating a comparison of data to current times) (EC, 2006b).

Water levels have been measured for at least one gauge on each of the Great Lakes since about 1860, though there is greater uncertainty about the reliability and comparability of some older data given variations in the timing, frequency, and types of measurements used over the years. A coordinated water level dataset is available from 1918 to present for each of the Great Lakes. This dataset provides lakewide average monthly water levels using a consistent set of gauges on each lake and ensuring comparability in the methods, timing, and frequency of water level measurements. The use of gauges on each lake reflects efforts to account for glacial isostatic adjustment over time and the differences in short-period water level changes at various locations around the lake shoreline. The coordinated dataset facilitates a comparison of long term water level conditions on each of the Great Lakes (EC, 2006b).

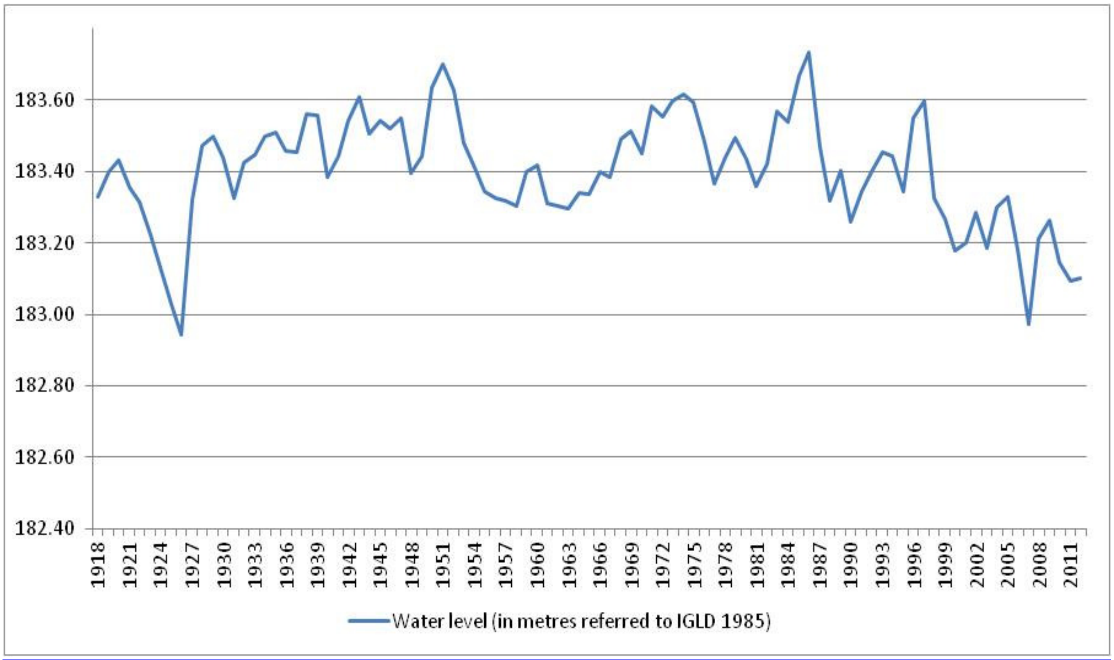
Fluctuations in water levels in non-tidal areas are the result of several natural factors and may also be influenced by human activities. These factors operate on a time-scale that varies from hours to years. The levels of the Great Lakes depend on their storage capacity, outflow characteristics of the outlet channels, operating procedures of the regulatory structures, and the amount of water supply received by each lake. The primary natural factors affecting lake levels include precipitation on the lakes, run-off from the drainage basin, evaporation from the lake surface, inflow from upstream lakes, and outflow to the downstream lakes. Man-made factors include diversions into or out of the basin, consumption of water, dredging of outlet channels and the regulation of controls/outflows (CHS, 2007).

3.3.1 Long-term Fluctuations

Long-term fluctuations result from persistent low or high net basin supplies (net basin supply = net water supply in the basin resulting from precipitation on the Lakes' surfaces, runoff from their tributary drainage areas, groundwater flow into or out of the Lakes, and evaporation). They result in extremely low levels such as those currently observed on Lake Huron, as well those recorded on some lakes during the late 1920s and 1930s, and the mid-1960s, or in extremely high levels such as the early 1950s, 1973 and 1985-86 (CHS, 2007).

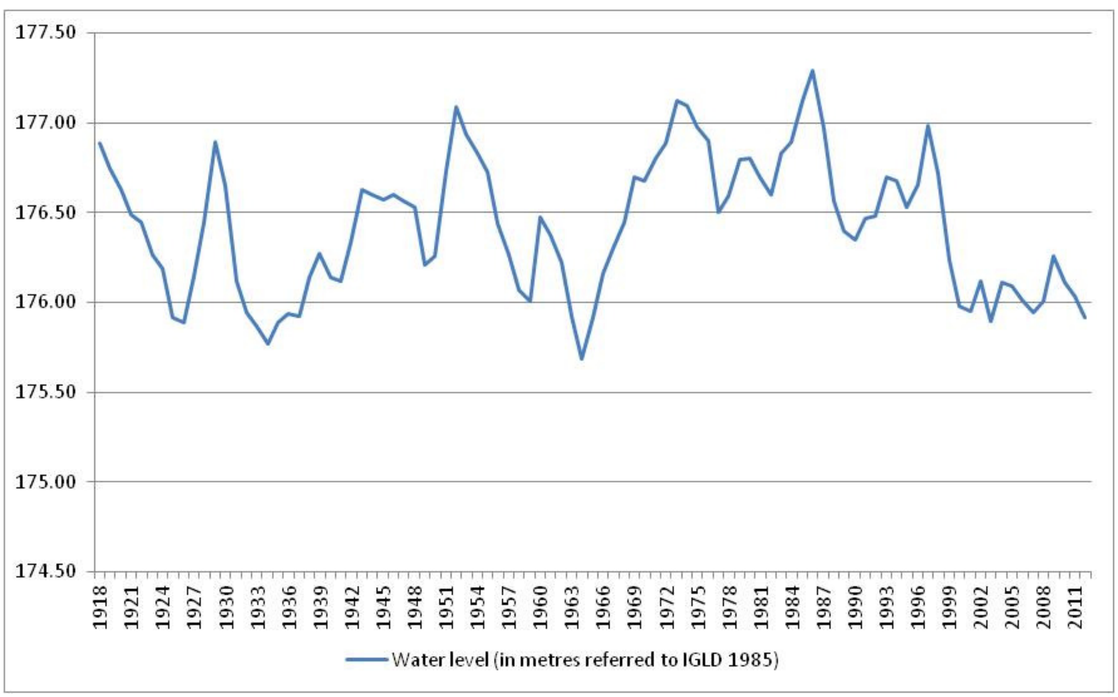
Highest levels occur during periods of abundant precipitation and lower temperatures that decrease evaporation. During periods of high lake levels, storms cause considerable flooding and shoreline erosion, which often result in property damage. Much of the damage is attributable to intensive shore development, which alters protective dunes and wetlands, removes stabilizing vegetation, and generally reduces the ability of the shoreline to withstand the damaging effects of wind and waves. During periods of low lake levels erosion to shoreline structures can occur due to the undercutting action of waves and increased rotting of foundation cribbing that was historically constructed of wooden timbers (EPA, 1995).

No precise patterns in fluctuating water levels are evident in the data records of the past century. The intervals between periods of high and low levels and the length of such periods can vary widely and erratically over a number of years, and only some of the lakes may be affected. The maximum recorded range of monthly water-levels, from extreme high to extreme low, have varied from 1.2 metres for Lake Superior to over 1.8 metres for the other lakes. The ranges of levels on Lakes Michigan-Huron, Erie and Ontario reflect not only the fluctuation in supplies from their own basins, but also the fluctuations of the inflow from upstream lakes (CHS, 2007).



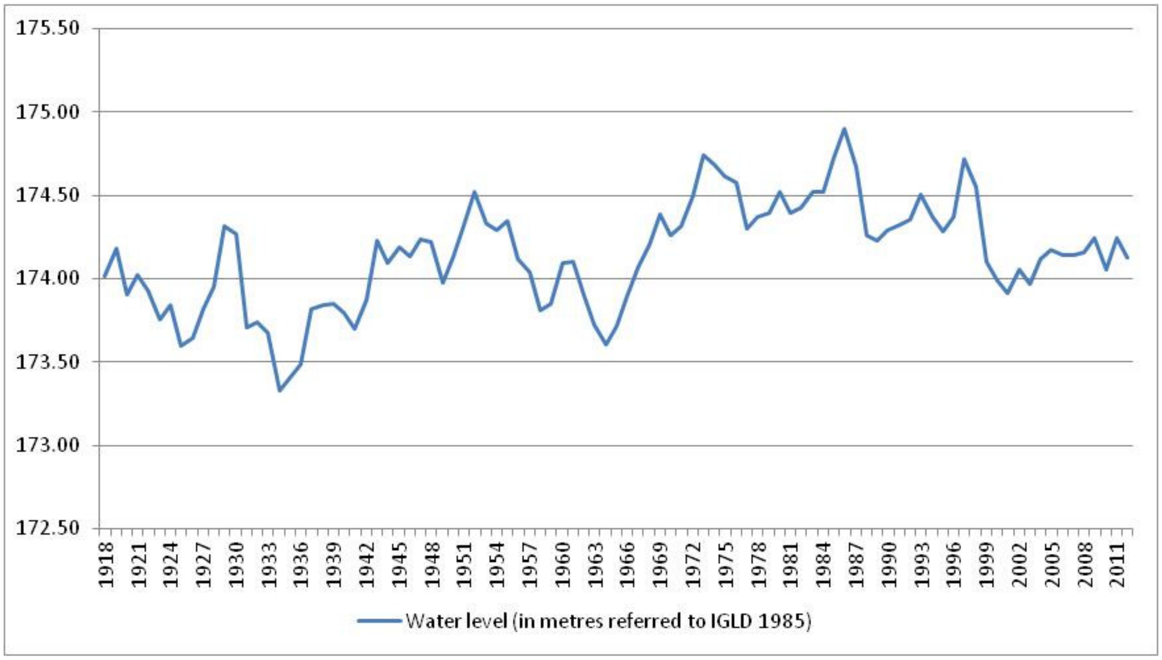
Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html

Figure 43: Average annual water level recorded on Lake Superior for the period 1918 to 2012



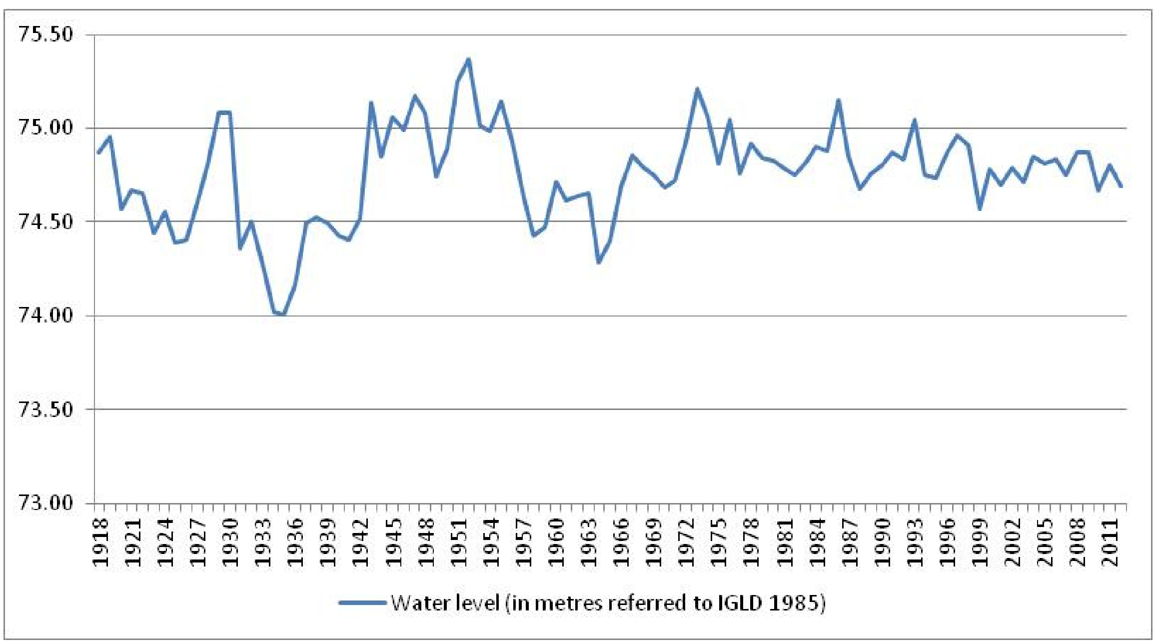
Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html

Figure 44: Average annual water level recorded on Lake Huron-Michigan for the period 1918 to 2012



Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html

Figure 45: Average annual water level recorded on Lake Erie for the period 1918 to 2012



Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html

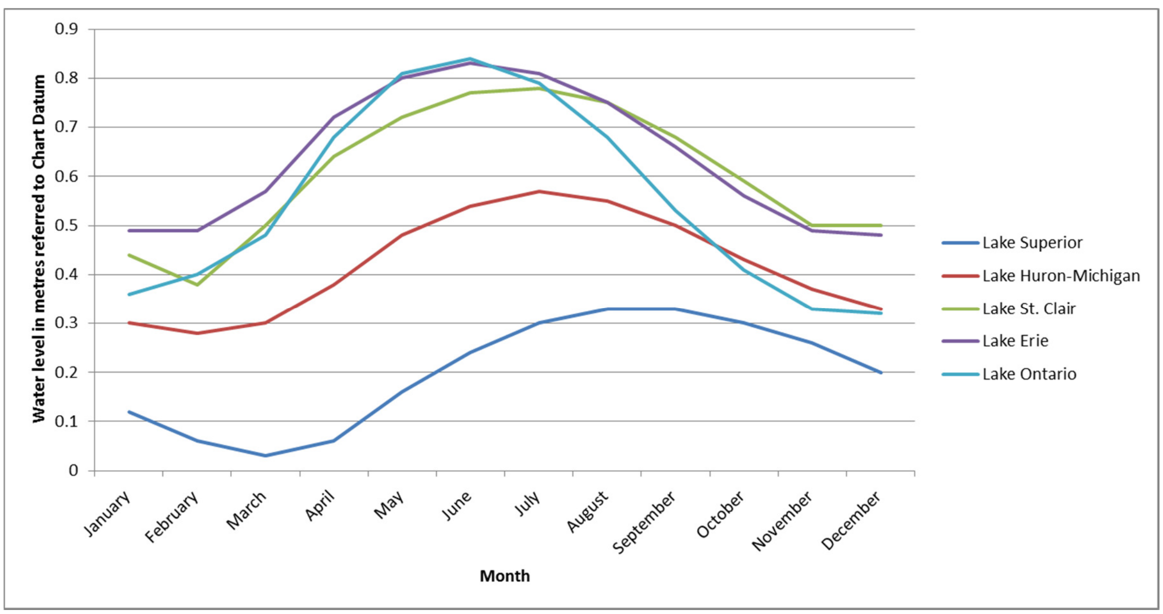
Figure 46: Average annual water level recorded on Lake Ontario for the period 1918 to 2012

3.3.2 Seasonal Fluctuations

Seasonal fluctuations of the Great Lakes levels reflect the annual hydrologic cycle. Generally, the lowest levels occur in winter when much of the precipitation is locked up in ice and snow on land, and dry winter air masses pass over the lakes enhancing evaporation. Levels are highest in summer after the spring thaw when runoff increases (EPA, 1995).

The maximum lake level usually occurs in June on Lakes Ontario and Erie, in July on Lakes Michigan-Huron, and in August on Lake Superior. The minimum lake level usually occurs in December on Lake Ontario, in February on Lakes Erie and Michigan-Huron, and in March on Lake Superior. Based on the monthly average water levels, the magnitudes of seasonal fluctuations are quite small, averaging about 0.4 metres on Lakes Superior, Michigan and Huron, about 0.5 metres on Lake Erie, and about 0.6 metres on Lake Ontario. However, in any one season it has varied from less than 0.2 metres to more than 0.6 metres on the upper lakes, from less than 0.3 metres to more than 0.8 metres on Lake Erie and from 0.22 metres to 1.10 metres on Lake Ontario. These fluctuations are essential in maintaining healthy biodiversity in coastal wetland ecosystems (CHS, 2007).

Figure 47 illustrates a plot of the average (for the period 1918 to 2000) monthly mean water level shows the features mentioned above for each of the Great Lakes.

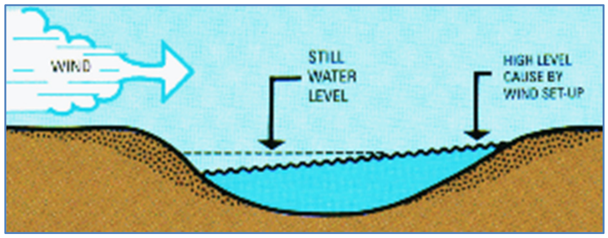


Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html

Figure 47: Monthly mean water levels of the Great Lakes from 1918 to 2012

3.3.3 Short-term

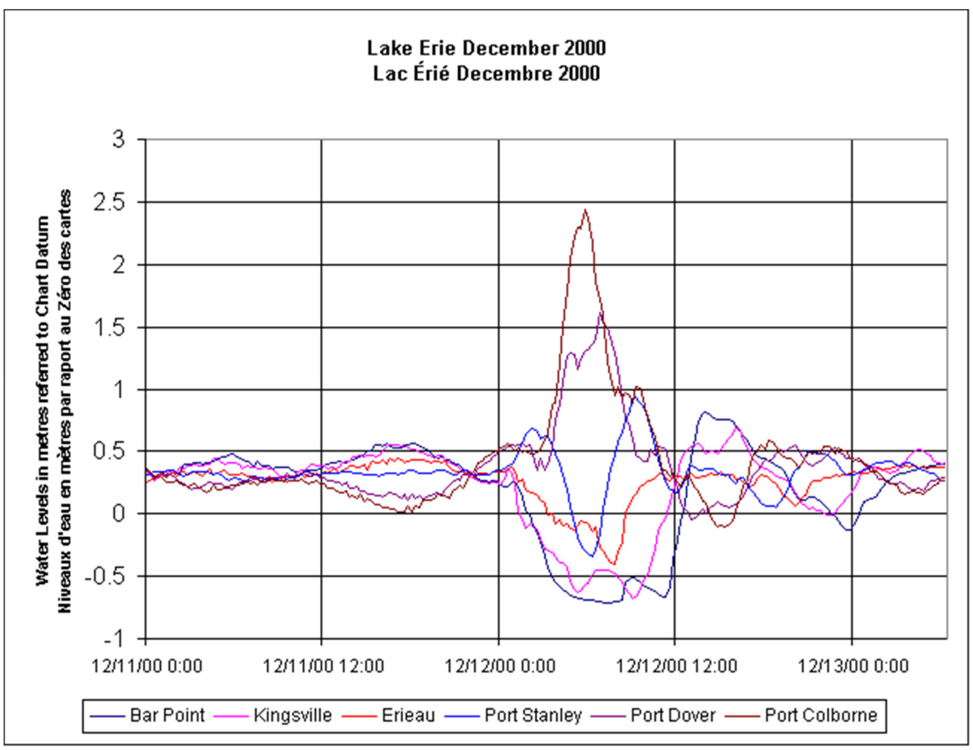
Short-term fluctuations, lasting from a less than an hour to several days, are caused by meteorological conditions. The effect of wind and differences in barometric pressure over the lake surface create temporary imbalances in the water level at various locations (Figure 2). Storm surges are largest at the ends of an elongated basin, particularly when the long axis of the basin is aligned with the wind. In deep lakes such as Lake Ontario, the surge of water level rarely exceeds 0.5 metre, but in shallow Lake Erie, water-level differences from one end of the lake to the other of more than 5 metres have been observed. Although the range of fluctuations may be large, there are only minor changes in the volume of water in the lake. A 'seiche' is the free oscillation of water in a closed or semi-closed basin; it is frequently observed in harbours, bays, lakes and in almost any distinct basin of moderate size (CHS, 2007).



Source: www.epa.gov/glnpo/atlas/glat-ch2.html#Lake%20Levels

Figure 48: Wind Set-up is a local rise in water caused by winds pushing water to one side of a lake

A plot of hourly water level for three days, from December 11 to 13, 2000, at six gauging stations on the north shore of Lake Erie shows the water level fluctuations caused by storms. The Bar Point gauge is located at the mouth of the Detroit River, Kingsville is in the western basin, Erieau and Port Stanley are in the central basin, Port Dover and Port Colborne are in the eastern basin (CHS, 2007).



Source: www.waterlevels.gc.ca/C&A/fluctuations_e.html#TC11

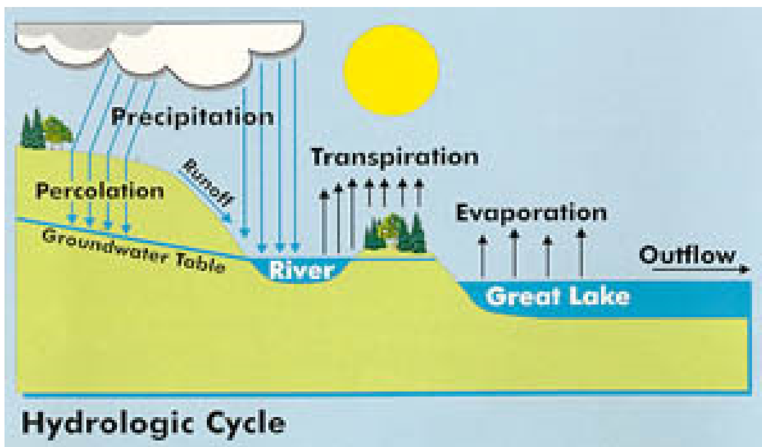
Figure 49: Plot of short-term fluctuations on Lake Erie

3.4 Factors Affecting Lake Levels

Natural variability and human-induced changes influence the individual water balance components and contribute to the timing and magnitude of fluctuations in lake levels that are observed. Natural factors affecting lake levels are presented in Section 3.4.1 and Section 3.4.2 discusses human-induced changes.

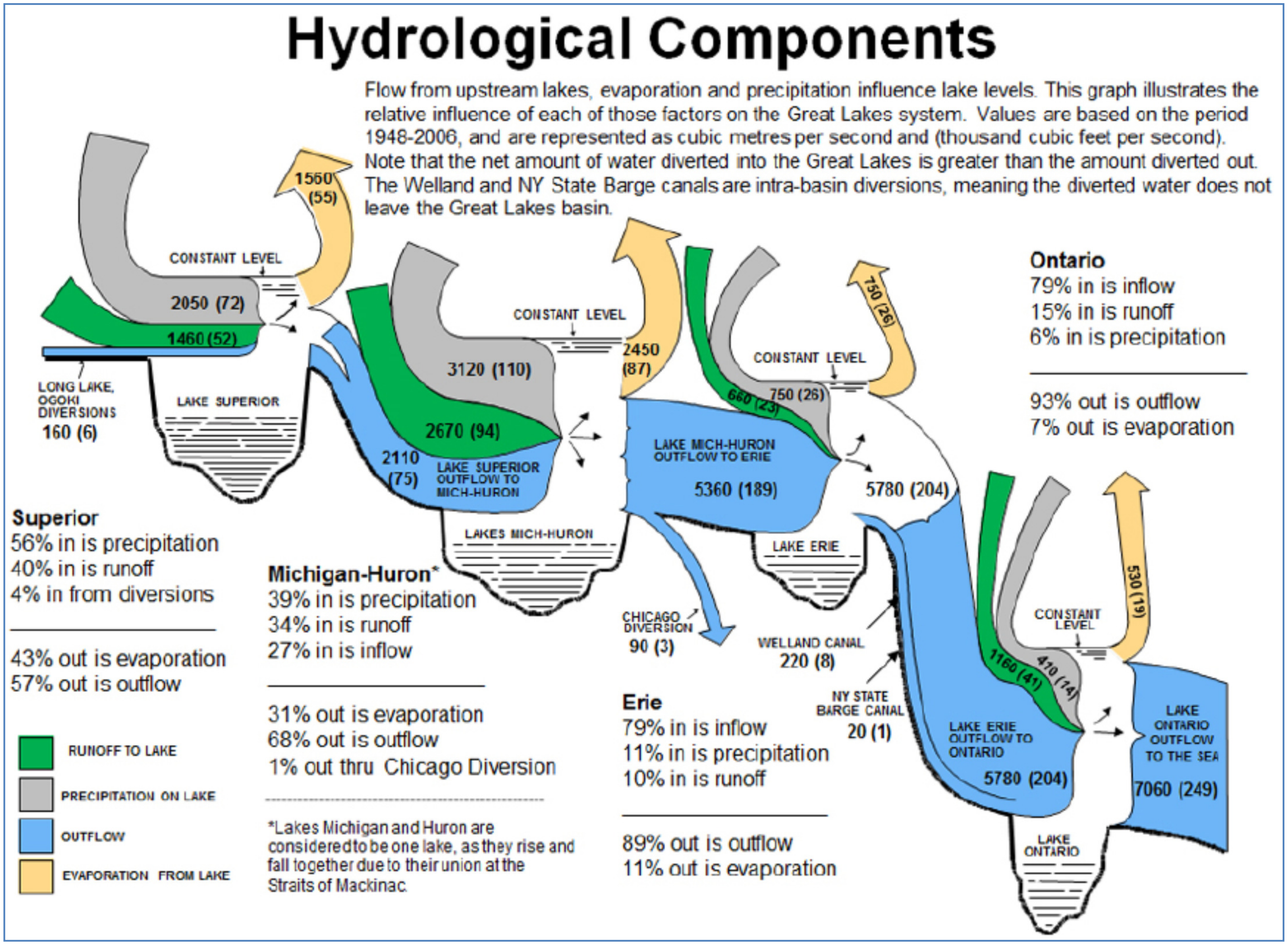
3.4.1 Natural Factors Affecting Lake Levels

The natural factors that affect water level fluctuations include: precipitation, evaporation, runoff, groundwater, ice retardation, aquatic growth, meteorological disturbances, tides, crustal movements, and meteorological disturbances. Figure 50 illustrates the natural inputs and outputs that comprise the hydrologic cycle. Figure 51 illustrates the relative influence of flow from upstream lakes, evaporation, and precipitation on lake levels.



Source: www.kalkaskacounty.net/planningeduc0026.asp

Figure 50: Hydrologic cycle



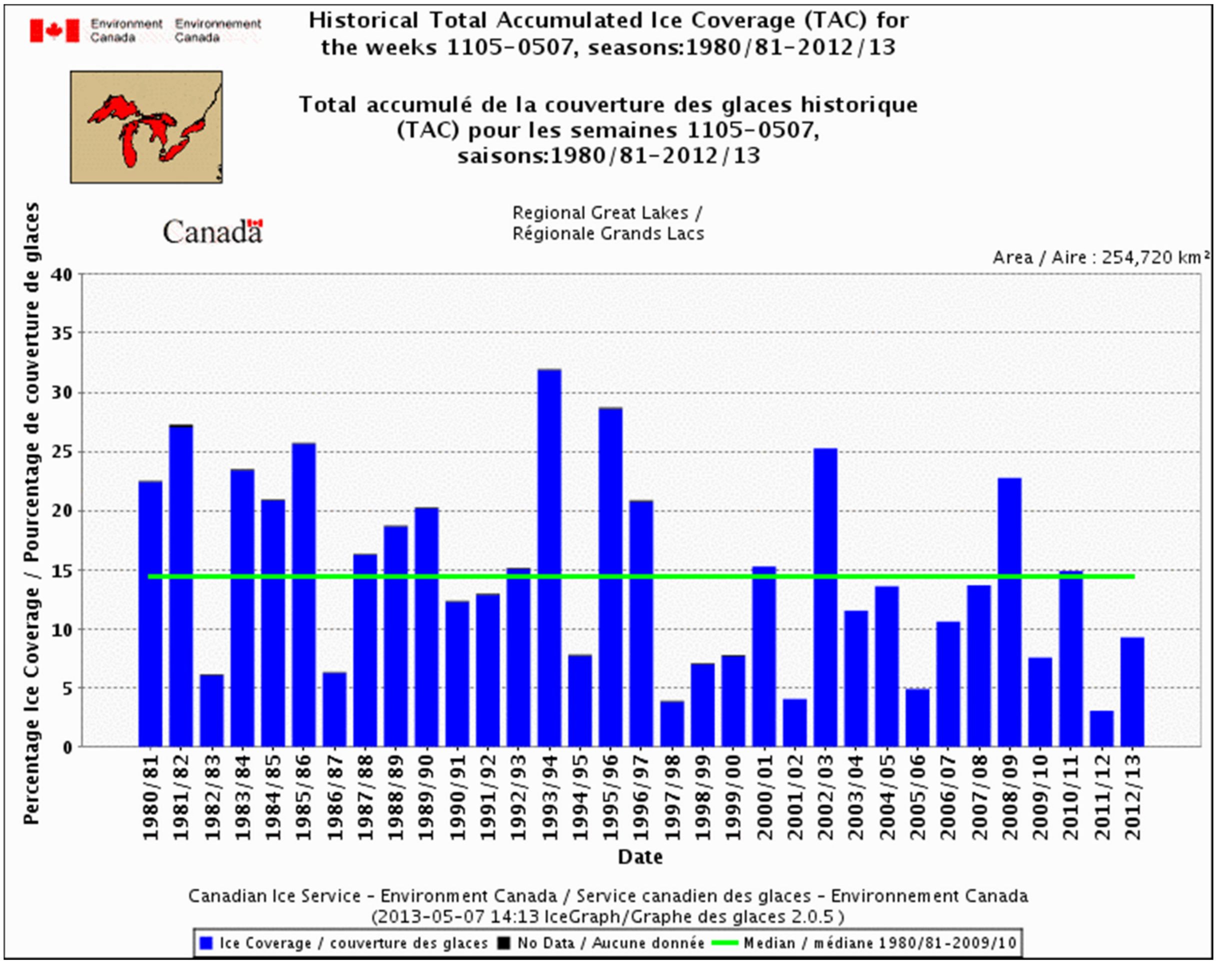
Source: IJC, 2013.

Figure 51: Hydrological components of the Great Lakes

Precipitation in the form of rain, snow and condensation is the source of all waters reaching the Great Lakes. Over-lake precipitation represents a large and immediate supply of water to the Great Lakes because about one third of the Great Lakes basin area is lake surface. The land area contributing runoff to the Great Lakes, in a band from about 10 to 150 km wide around the lake shores, is drained by a system of rivers and intermittent streams (Figure 41). The amount of precipitation is fairly constant throughout the year, but winter precipitation stored as snowpack is a major contributor to spring runoff to the lakes (CHS, 2010a).

Evaporation from the land and water surfaces depends on solar radiation, on temperature differences between the air mass and the water, and on humidity and wind. Evaporation from the Great Lakes is greatest in the fall and early winter when the air above the lakes is cold and dry and the lakes are relatively warm. Conversely, the evaporation is least in the spring and early summer when the air above the lakes is warm and moist and the lakes are cold. Condensation to the lake surface may result instead of evaporation. On the Great Lakes, the average annual evaporation from the lake surface is almost equivalent to the average annual precipitation onto the lake surface. Lake Michigan-Huron has the largest surface area of all of the Great Lakes and therefore the impact of evaporation is most pronounced on this lake (CHS, 2010a).

Due to climate change, the amount of ice cover has significantly dropped over recent years. Researchers from the US Great Lakes Environmental Research Laboratory (GLERL) in Michigan found a decrease in ice cover for the period 1973–2010, with a total loss in all Great Lakes ice coverage of 71% over the entire 38 year record (Wang et al., 2012). Changes in the extent and duration of winter ice cover may influence lake levels via water loss through evaporation. Loss of ice cover earlier in the spring can lead to higher water temperatures by affecting the onset of summer warming.



Source: http://ice-glaces.ec.gc.ca/prods/CVCHACTGL/20130506180000_CVCHACTGL_0007050246.gif

Figure 52: Historical total accumulated ice coverage for the Great Lakes

Figure 52 presents data from Environment Canada's Canadian Ice Service on Great Lakes ice coverage for the period November 5 - May 7, from the winter of 1980 - 1981 through 2012 - 2013. The winter of 2011 - 2012 had the lowest ice cover at 4%, and the winter of 1993 - 1994 had the highest ice cover at 32%. The median ice coverage between 1980 - 2013 was about 14%. Lake Huron typically averages 68% ice cover (Croley et al., 1996).

The changes in ice cover are an alarming trend because it could have significant consequences to our coast. The factors influencing this reduction in ice cover are thought to be due to higher air temperatures (in recent years), as well as an increase of Great Lakes water temperatures. The GLERL study (Wang et al., 2012) found that summer (July–September) surface water temperatures have increased approximately 2.6°C over the interval 1979–2006 significantly in excess of regional atmospheric warming. According to the researchers, this excessive warming of lake water temperature relative to the local surface air temperature is caused by a positive ice/water albedo feedback due to the declining winter ice cover. In other words, with less ice cover to reflect solar radiation back to the atmosphere, the open water, being much darker, absorbs radiant heat causing water temperatures to increase. Such changes may have significant effects on breeding cycles of fish and other aquatic organisms.

Groundwater is important to the Great Lakes ecosystem because it provides a reservoir for storing water and for slowly replenishing the Great Lakes through base flow in the tributaries and through direct inflow to the lakes. Groundwater also serves as a source of water for many human communities and provides moisture and sustenance to plants and other biota. Recent U.S. studies have estimated that groundwater makes a significant contribution to the overall water supply in the Great Lakes Basin, accounting for approximately 22 percent of the U.S. supply to Lake Erie, 33 percent of the supply to Lake Superior, 35 percent of the supply to Lake Michigan, and 42 percent of the supply to Lakes Huron and Ontario. Over most of Ontario, the contribution of groundwater to stream flow is less than 20 percent. This is because of the predominance of silt and clay or poorly fractured bedrock at the surface. However, in some portions of the Lake Erie and Lake Ontario basins, where sand and gravel are found at the surface, the contribution of groundwater to local streams can be as high as 60 percent or more (IJC, 1999).

Ice retardation in the winter, when the flows in the outlet rivers of the Great Lakes are often impeded by ice formation or ice jams, and aquatic growth during the summer also have an effect on outlet flows and hence lake levels (CHS, 2010a).

Tides, which are the periodic rise and fall of the water resulting from the gravitational interactions of the sun, moon, and earth, are only a few centimetres in the Great Lakes and are masked by larger fluctuations caused by meteorological disturbances (CHS, 2010a).

Crustal uplift (glacial isostatic adjustment) since the last glaciations (Figure 53) may tilt the basin and/or change the elevation of the outlet channels and have a long-term effect on lake levels. Figure 54 illustrates the vertical velocity (i.e. uplift of the earth/ground) relative to each outlet. For example, Parry Sound will experience a rise of the earth of 24 cm over the next century, whereas Cleveland will experience a drop/decrease of 10 cm.

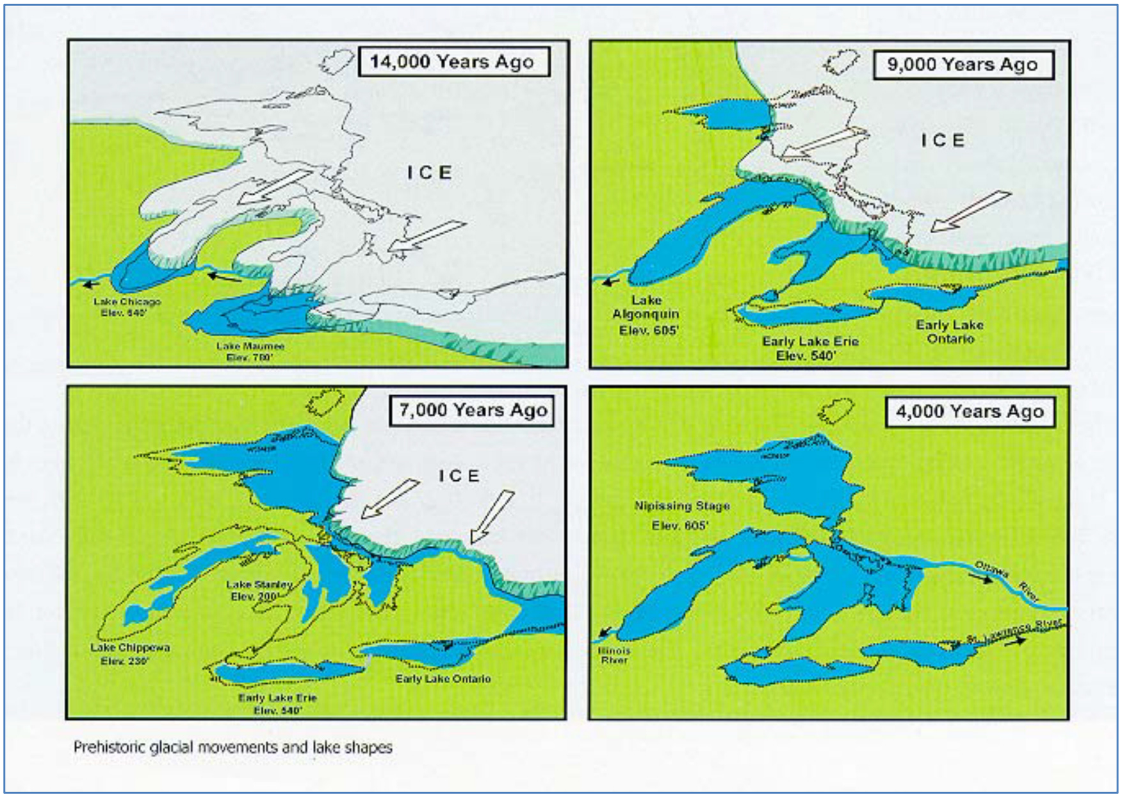
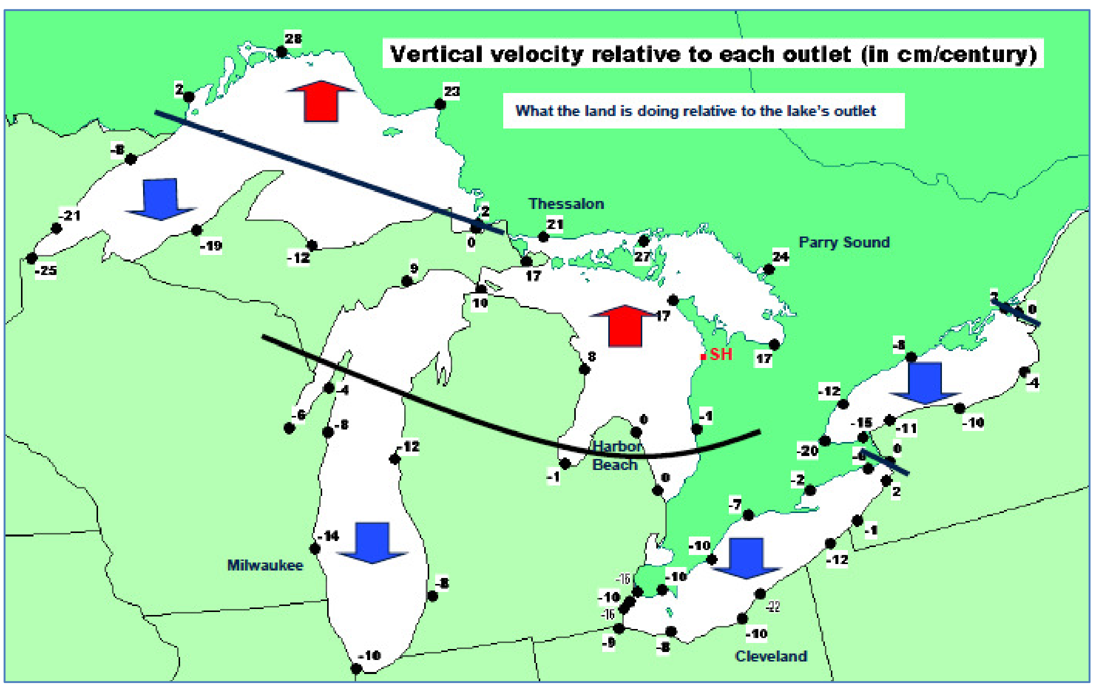


Figure 53: Prehistoric glacial movements and lake shapes



Source: http://lakehuron.ca/uploads/pdf/municipal-clinics/Lake.Levels_22Feb2013-Chuck.Southam-low-res.pdf

Figure 54: Glacial isostatic adjustment represented as vertical velocity of the Great Lakes

Superimposed on this annual cycle of water levels and the multi-year fluctuation in supplies are meteorological disturbances causing short-term fluctuations over time frames ranging from hours to days. When there is a difference in atmospheric pressure over a body of water, the water level will be lower under the area of high pressure and higher under the area of low pressure. In the absence of other forces, the water surface slopes to adjust to the differences in atmospheric pressure along the surface. The term wind set-up (Figure 2) refers to the slope of the water surface in the direction of the wind stress; the water level at the downwind end of the lake will rise. The difference in water level between the two ends of the lake depends on the length, shape and depth of the lake and the duration, direction and speed of the wind; the change in water level is greatest when a strong wind blows over a long, shallow lake for a long time. Storm surges are pronounced increases in the water level associated with the passage of storms. Although most of the change is a direct result of atmospheric pressure and wind set-up, the storm traveling over the water surface can cause a long surface wave to travel with it. The change in water level caused by these disturbances may be more pronounced in certain parts of a lake as a result of shoaling water, of funneling by shoreline configuration or of a gradually sloping inshore bottom which reduces the reverse sub-surface flow (CHS, 2010a).

3.4.2 Controls, Diversions and Consumptive Use Studies

Controls on the Great Lakes

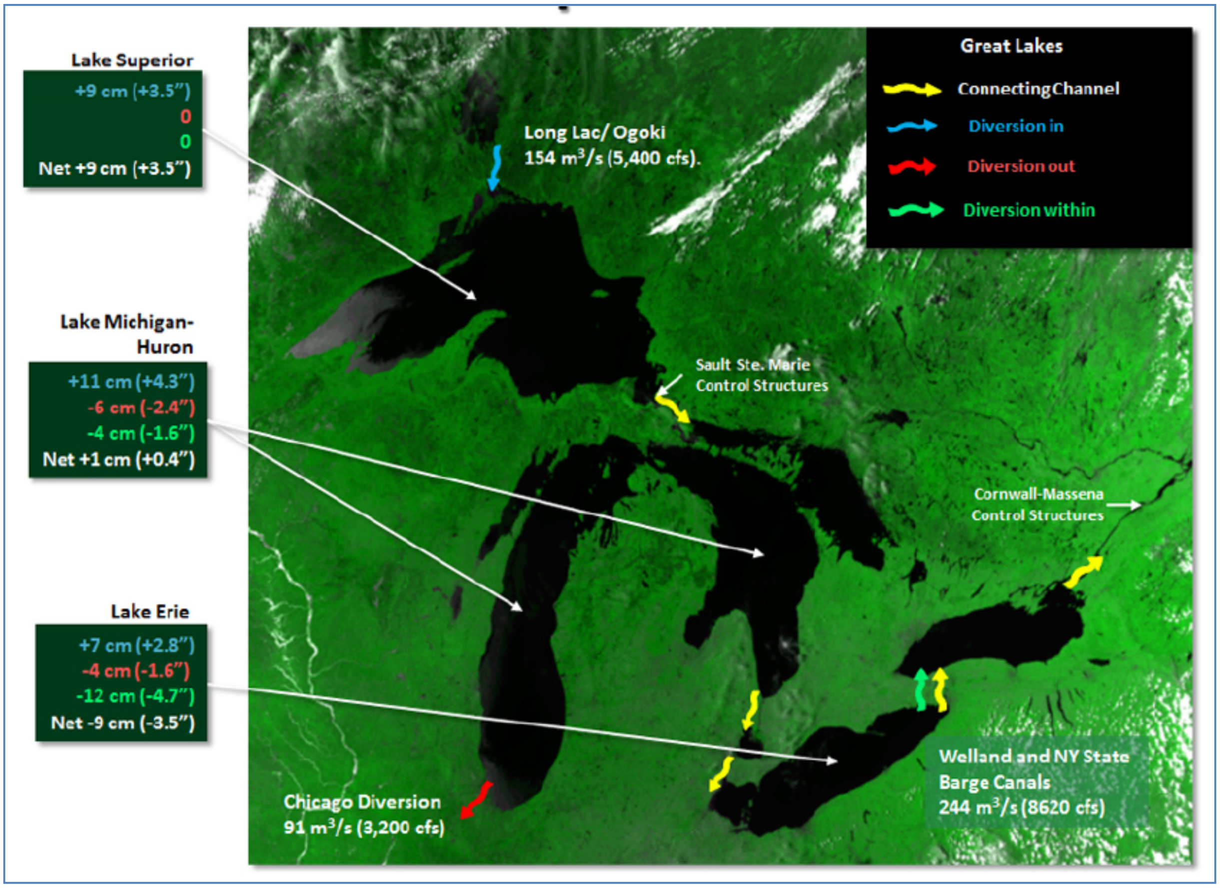
Control works that are operated under the authority of the IJC have been constructed in the St. Marys River at the outlet of Lake Superior and in the St. Lawrence River below the outflow from Lake Ontario. These channels have been altered by enlargement and placement of control works associated with deep-draft shipping and power generation. Moreover, the level of Lake Erie has been increased by obstructions in the Niagara River, including a number of fills on both sides of the river, with a cumulative effect of about 12 cm (IJC, 1999).

Diversions and Consumptive Use on the Great Lakes

Two human activities, diversion and consumptive use, have potential for affecting lake levels, although they have had relatively little impact to date (IJC, 1999). Diversion refers to transfer of water from one watershed to another (Figure 55). For example, the City of London (Ontario) diverts water from the Lake Huron-Michigan watershed for municipal use. Consumptive use refers to water that is withdrawn for use and not returned.

Diversions have been constructed to bring water into the Great Lakes system from the Albany River system (Hudson Bay watershed) in northern Ontario at Longlac and Ogoki. They have also been constructed to take water out of the system at Chicago and, to a much lesser extent, through the Erie Canal. These two diversions are almost equally balanced and in the opinion of the IJC (1999) have had little long-term effect on levels of the lakes. Overall, the IJC (1999) has concluded that more water is diverted into the system than is taken out. In addition to these diversions in and out of the Great Lakes basin there are also intrabasin diversions, for example water is diverted from Lake Erie to

Lake Ontario through the Welland Canal. Asides from these major diversions, there are also a few small diversions illustrated in Figure 55. Data for all existing diversions, both interbasin and intrabasin, are presented in Table 12. Water is also diverted around Niagara Falls for hydro-electric power generation, although it isn't considered to be an intrabasin diversion as the water is returned to the river downstream of the falls.



Source: IJC, 2013.

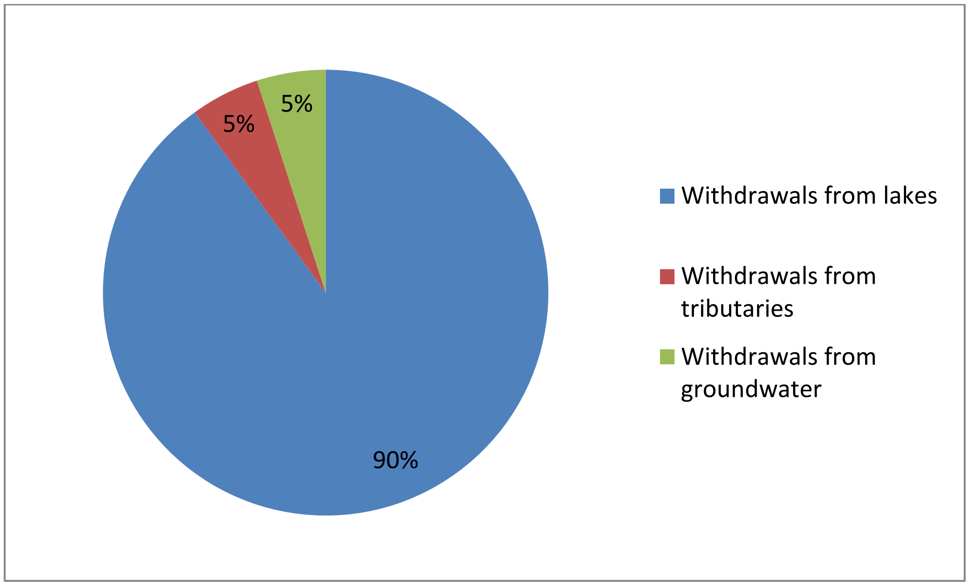
Figure 55: Diversions and impacts on water levels

Table 12: Data for existing diversions in the Great Lakes basin

	Date Operational	Average Annual Flow	
		CMS	CFS
Interbasin			
Longlac (into Lake Superior)	1939	45	1,590
Ogoki (into Lake Superior)	1943	113	3,990
Chicago (out of Lake Michigan)	1900	91	3,200
Forrestport (out of Lake Ontario)	1825	3	120
Portage Canal (into Lake Michigan)	1860	1	50
Pleasant Prairie (out of Lake Michigan)	1990	0.1	5
Akron (out of Lake Erie)	1998	0.1	6
Intrabasin			
Welland Canal	1932	260	9,200
NY State Barge Canal (Erie Canal)	1918	20	700
Detroit	1975	4	145
London	1967	3	110
Raisin River	1968	0.7	25
Haldimand	1997	0.1	2

Source: IJC, 1999.

The Great Lakes Commission conducted a preliminary examination of water use data in the Great Lakes Basin based on data from the period 1987 to 1993. The study presents water uses in two categories: consumptive use and removals. The study concluded that close to 90 percent of withdrawals are taken from the lakes themselves, with the remaining 10 percent coming from tributary streams and groundwater source (Figure 56) (IJC, 1999).

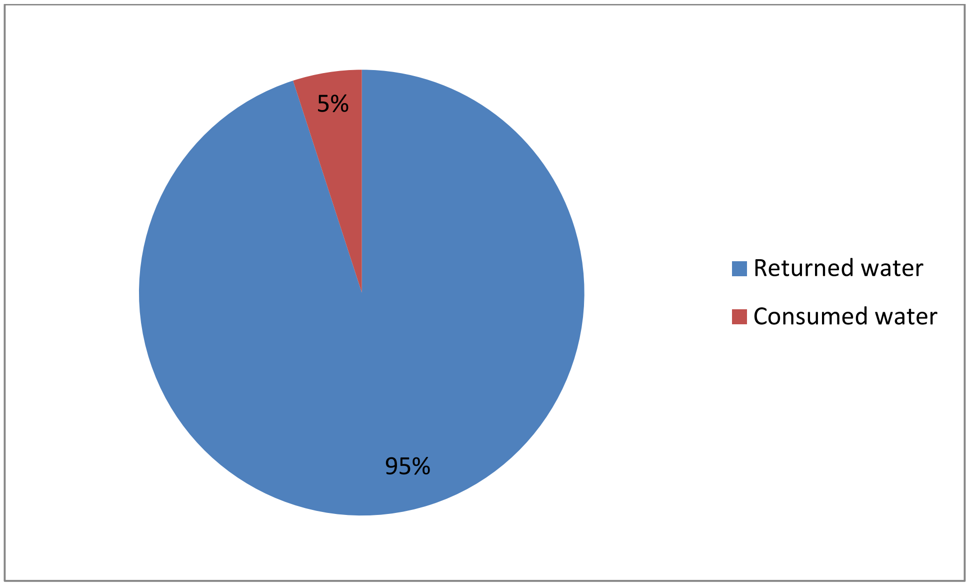


Source: IJC, 1999.

Figure 56: Sources of water withdrawals in the Great Lakes basin

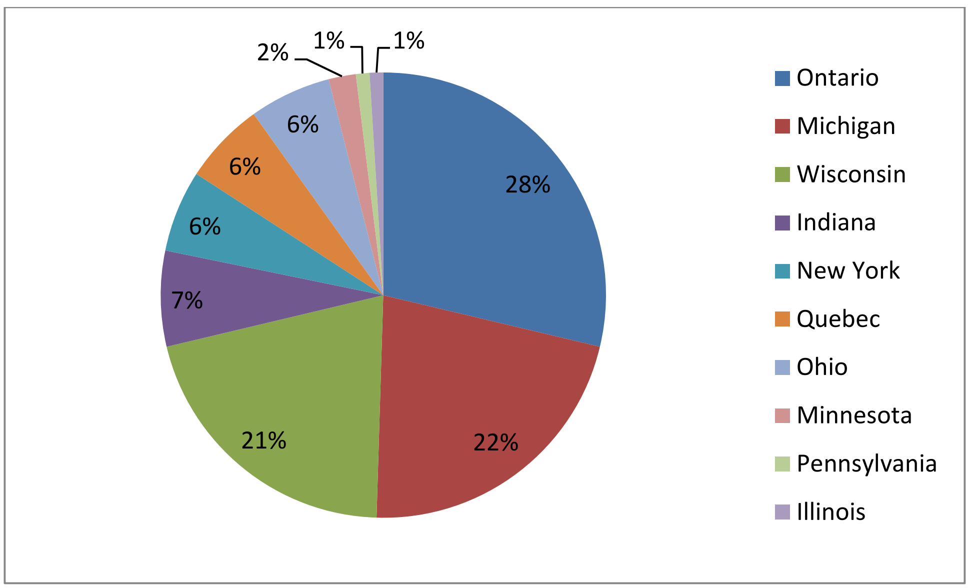
The study (IJC, 1999) also notes that an estimated 5 percent of water withdrawn from the Great Lakes is consumed and is therefore lost to the basin. This value was calculated using the Regional Water Use Data Base – a database maintained by the Great Lakes Commission since 1988 on behalf of the states and provinces and at the time of the study was current to 1993. In 1993, consumptive use in the Great Lakes Basin was estimated to be 116 cms (cubic metres per second) (4,096 cfs – cubic feet per second) as compared to a withdrawal of about 2,493 cms (88,000 cfs) (Figure 57). However, this study did not include withdrawals for hydroelectric purposes, because the water withdrawn for use in hydroelectric facilities is immediately returned to its source. The 1993 consumptive use in the Great Lakes Basin can be summarized as follows:

- By country: In total, consumptive use is 36 percent for Canada and 64 percent for the United States, with per capita consumptive use being approximately equal for the two countries.
- By jurisdiction: The largest user is Ontario at 29 percent, followed by Michigan at 22 percent; Wisconsin at 21 percent; Indiana at 7 percent; New York, Quebec, and Ohio at 6 percent each; Minnesota at 2 percent; and Pennsylvania and Illinois (not including Chicago) at less than 1 percent each (Figure 58).
- By type of water use: The largest user is irrigation at 30 percent, followed by public water supply at 26 percent, industrial use at 25 percent, fossil fuel thermoelectric and nuclear thermoelectric uses at 6 percent each, self-supplied domestic use at 4 percent, and livestock watering at 3 percent (Figure 59).



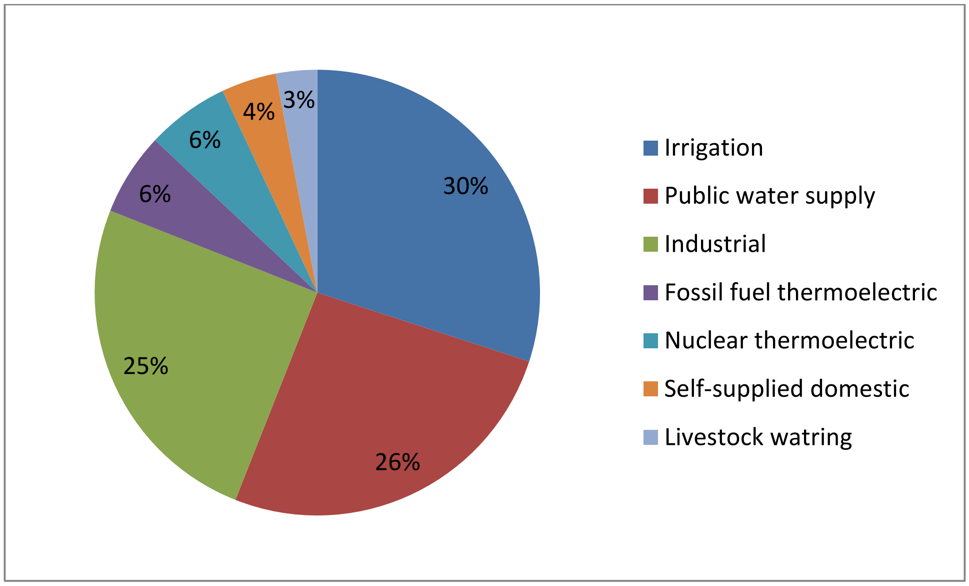
Source: IJC, 1999.

Figure 57: Consumed versus returned water in the Great Lakes basin



Source: IJC, 1999.

Figure 58: Consumptive use of water by jurisdiction in the Great Lakes basin



Source: IJC, 1999.

Figure 59: Types of consumptive use in the Great Lakes basin

3.4.3 Climate Change

There is world-wide consensus among scientists that climate change, driven by increasing concentrations of greenhouse gases in the atmosphere, is occurring and will continue. The regional effects of climate change are expected to differ from one region to another. Understanding the effects of climate change is essential to the management of the Great Lakes, including government and community efforts to reduce and adapt to those effects (IUGLS, 2009).

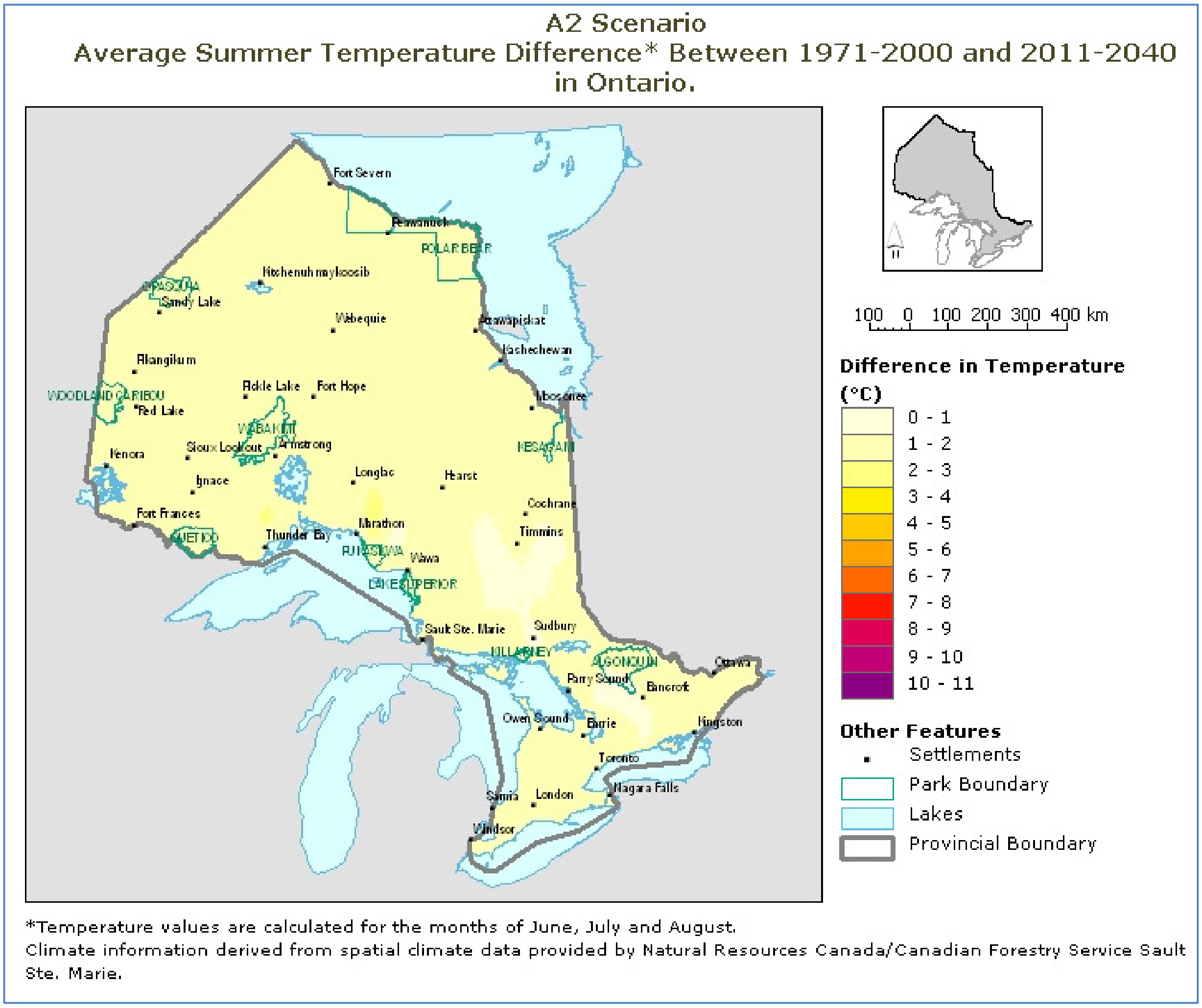
The climate of the Great Lakes basin varies considerably due to: the basin's north-south extent; the effects of the lakes on near-shore temperatures and precipitation; and the fact that the lakes themselves create their own micro-climate. Over the long-term, regional climatic patterns affect the amount of water that can be stored in or released from a lake. Contributing climatic factors include the amount of water the lakes receive through precipitation and runoff from their drainage basins, water lost through evaporation, and the extent and timing of ice cover on the lakes and connecting channels (IUGLS, 2009).

In the past, water supplies to the upper Great Lakes basin have varied considerably, over periods of years, centuries and longer. Periods of higher and lower water supplies can be expected in the future due to climatic variations. Beyond these variations in climatic patterns are the still uncertain implications of global climate change, particularly the effects of changing climatic patterns at the regional level (IUGLS, 2009).

Climatologists have predicted the affects from an increase of carbon dioxide emissions on the climate in the Great Lakes basin. These projections are based on scenarios of future atmospheric greenhouse gas concentrations used in one of the many global climate models available to climatologists. In this case, projections were made using version 2 of Environment Canada's climate model, the Canadian Coupled Global Circulation Model (CGCM2). Maps show climate projections based on the A2 or B2 climate scenarios, which depict two potential climatic outcomes caused by different amounts of global atmospheric greenhouse gas concentrations during the 21st century. In the A2 scenario atmospheric levels of greenhouse gases reach 1320 parts per million by volume (ppmv) in CO_2 equivalents by 2100. In comparison, greenhouse gas levels in the B2 scenario reach 915 ppmv by the end of this century. Greenhouse gas emissions in B2 are lower than A2 because human population growth is slower (15 billion in A2 and 10.4 billion in B2 by 2100) and in B2 there is greater emphasis on environmental protection (MNR, 2012a).

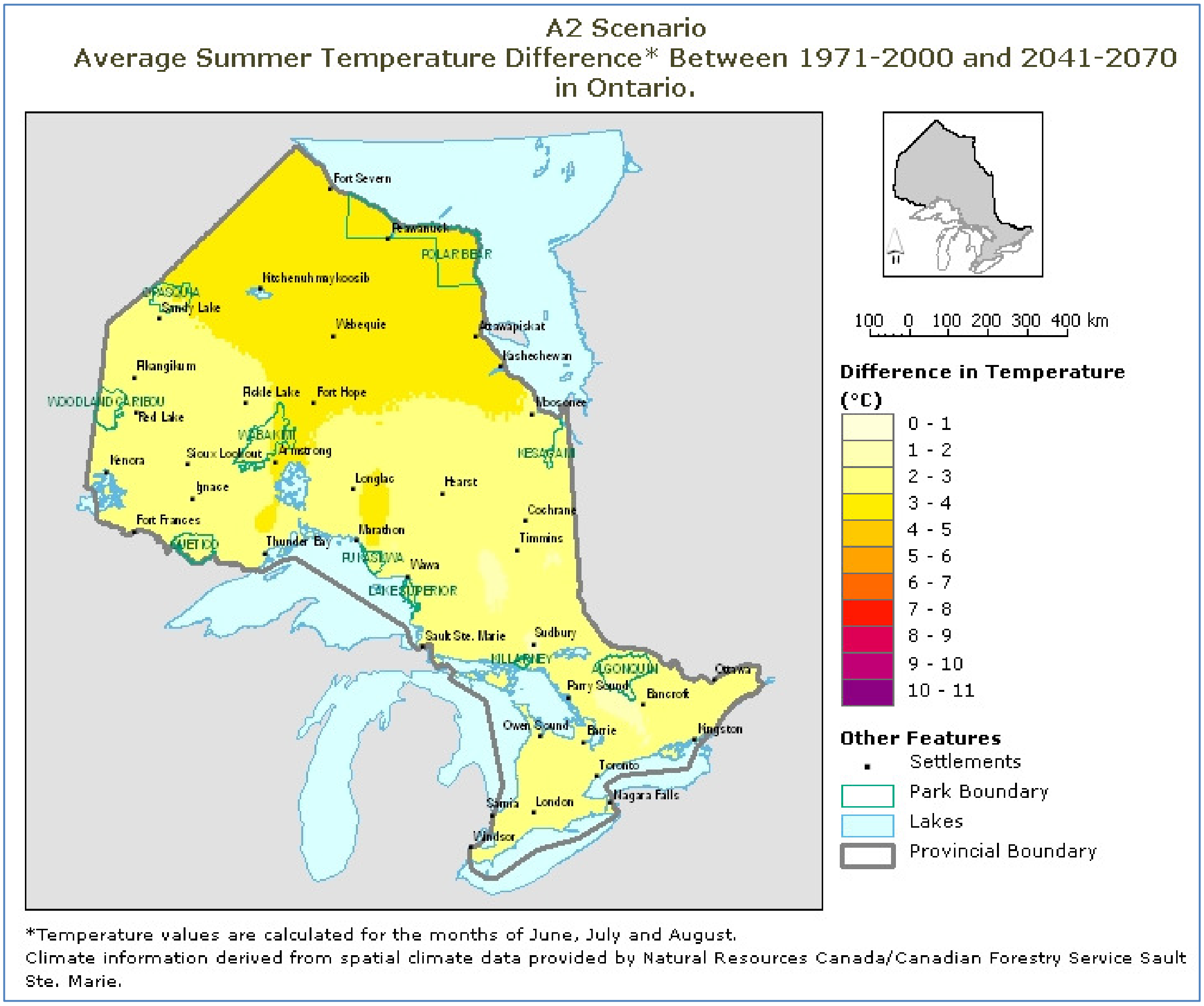
The A2 and B2 scenarios are two of many possible future outcomes. Given that the amount of greenhouse gas in the atmosphere depends on human behaviour, technological development, and the sink/source behaviour of land and water ecosystems, it is impossible to be certain how much greenhouse gas will be in the atmosphere in future. Therefore, these maps indicate the direction of climate change, but are not precise predictions of the magnitude or the timing of the change (MNR, 2012a).

Potential future climate projections for Ontario have been calculated for summer and winter temperature, and warm period precipitation change (April to September) and cold season precipitation change (October to March) for three time periods: 2011-2040, 2041-2070, and 2071-2100. These maps show that over the period of 2011-2100, the climate of the Ontario will be warmer by 1-6°C (Figure 60, Figure 61, and Figure 62) and slightly damper than at present (Figure 63, Figure 64, and Figure 65). Different regions of Ontario are predicted to experience different rates of change. For example, the Parry Sound area, for the period 2011-2040, is projected to experience an increase in summer temperatures by 1-2°C (Figure 60) and an increase in summer precipitation by 0-10% (Figure 63) (MNR, 2012a). In terms of changes to ecosystems, it is predicted that southern Ontario's climate will resemble the present climate of South Carolina in 70-100 years (McKenney et al., Date unknown).



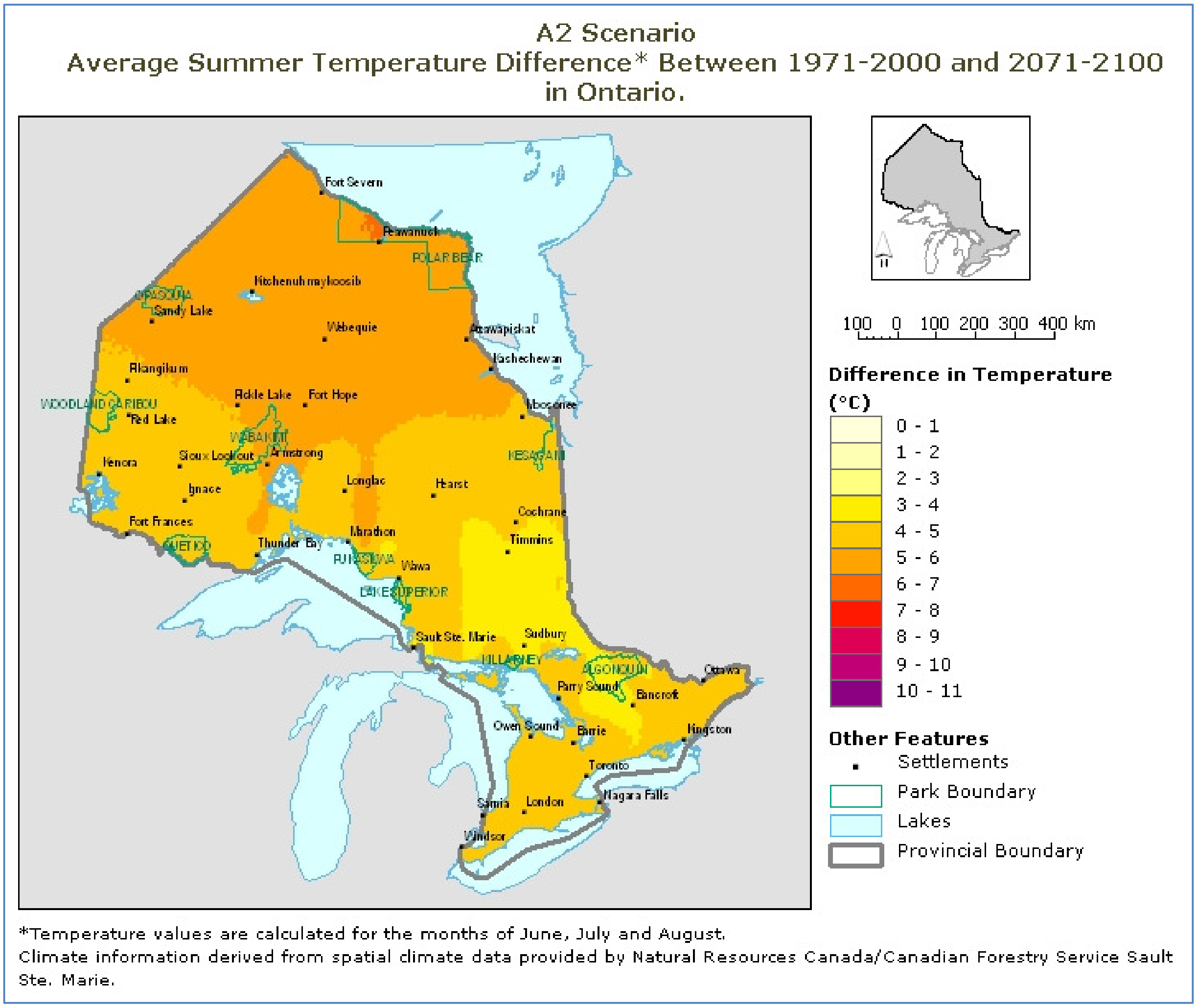
Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 60: Average summer temperature difference between 1971-2000 and 2011-2040 in Ontario



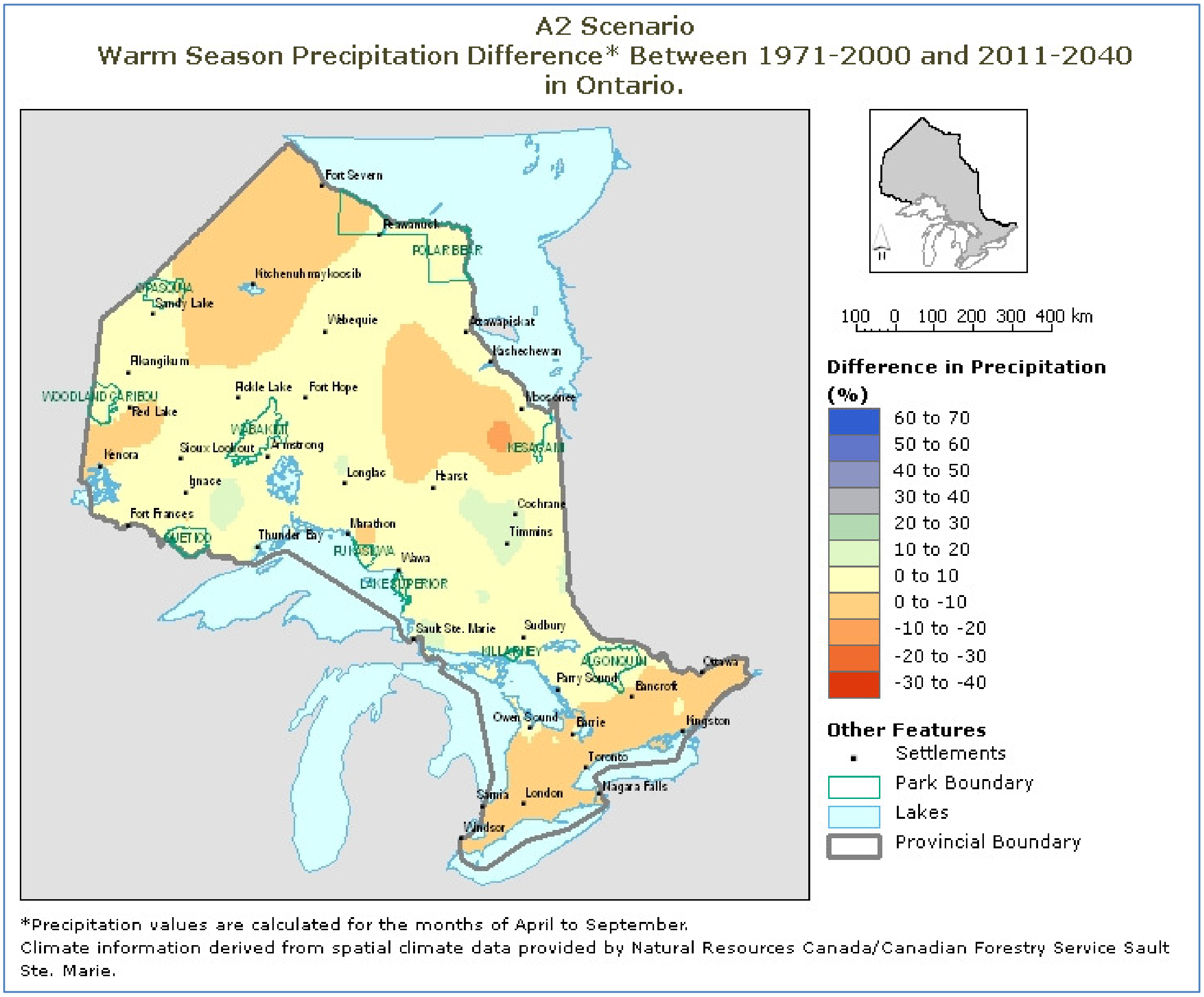
Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 61: Average summer temperature difference between 1971-2000 and 2041-2070 in Ontario



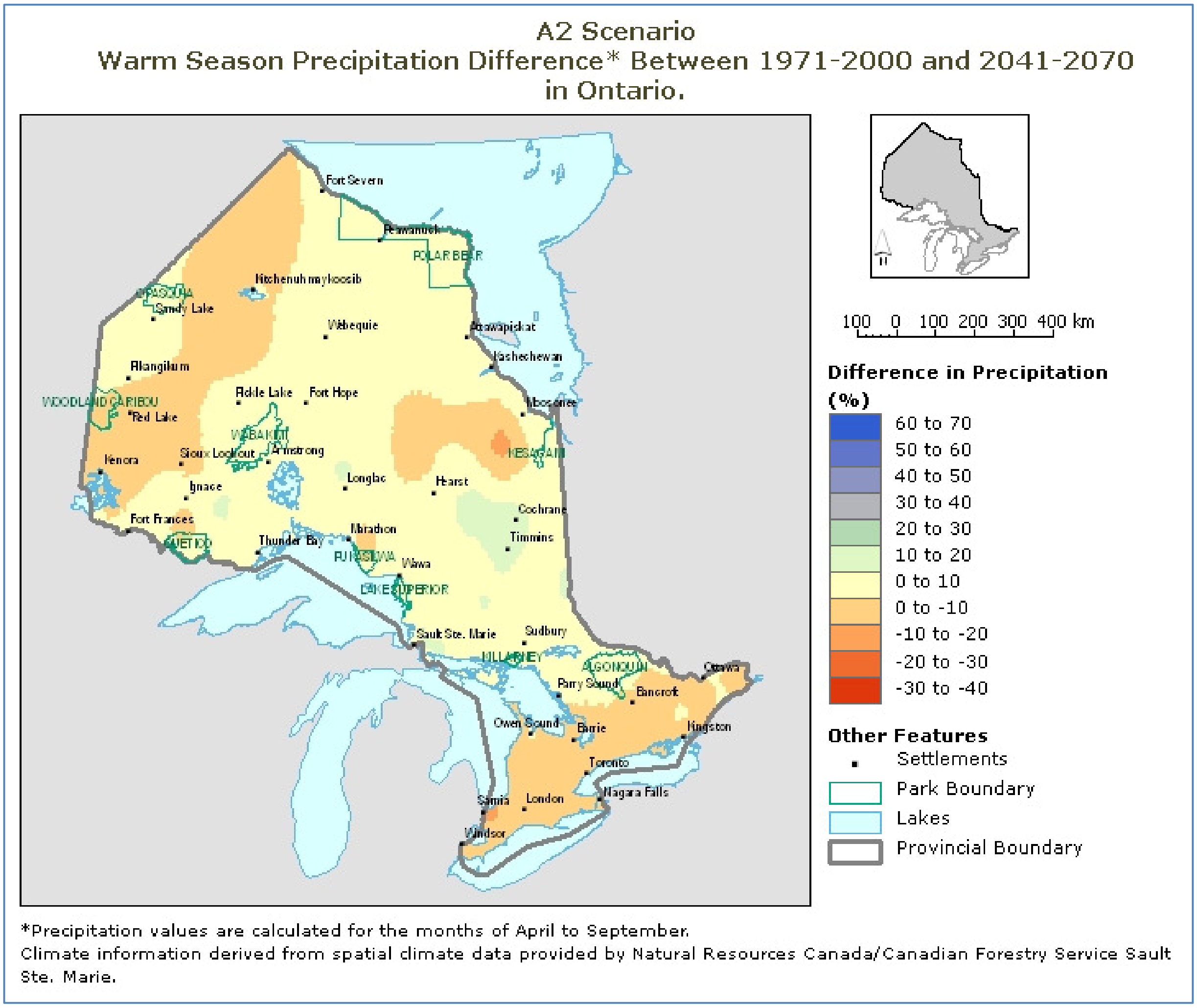
Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 62: Average summer temperature difference between 1971-2000 and 2071-2100 in Ontario



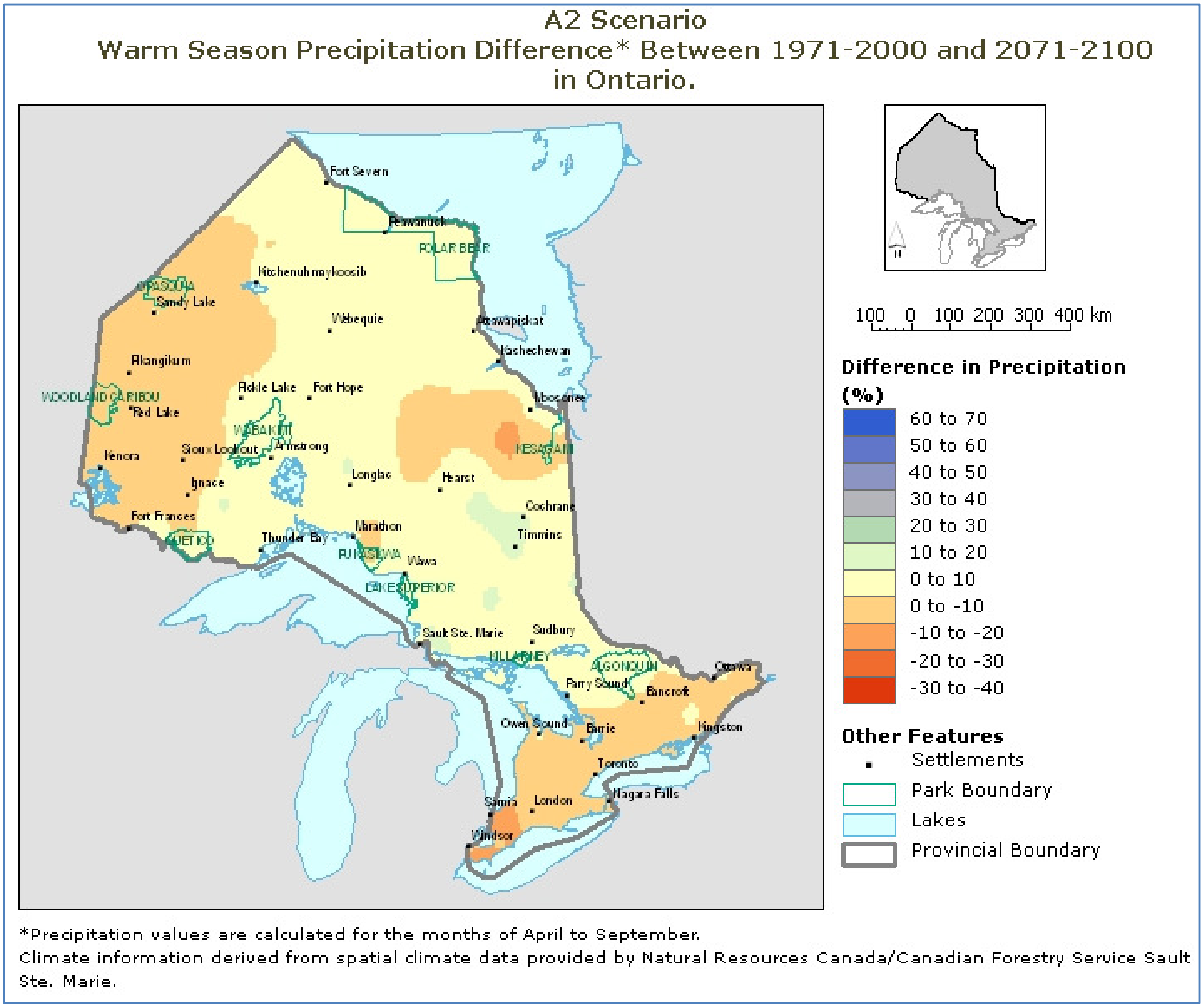
Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 63: Warm season precipitation difference between 1971-2000 and 2011-2040 in Ontario



Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 64: Warm season precipitation difference between 1971-2000 and 2041-2070 in Ontario



Source: www.mnr.gov.on.ca/en/Business/ClimateChange/2ColumnSubPage/STDPROD_090054.html

Figure 65: Warm season precipitation difference between 1971-2000 and 2071-2100 in Ontario

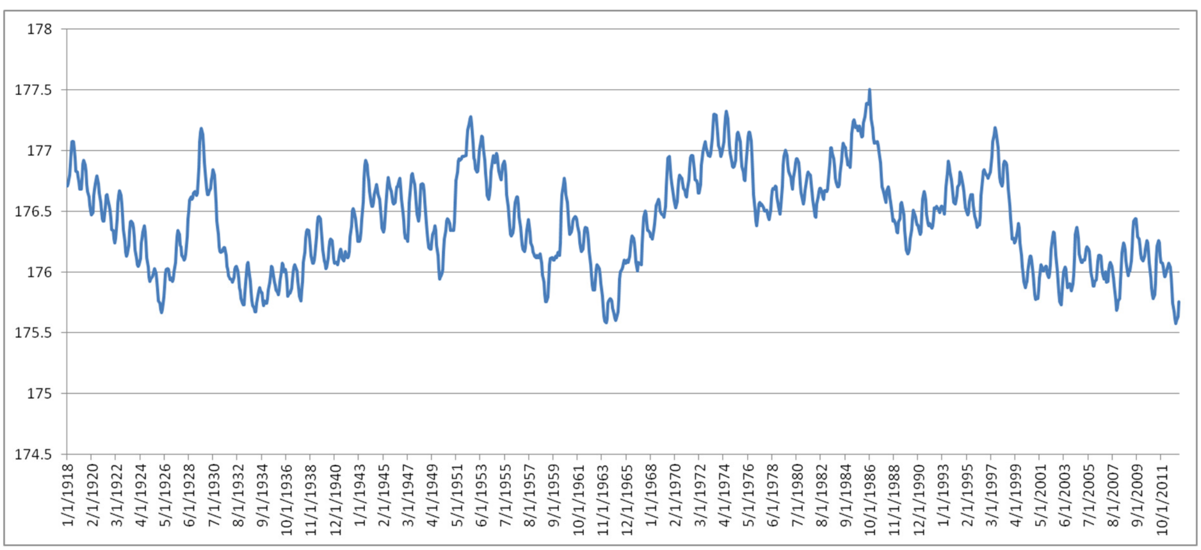
Warmer climates mean increased evaporation from the lake surfaces and evapotranspiration (evaporation from plant leaves) from the land surface of the basin. This in turn will augment the percentage of precipitation that is returned to the atmosphere. Studies have shown that the resulting net basin supply, the amount of water contributed by each lake basin to the overall hydrologic system, will be decreased by 23 to 50 percent. The resulting decreases in average lake levels will be from half a metre to two metres, depending on the climate change model used (EPA, 1995).

Large declines in lake levels would create large-scale economic concern for the commercial users of the water system. Shipping companies and hydroelectric power companies would suffer economic repercussions, and harbors and marinas would be adversely affected. While the precision of such projections remains uncertain, the possibility of their accuracy embraces important long-term implications for the Great Lakes. Georgian Bay Forever is initiating a study on the economic impacts of prolonged low water levels.

The potential effects of climate change on human health in the Great Lakes region are also of concern, and researchers can only speculate as to what might occur. For example, weather disturbances, drought, and changes in temperature and growing season could affect crops and food production in the basin. Changes in air pollution patterns as a result of climate change could affect respiratory health, causing asthma, and new disease vectors and agents could migrate into the region (EPA, 1995).

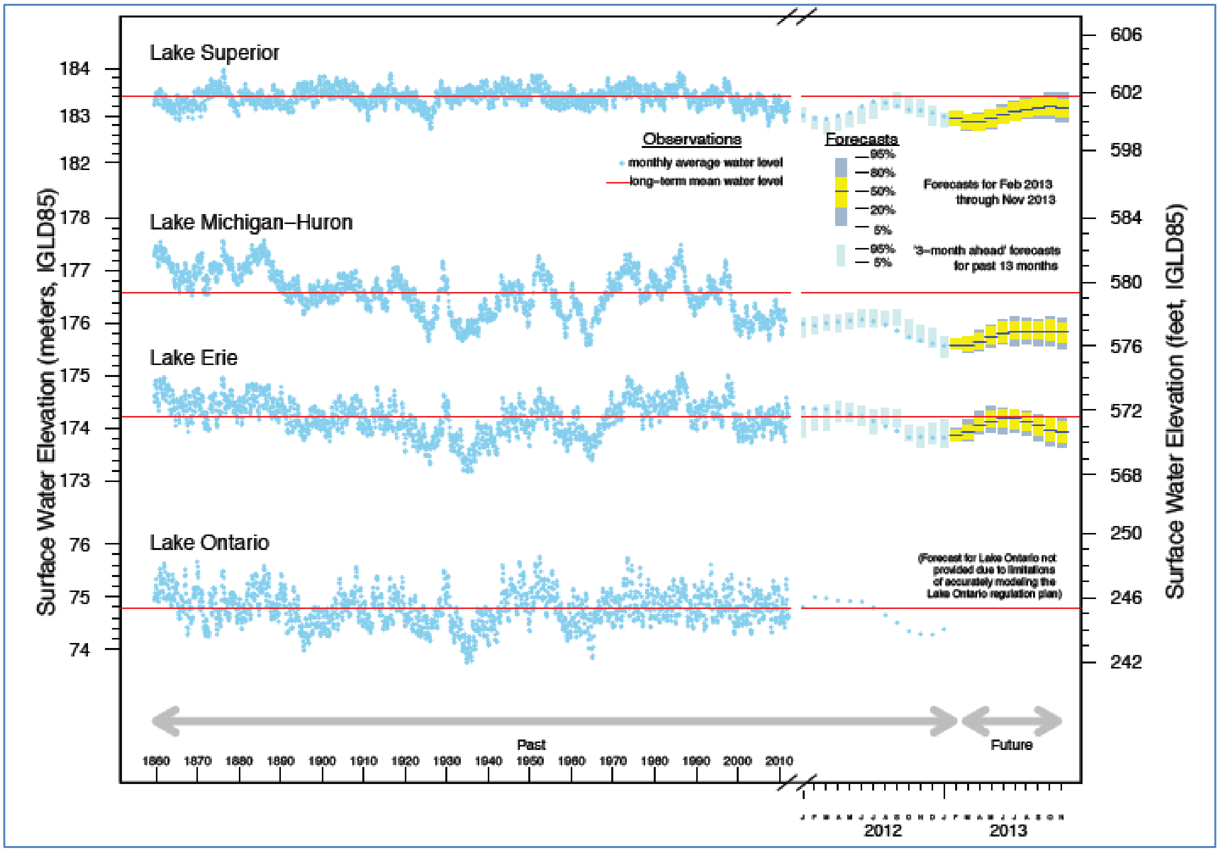
3.4.4 Current Low Water Levels on Lake Huron

In December 2012 and January 2013, the monthly average water level on Lake Michigan-Huron dropped below the previously recorded (1964) low for the period of record beginning in 1918 (Figure 66). Seasonal outlooks indicate that water levels may continue to set new record lows (Figure 67). The current record-setting low water levels on Lake Michigan and Huron are thought to be the result of two main factors: 1) climate change impacts leading to a large decrease in water supplies on the upper Great Lakes and increases in overlake evaporation; and 2) post 1960s dredging erosion in the St. Clair River and a minor contribution from glacial isostatic adjustment.



Source: www.glerl.noaa.gov/data/now/wlevels/dbd/

Figure 66: Monthly average water level recorded on Lake Huron-Michigan for the period 1918 to 2013



Source: GLERL, 2013.

Figure 67: Forecasts of Great Lakes water levels

3.5 Studies on Water Levels

Management of levels and flows in the Great Lakes falls under the responsibility of the International Joint Commission (IJC). Decisions about levels and flows are made to comply with the terms of the 1909 Boundary Waters Treaty.

3.5.1 The Boundary Waters Treaty of 1909

In 1905 the International Waterways Commission was created to advise the governments of both countries about levels and flows in the Great Lakes, especially in relation to the generation of electricity by hydropower. Its limited advisory powers proved inadequate for problems related to pollution and environmental damage. One of its first recommendations was for a stronger institution with the authority for study of broader boundary water issues and the power to make binding decisions (EPA, 1995).

The Boundary Waters Treaty was signed in 1909 and provided for the creation of the IJC. The IJC has the authority to resolve disputes over the use of water resources that cross the international boundary. Most of its efforts for the Great Lakes have been devoted to carrying out studies requested by the governments and advising the governments about problems (EPA, 1995).

3.5.2 The International Joint Commission

The 1909 Boundary Waters Treaty established the International Joint Commission of Canada and the United States. The treaty created a unique process for cooperation in the use of all the waterways that cross the border between the two nations, including the Great Lakes (EPA, 1995).

The IJC has six members, three appointed from each side by the heads of the federal governments. The authors of the 1909 Boundary Waters Treaty saw the Commission not as separate national delegations, but as a single body seeking common solutions in the joint interests of the two countries. All members are expected to act independently of national concerns, and few IJC decisions have split along national lines (EPA, 1995).

The IJC has three responsibilities for the Great Lakes under the original treaty. The first is the limited authority to approve applications for the use, obstruction or diversion of boundary waters on either side of the border that would affect the natural level or flow on either side. Under this authority, it is the IJC that determines how the control works on the St. Marys River and the St. Lawrence River will be operated to control releases of water from Lakes Superior and Ontario. It also regulates flows into Lake Superior from Long Lake and Lake Ogoki. Until 1973, the IJC managed levels and flows for navigation and hydropower production purposes. Since then, the IJC has tried to balance these interests with prevention of shore erosion (EPA, 1995).

The second responsibility is to conduct studies of specific problems under references, or requests, from the governments. The implementation of the recommendations resulting from IJC reference studies is at the discretion of the two governments. When a reference is made to the IJC, the practice has been to commission a board of experts to supervise the study and to conduct the necessary research. A number of such studies have been undertaken in the history of the IJC (EPA, 1995).

The third responsibility is to arbitrate specific disputes that may arise between the two governments in relation to boundary waters. The governments may refer any matters of difference to the Commission for a final decision. This procedure requires the approval of both governments and has never been invoked (EPA, 1995).

In addition to these specific powers under the 1909 Treaty, the IJC provides a procedure for monitoring and evaluating progress under the Water Quality Agreement. For this purpose, two standing advisory boards are called for in the Agreement (EPA, 1995).

The Water Quality Board is the principal advisor to the Commission and consists mainly of high-level managers from federal, state and provincial agencies selected equally from both countries. Its responsibilities include evaluating progress being made in implementation of the Agreement and promoting coordination of Great Lakes programs among the different levels of government (EPA, 1995).

The Science Advisory Board consists primarily of government and academic experts who advise the Water Quality Board and the IJC about scientific findings and research needs. The Council of Great Lakes Research Managers, in addition to the Science Advisory Board, was established to provide effective guidance, support and evaluation for Great Lakes research programs. Both groups have substructures involving special committees, task forces and work groups to address specific issues (EPA, 1995).

The IJC relies on work done by the various levels of the two governments and the academic community. It maintains an office in each of the national capitals and a Great Lakes Regional Office in Windsor, Ontario. The Great Lakes Office provides administrative support and technical assistance to the boards and a public information service for the programs of the Commission (EPA, 1995).

As part of its management of levels and flows in the Great Lakes, the IJC needs to consider the Great Lakes/St. Lawrence Seaway. The Seaway was built as a binational partnership between the U.S. and Canada, and continues to operate as such. Administration of the system is shared by two entities, the Saint Lawrence Seaway Development Corp. in the U.S., a federal agency within the U.S. Department of Transportation, and The St. Lawrence Seaway Management Corporation in Canada, a not-for-profit corporation (ownership of the Canadian portion of the Seaway remains with the Canadian federal government) (EPA, 1995).

The IJC has previously carried out several special studies on levels issues in response to references, or requests, from the governments. In 1964, when water levels were very low, the governments asked the IJC whether it would be feasible to maintain the waters of all the Great Lakes, including Michigan and Huron, at a more constant level. After a 9-year study, in 1973, when water levels were very high, the IJC advised the governments that the high costs of an engineering system for further regulation of Michigan and Huron could not be justified by the benefits. The same conclusion was reached for further regulation of Lake Erie in 1983 (EPA, 1995).

Following the period of high lake levels in the 1980s, the IJC conducted another study of levels and the feasibility of modifying them through various means. In 1993, the study concluded that the costs of major engineering works to further regulate the levels and flows of the Great Lakes and St. Lawrence River were too costly to implement. The study acknowledged the effect of climate change on reducing lake levels, as well as the fact that erosion and flooding damage cannot be entirely prevented through any form of regulation. The needs of various interests were also explained: recreational boating and commercial shipping benefit from higher levels; hydroelectric power plants benefit from stable levels, while wetlands and fish populations require fluctuation to thrive. In response to water level crises, the study notes that emergency measures could utilize existing diversions, regulation structures and land-based measures, though this will require coordination between all levels of government in Canada and the United States. The study recommended: 1) considering a series of guiding principles for future activities, including environmental sustainability; and 2) looking into the effects of further regulation on hydroelectric power, navigation, and recreational boating (EPA, 1995).

3.5.3 The Great Lakes Navigation System Review

In the early 2000s, the U.S. Army Corps of Engineers (USACE) (USACE, 2012) was authorized by the United States Congress to conduct an analysis of the Great Lakes Navigation System (GLNS) (excluding the mostly-Canadian St. Lawrence Seaway). The infrastructure of the GLNS is starting to show its age and after 50 to 70 years of service, the system of locks and approach channels shows wear and tear from the passage of tens of thousands of ships. As the GLNS ages the demands for maintenance grow, as do the costs.

The GLNS has served as a vital transportation corridor for the single largest concentration of industry in the world. Straddling the Great Lakes Basin, North America's industrial heartland depends on this system of locks, channels, ports and open water. Yet the waterway is facing new challenges that could not have been anticipated when it came into full operation in 1959. Changes in the economy and in the transportation industry have altered product demand, traffic patterns and shipping volumes. Although these developments have transformed the economic drivers underlying the system, it continues to fulfill a vital transport function not only for the Great Lakes region, but also for the entire industrial core of the North American economy. Given its ongoing importance, it is essential that the system be maintained as a safe, reliable, efficient and sustainable component of the continent's overall transportation network (USACE, 2012).

Separately, but on a similar schedule to the USACE (2002) report, a joint Canadian/United States study (the bi-national Great Lakes St. Lawrence Seaway Study (Transport Canada, 2007)) was begun in May 2003, following the signing of a Memorandum of Cooperation (MOC) between Transport Canada and the U.S. Department of Transportation. The MOC facilitated a binational study partnership that included Canadian and United States departments and agencies with expertise in transportation policy and economics, navigation-related infrastructure engineering and environmental science. These experts acted as the members of the Project Delivery Teams for the study.

The bi-national study (Transport Canada, 2007) facilitated an international, collaborative effort to produce a wide-ranging investigation that addresses the fundamental question: What is the current condition of the GLNS, and how best to use and maintain the system, in its current physical configuration, in order to remain competitive in the world market while facing the challenges that will present themselves in coming years?

Furthermore, there are two common findings in reports written recently by the Brookings Institute, the RAND Corporation, the National Academy of Science, and various U.S. and Canadian departments; the first being that the GLNS is at a tipping point that will see the commercial navigation industry either flounder or flourish in the next several decades; the second, that success of the navigation system hinges on coordinated planning and action among stakeholders. The reports also indicate that the future viability of the GLNS will come directly from maintaining the value and function of the existing infrastructure, while bringing more containerized cargo into the Great Lakes, and through providing options to alleviate congested overland transportation.

USACE (2012) states that the point of view for managing the system in a way that focuses on economic growth is compelling. Trends indicate that the population and wealth of North America will be greater in the future and more raw materials and goods will be moved. These materials and goods can be transported on railroads, trucks or ships. Highways are heavily congested now and will be more congested in the future. Some rail systems are underutilized while others are congested. Expanding rail or roadways almost always requires widening existing routes, which is extraordinarily costly because it requires rebuilding bridges across the wider routes. It is estimated that the GLNS is at about half capacity and could accept more traffic without expansion. Also, Ships use less fuel per ton to carry the same cargo and produce less atmospheric carbon; the European Union touts inland shipping as the green alternative.

There are clear disadvantages to shipping as well. Ships are slower than terrestrial or airborne transportation, and delivery speed is an important financial factor for finished, perishable and high value goods. Further, water-borne shipping, especially ocean-lake transit, is considered the leading cause for the introduction of invasive species that have caused enormous financial and environmental disruption. This risk can be reduced but not eliminated (USACE, 2012).

The GLNS infrastructure (locks, dams, breakwaters) is old, risking serious and costly delays, which makes shipping even less attractive for moving high value cargo. Winter ice impedes or stops navigation each year, meaning that shippers have to employ a winter alternative to waterborne transit. Shorelines are impacted by the wakes of these big vessels; more ship traffic means more impacts. Climate change poses additional uncertainties. Navigation requires dredging of shoaled sediments, much of which has to be stored in confined disposal areas because it is contaminated from past industrial discharges (USACE, 2012).

More effective and coordinated management of the GLNS will improve the chances of economic viability into the future. As such, the binational (Transport Canada, 2007) and USACE (2012) reports both conclude that the GLNS remains an important element in the North American economy, with a transportation rate savings of approximately $3.6 billion per year (U.S. only, and not including St. Lawrence Seaway shipping). Its upheld value and future prospects justify the costs of maintaining its infrastructure. Moreover, future operation and maintenance of the system can likely be performed in a manner that minimizes environmental impacts.

The USACE (2012) supplemental report (to the GLNS Review (USACE, 2002)) concludes that the Great Lakes and Ohio River Division should, subject to the Federal budget process, further investigate or implement:

- Improved Water Level Data Access, subject to interest by NOAA and the Canadian Marine Environmental Data Service (MEDS);
- Review of GLNS Activities to Reduce Environmental Impacts;

- Maintenance of the Great Lakes Connecting Channels and Harbors using a system approach that recognizes the interdependency of Great Lakes harbors and the need for a Long Term Dredged Material Management Strategy;
- Maintenance of the GLNS Infrastructure, using an Asset Management approach and investigation of harbor impacts associated with structure degradation;
- Investigation of the navigational restrictions within the Chicago Sanitary and Ship Canal and the practicality of a St. Clair River Ice Boom; and
- Deepening individual ports, (and possibly key connecting channel pinch-points) subject to interest by a viable cost-sharing sponsor.

3.5.4 International Upper Great Lakes Study

Background

In 2002, the Upper Great Lakes Plan of Study Team presented a report to the IJC regarding the regulation of outflows from Lake Superior on the Upper Great Lakes. This report was replaced with a revised Plan of Study following work undertaken in 2004 by Georgian Bay Forever to provide evidence of changes in the St. Clair River system. The St. Clair was subsequently added to the revised work plan delivered in 2005.

In May 2005, the IJC established a new team (Upper Lakes Plan of Study Revision Team) to revise the 2002 report, directing the addition of three objectives. The first objective was to examine, during the early part of the study, past and on-going physical changes in the St. Clair River and their impacts on the river flow and water levels of the upper Great Lakes. A second objective was to take into consideration the lessons learned from the five-year International Lake Ontario – St. Lawrence River Study, which was nearing its completion. Lastly, the IJC directed that the new team streamline the existing Plan of Study. The 2005 Directive retains the main purpose of the 2001 Directive concerning Lake Superior outflow regulation.

Scope of the International Upper Great Lakes Study

In 2007, the IJC launched a five-year investigation of low water on levels in the upper Great Lakes, which was conducted by the bi-national International Upper Great Lakes Study. The investigation was established to examine a recurring challenge in the upper Great Lakes system: how to manage fluctuating lake levels in the face of uncertainty over future water supplies to the basin while seeking to balance the needs of those interests served by the system. The geographical scope of the Study was the upper Great Lakes basin, from the headwaters of Lake Superior downstream through lakes Michigan, Huron, St. Clair and Erie and the connecting channels (the St. Marys, St. Clair and Detroit rivers, the Straits of Mackinac and the upper Niagara River) (IUGLS, 2009).

The first phase of the investigation examined the physical processes and possible ongoing changes in the St. Clair River and the effects of such changes on the levels of Lake Michigan-Huron. Scheduling of the St. Clair River part of the investigation was accelerated by nearly one year to address widespread concerns among governments at all levels, property owners and other interests about the long term economic and environmental effects of low water levels in the upper Great Lakes. The second part of the investigation focuses on the formulation and evaluation of options for a new regulation plan for Lake Superior (IUGLS, 2012).

International Upper Great Lakes Study, Phase 1 – St. Clair River Study

In 2009, the findings of the (2007) investigation for the St. Clair was released, titled; Impacts on Upper Great Lakes Water Levels: St. Clair River (IUGLS, 2009). A bi-national Study Board directed the work of nearly 100 scientists and engineers from governments, academia and the private sector in both countries. The Study's Public Interest Advisory Group played a significant role in the Study's public information and engagement effort. The Study Board (IGULS, 2009) concluded that:

1. The difference in water levels between Lake Michigan-Huron and Lake Erie has declined by about 23 centimetres (cm) (9 inches) between 1963 (following the last major navigational channel dredging in the St. Clair River) and 2006.

2. Three key factors contributed to this 23 cm (9 inches) change:
    a. A change in the riverine conveyance (water-carrying capacity) of the St. Clair River accounts for an estimated 7 to 14 cm (2.8 to 5.5 inches) of the decline.
    b. Glacial isostatic adjustment (the uneven shifts of the earth's crust since the last period of continental glaciations ended) accounts for about 4 to 5 cm (1.6 to 2.0 inches) of the fall.
    c. Changes in climatic patterns account for 9 to 17 cm (3.5 to 6.7 inches); this factor has become even more important in recent years, accounting for an estimated 58 to 76 percent of the decline between 1996 and 2005.

    Determining the total decline is not as simple as adding up the estimates of the three contributing factors. These estimates are highly dependent on the choice of the specific time period being analyzed within the 1963-2006 timeframe.

3. There has been no significant erosion of the channel along the length of the St. Clair River bed since at least 2000. Based on survey data collected in 1971, there appears to have been some enlargement of the channel between 1971 and 2000 (likely during the high water episode in the mid 1980s). However, the changes in the channel are within the error of the surveys. In addition, there are issues regarding the reliability of the 1971 data.

    On the basis of these findings and in accordance with its mandate, the Study Board recommends that:

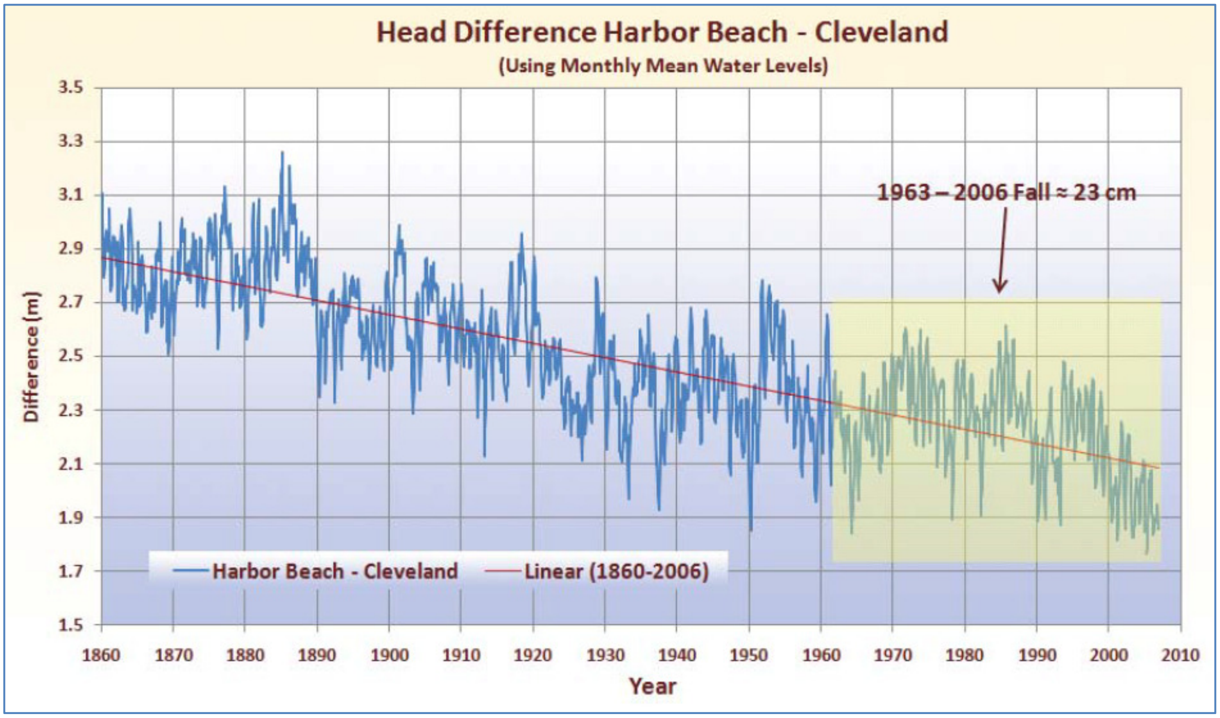
    a. Remedial measures (to address past damages or adverse effects) not be undertaken in the St. Clair River at this time.

b. The need for mitigative measures (to address possible future changes that might result in adverse effects) in the St. Clair River be examined as part of the comprehensive assessment of the future effects of climate change on water supplies in the upper Great Lakes basin in Report 2 of the Study, on Lake Superior regulation, to be completed in 2012.

The Study Board also developed a set of recommendations addressing specific challenges in data collection, modelling and data management and coordination. Implementation of these measures by governments will be an important part of the legacy of the Study, helping provide water resource managers and policy makers with the information they need to regulate the upper Great Lakes more effectively under a changing climate regime and for adaptive management purposes.

As discussed in Section 3.4.2, Canada and the United States have only a very limited ability to regulate lake levels in the upper Great Lakes – on the St. Marys River, where the IJC has regulated Lake Superior outflows within a rule-based operation since 1921. This limited capacity to regulate flows in such a huge basin means that the natural flow from Lake Michigan-Huron to Lake Erie through the St. Clair River, Lake St. Clair and the Detroit River is a key factor in determining water levels of the upper Great Lakes (IUGLS, 2009).

What drives the flow of the St. Clair River is the difference in the levels of Lake Michigan-Huron and Lake Erie (known as the head difference or the lake-to-lake fall). Figure 68 illustrates how this difference has changed considerably from 1860 to the present day and how it can even fluctuate from year to year. Records of annual mean water levels recorded at Harbor Beach, Michigan on Lake Huron (about 100 kilometres north of the lake's outlet) and Cleveland, Ohio on Lake Erie show that the head difference between the two lakes was about 2.9 metres (9.5 feet) between 1860 and 1880. The difference then decreased sharply through the turn of the century and generally continued to decline for more than 100 years (IUGLS, 2009).



Source: IUGLS, 2009.

Figure 68: The head difference (lake-to-lake fall) between Lake Michigan-Huron and Lake Erie

In 2008, the head difference was about 1.9 metres (6.2 feet). Between 1963 and 2006, the time period on which the study focused, the head difference declined by about 23 centimetres (cm). The study notes that there is a distinction between the actual head difference in individual years, which can vary from one year to the next, and the trend line shown in Figure 68, which represents the best linear fit to the changes in the measured data over the longer time period (IUGLS, 2009).

The connecting channels in the Great Lakes basin, including the St. Clair River, are subject to a range of physical forces, both natural and human-caused, that can contribute to changes in their conveyance (or water-carrying capacity). Natural forces can include sedimentation and bed erosion, aquatic vegetation growth or decline, fluctuations between extreme high and low water levels in the upper lakes, and seasonal ice cover and ice jams. Human activities can include mining, dredging, shoreline protection works and obstructions in the river, such as bridges and shipwrecks (IUGLS, 2009).

The IUGLS (2009) study notes that dredging has altered the natural state of the St. Clair River more than any other human activity. Dredging in the St. Clair River began in the late 1850s and has continued for the last 150 years. Most of this dredging was undertaken to support the rapid increase in commercial navigation on the Great Lakes. Additional material was removed in the early 1900s by commercial sand and gravel mining operations. These dredging projects were authorized by the

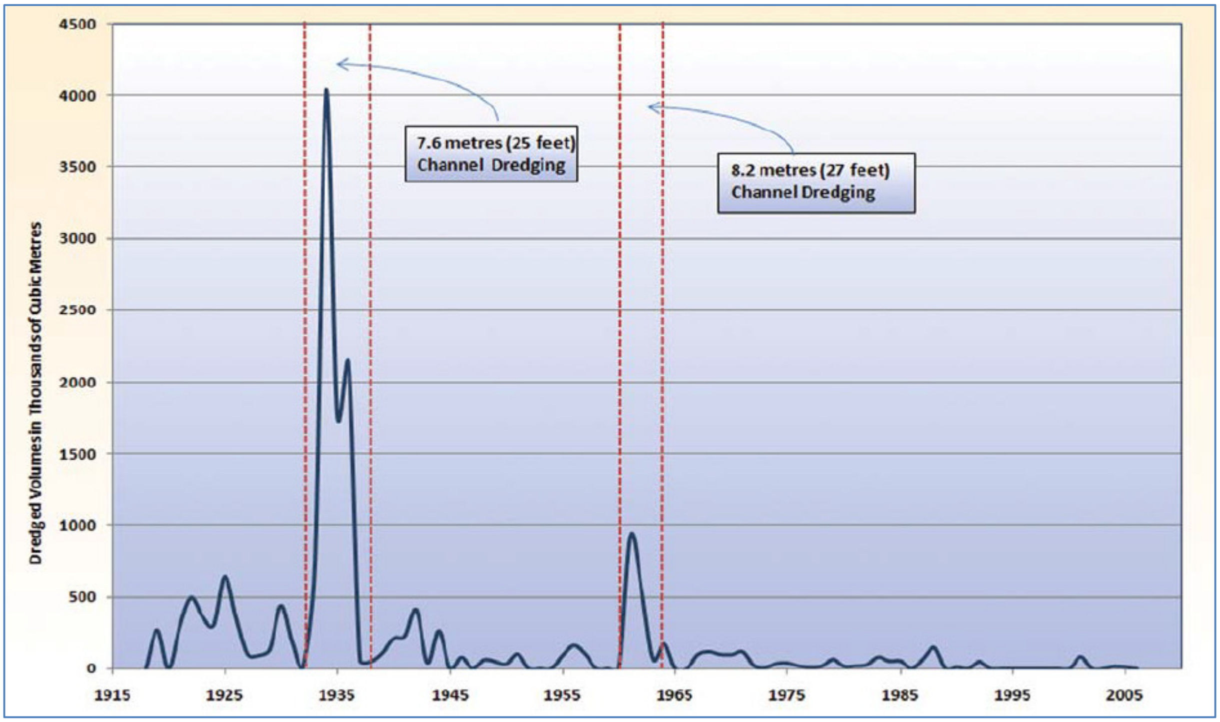
United States Congress, following consultation between Canada and the United States and approval of both countries.

The largest dredging activity ever undertaken in the river occurred between 1933 and 1936, when 8.4 million cubic metres (11 million cubic yards) of material were excavated to deepen the channel to 7.6 metres (25 feet). This volume accounts for one third of the total volume of dredging that has taken place in the St. Clair River over the last 150 years (IUGLS, 2009).

The last major dredging in the St. Clair River was undertaken between 1960 and 1962, when the navigation channel was deepened again to 8.2 metres (27 feet) throughout the entire river. The total volume of dredging during this period was about 1.5 million cubic metres (2 million cubic yards) of material. This volume represents only about 18% of the total volume dredged between 1933 and 1936, and accounts for about 27% of the total volume dredged since 1936. Most of the dredged material was deposited in various locations within the river where it would not impede navigation and therefore helped to maintain the cross sectional area of the river by offsetting the increased depth (IUGLS, 2009).

Since 1962, all dredging in the St. Clair River has been related to maintenance dredging. This work involves the removal of relatively small volumes of sediment and obstructions to restore the channel bottom to its authorized navigation channel depths (IUGLS, 2009).

Figure 69 illustrates the volume of dredging in the St. Clair River since 1918, and indicates the relative magnitude of the 7.6 metres (25 feet) and 8.2 metres (27 feet) dredging projects undertaken in 1933-1936 and 1960-1962, respectively.



Source: IUGLS, 2009.

Figure 69: Dredging volumes in the St. Clair River, 1918-2006

In the 1960s, Canada and the United States agreed to construct compensating works in the St. Clair River in response to water level concerns related to dredging of the channel, however, the works were never built. The Canadian government requested improved data flows (prior to the construction of these works), and during the time required to obtain this data, the Great Lakes region moved from record low water levels in the mid-1960s to record highs by the mid-1970s and record highs again in the mid-1980s (IUGLS, 2009).

International Upper Great Lakes Study, Phase 2 – Lake Superior Regulation Study

In the entire upper Great Lakes basin, water levels are affected by regulation at only one location upstream from Niagara Falls: at the outlet of Lake Superior on the St. Marys River. The IJC issued its first Orders of Approval in 1914 for hydropower development on the St. Marys River and the first Lake Superior regulation plan was implemented in 1921. Since then, the IJC has sought to incorporate new knowledge, data and modelling strategies to address the challenge of regulating water levels in the upper Great Lakes. In that sense, the existing Lake Superior regulation plan, 1977A, in effect since 1990, represents the culmination of nearly 75 years of regulation experience responding to changing economic, environmental and social conditions (IUGLS, 2012).

The rationale for reviewing the existing plan is based on several important factors that have emerged over the past 20 years since the current plan was implemented (IUGLS, 2012):

- First, there is considerable uncertainty about water supplies or net basin supplies and corresponding water levels in the Great Lakes basin in the future as a result of natural climate variability and human-induced climate change. Compounding uncertainty about net basin supplies are the impacts of glacial isostatic adjustment, the differential adjustment of the earth's crust that has the effect of gradually "tilting" the Great Lakes basin over time.
- Second, there is better information available today than 20 years ago about the hydrology and hydraulics of the Great Lakes. Researchers have more confidence in the newer models that describe how the system performs under a variety of conditions. New knowledge has also been gained through recent investigations, such as the Study's own analysis of the changes in the conveyance of the St. Clair River.
- Finally, there is improved information about the different sectors and public interest concerns that any new regulation plan must address. Under the Boundary Waters Treaty of 1909, the interests of domestic and sanitary water uses, navigation, and power and irrigation are given order of precedence. However, it is now recognized that in developing a new regulation plan, the needs of other interests, such as ecosystems, coastal zone uses, and recreational boating and tourism must be taken into account, as well.

The IJC's Directive to the Study Board called for an understanding of the key interests served by the upper Great Lakes system, an examination of the changing conditions in the water levels of that system, and the identification and evaluation of options to regulate water levels while balancing the needs of the interests. Addressing these closely related issues required a thorough analysis of past, present and projected future hydroclimatic conditions in the system and an effective approach to testing regulation options in relation to impacts on water levels and flows on the key water interests (IUGLS, 2012).

Future changes in water levels in the upper Great Lakes basin will affect a complex and interrelated network of individual, institutional and commercial interests. With this in mind, the Study commissioned detailed analyses of the current and emerging conditions and perspectives of six key interests likely to be affected by possible future changes in water levels in the upper Great Lakes basin (IUGLS, 2012).

- Domestic, municipal and industrial water uses;
- Commercial navigation;
- Hydroelectric generation;
- Ecosystems;
- Coastal zone; and
- Recreational boating and tourism.

The key findings of the study (IUGLS, 2012) are summarized below and further details are available in the online report (online link provided in Section 3.7).

1. **The Key Interests Served by the Upper Great Lakes System**
   Most of the key interests have demonstrated their capacity to adapt to changes in water level conditions that have been within historical upper or lower ranges. However, future water levels that are outside these ranges would require some interests to carry out more comprehensive and costly adaptive responses than any undertaken to date.
2. **Uncertainty in Future Upper Great Lakes Water Levels**
   Changes in the levels of the upper Great Lakes may not be as extreme in the near future as previous studies have predicted. Lake levels are likely to continue to fluctuate, but still remain within the relatively narrow historical range – while lower levels are likely, the possibility of higher levels cannot be dismissed. Both possibilities must be considered in the development of a new regulation plan.
3. **Lake Superior Regulation Plan 2012**
   The Study Board identified a regulation plan that will be more robust than the existing plan and that will provide important benefits related to the maintenance of Lake Superior levels, environmental impacts, economic benefits and ease of regulation.
4. **Restoration of Lake Michigan-Huron Levels**
   Restoration structures designed to raise Lake Michigan-Huron water levels would result in adverse effects on certain key interests served by the upper Great Lakes system.
5. **Multi-lake Regulation**
   The potential for multi-lake regulation to address extreme water levels is limited by the uncertainty regarding future climatic conditions and NBS, very high costs, environmental concerns and institutional requirements.
6. **Adaptive Management**
   Adaptive management has an important role to play in addressing the risks of future extremes in water levels in the upper Great Lakes, though it requires leadership and strengthened coordination among institutions on both sides of the international border.
7. **Public Concerns about Upper Great Lakes Water Levels**
   Public concerns about water levels in the upper Great Lakes differ strongly depending on geographical location.

On the basis of these seven key findings, the study (IUGLS, 2012) made two recommendations:

1. The IJC should approve Lake Superior Regulation Plan 2012 as the new plan for regulating Lake Superior outflow and advise governments that the 1977A plan will be replaced with the new plan.

2. The IJC should prepare and issue new integrated Orders of Approval that consolidate all of the applicable conditions and requirements of the original and Supplementary Orders, as

well as the additional considerations required to implement the recommended new plan, Lake Superior Regulation Plan 2012.

IJC Recommendations - A Report to the Governments of Canada and the United States

After reviewing the recommendations made by the International Upper Great Lakes Study Board, the IJC (2013) provided advice to the Governments of Canada and United States:

1. **Lake Superior Regulation Plan 2012 and an Updated Order of Approval**
   The Commission agrees with the Study Board recommendation to adopt Lake Superior Regulation Plan 2012 to replace Plan 1977A. The Commission also accepts the nine provisions recommended by the Study Board to be included in a new Order. The Commission will proceed immediately to prepare a Supplementary Order that incorporates these changes recommended by the Study Board.
2. **Multi-lake Regulation**
   The Commission supports the Study Board recommendation that multi-lake regulation not be pursued at this time.
3. **Restoration of Lake Michigan-Huron Levels**
   The Commission recommends that the Governments undertake further investigation of structural options to restore water levels in Lake Michigan-Huron by 13 to 25 cm (about 5 to 10 in). The low end of the range addresses compensation for the early 1960s channelization and the higher end would offset the additional change in conveyance capacity that has been estimated by the Study Board to have occurred since then.
   The Commission recognizes that the change in conveyance capacity since 1963 cannot be attributed directly to a particular human action and thus any restoration actions will warrant further deliberation by the Governments.
   The Commission encourages the Governments to focus on an option that would not result in a permanent restoration change that could exacerbate future high water levels, but rather one that could primarily provide relief during low water periods.
   The Commission also recommends that the Governments undertake a comprehensive benefit-cost analysis and a detailed environmental study that includes upstream and downstream impacts of potential structural restoration options as part of this more comprehensive investigation.
   Finally, the Commission recommends that the Governments undertake periodic bathymetric surveys along the full reach of the St. Clair River and its delta in order to better understand the conveyance issue in the St. Clair River.
4. **Adaptive Management and Great Lakes-St. Lawrence River Water Levels Advisory Board**
   The Commission supports in principle the Study Board's adaptive management recommendations, with the understanding that the Commission will provide its advice to

Governments on the scope and extent of the binational adaptive management plan after it has had the opportunity to review the Task Team's final report.

Through its Task Team, the Commission is also evaluating institutional arrangements and processes for administering the proposed plan, including the Great Lakes-St. Lawrence River Water Levels Advisory Board recommendation made by the Study Board. The Commission will provide its advice to Governments on these two remaining Study Board recommendations in mid-2013.

5. **Further Advice to Governments**

The Commission has been involved in two major studies over the last decade: the International Lake Ontario-St. Lawrence River Study and the International Upper Great Lakes Study. The Commission has learned many important lessons from undertaking these major efforts.

First, both of these studies greatly benefitted from an external independent peer review process. Therefore, the Commission proposes that independent peer review be an integral part of future bi-national studies. Independent peer review helps to ensure that the best science is put forward by a study and that the scientific process is transparent.

Secondly, the Commission recognizes that storing and maintaining access to the valuable data and information collected by these comprehensive and costly studies is an important investment. In the past, many of these study data and reports have been stored in multiple places and now are either lost or no longer readily accessible. The Commission has for the first time ensured that these important study data and information materials will be stored by the Commission itself. The Commission would like to draw attention to www.ijc.org, where all the data and reports associated with the Study are available and are linked to the Study Board's decision-making process. Storing and making accessible these data and information materials will greatly save time and costs for the Governments and other parties in the future.

Finally, it is clear to the Commission that conducting major periodic studies may not be the most prudent approach to addressing water level regulation, particularly in light of a changing climate and the continually evolving and advancing state of science. The Commission believes that conducting ongoing monitoring and analyses to address uncertainty, for example, through the proposed adaptive management approach, may be a better investment of the Governments' resources and provide more timely information for a wide range of decision-makers.

3.6 What can I do to help?

Listed below are resources that you can draw on to engage on the water levels issue:

1. Support the work of Georgian Bay Forever:
    - www.georgianbayforever.org
2. Support the work of Georgian Bay Association:
    - www.georgianbay.ca http://www.georgianbayforever.org/

3. Support the work of Restore Our Water International:
    - www.restoreourwater.com
4. Support the work of Stop the Drop:
    - www.stopthedrop.ca
5. Become involved in the work of the IJC by participating in public consultations and providing your perspective and/or comments on their reports/studies:
    - www.ijc.org/en_/The_IJC_and_You

3.7 Resources and Further Reading

1. Interactive Great Lakes Water Level Dashboard
    - www.glerl.noaa.gov/data/now/wlevels/dbd
2. The Great Lakes Information Network:
    - www.great-lakes.net/envt/water/levels/hydro.html
3. Great Lakes Commission – Water Use Database
    - http://glc.org/waterusedata/
4. Environment Canada's LEVELnews - a newsletter that provides a monthly update on Great Lakes - St. Lawrence River water levels.
    - www.ec.gc.ca/eau-water/default.asp?lang=En&n=F6F3D96B-1
5. The Union of Concerned Scientists' interactive website walks you through the water cycle, how people place pressure on our Great Lakes waters, and how things are expected to be modified under climate change.
    - www.ucsusa.org/greatlakes/wincycle/glwincyc_int.html
6. Studies by the International Joint Commission:
    - Main website for reports and publications
      www.ijc.org/en_/Reports_and_Publications
    - International Joint Commission's Advice to Governments on the Recommendations of the International Upper Great Lakes Study
      www.ijc.org/files/publications/IUGLS-IJC-Report-Feb-12-2013-15-April-20132.pdf
    - Impacts on Upper Great Lakes Water Levels: St. Clair River
      www.ijc.org/files/publications/ID1284.pdf
    - Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels
      www.ijc.org/files/publications/IUGLS_Lake_Superior_Summary_Report.pdf

4 Invasive Species

4.1 What is an Invasive Species?

Invasive alien species (IAS) are defined as plants, animals or micro-organisms that have been introduced by human action outside their natural past or present distribution, and whose introduction or spread threatens the environment, the economy, or society, including human health. Invasive species may originate from other countries, or from other ecosystems within Canada. They are not native to the ecosystems they threaten, and are often introduced to new ecosystems without the predators or pathogens of their native range. They typically exhibit rapid growth, reproduction and dispersal, making them highly destructive, competitive and difficult to control (MNR, 2012b).

Many IAS have become naturalized species in parts of Ontario; examples include zebra mussels, quagga mussels, and round goby. Naturalized invasive species are introduced species with self-sustaining populations unlikely to be eradicated that continue to pose a threat to our environment, economy or society. Managing naturalized invasive species involves measures to prevent their spread beyond existing ranges, developing techniques to adapt to their presence, and finding ways to reduce their impacts (MNR, 2012b).

4.2 What is the problem?

The invasive alien species problem is the result of a complex combination of economic, social, geographic, and environmental factors.

4.2.1 Aquatic Invasive Species

Since Canada is home to 20% of the world's fresh water and has one of the world's longest coastlines, the economic and environmental consequences of inaction are extreme. Few people are sufficiently aware of the nature and magnitude of the threat and, as a result, there is a widespread lack of compliance with voluntary practices and regulations designed to limit the spread of IAS resulting from human activity. Although applicable legislation and regulations exist in many cases, they have not always been adequately brought to bear on the problem. The consequences of invasive species becoming established include damage to sensitive ecosystems, as well as negative impacts on fishing, tourism, and other industries that form the backbone of local economies (DFO, 2004).

In addition to the primary effects, which can be seen shortly after a species becomes established, the alteration of such things as food webs and water quality can cause secondary impacts that take much longer to manifest. This further complicates the ability of agencies to manage invasive species. For example, the filter feeding activity of zebra mussels rapidly increased water clarity in the lower Great Lakes (as discussed in Section 2.1.3). Over a much longer period, the increased light penetration (due to clearer water) produced significant growth and spread of aquatic vegetation and increased the frequency and severity of toxic algal blooms (DFO, 2004).

Nearly twice as many aquatic invasions occurred during the second half of the 20th century (as compared to the first half) and recent data suggests that the pace is still accelerating. The increase in both the volume and speed of global trade, especially in the case of goods or vessels from countries with similar climates to Canada, has led to ever-higher risks of alien invasive species entering Canada – risks that are further exacerbated by insufficient surveillance and enforcement (DFO, 2004).

The largest single source of new alien aquatic species, estimated at about 75% in the Great Lakes region, is ballast water in ships. Water taken on in foreign ports, complete with local organisms, is discharged in Canadian waters, along with undesirable hitchhikers. Ballast tanks have been known to house up to several hundred different species. Globalization and internet-based commerce have also increased the intentional and unintentional importation of alien species for various purposes, some of which pose a threat if released into the wild. Not all invasive species come from overseas, some are native to North America but became harmful invasives because they were introduced beyond their natural range (DFO, 2004).

4.2.2 Invasive Plants and Plant Pests

Many of the important issues of recent decades have involved introductions of invasive plants or invasive plant pests, necessitating costly measures to control or eradicate unwanted species, restore habitats or crops damaged by the incursion, and recover markets for Canada's agriculture or forest products lost as a result of the weed or pest's presence. Billions of dollars are spent each year in North America on remedial actions to mitigate the impacts of invasive alien species. Expenses include costs of preventing introductions, controlling or eradicating pest populations, and restoring habitats after control measures have been implemented. Costs attributable to invasive alien species include loss of marketability, reduction in yield of harvestable crops, and increased costs of production due to pest effects, as well as losses in property value, increased fire-fighting costs and others (TPPWG, 2004).

Canada's annual timber losses due to invasive alien species are estimated at 61 million m^3, which is equivalent to $720 million in financial losses to stumpage, royalties and rent revenues (Kremar-Nozic et al., 2000). The present-day cost of the damage caused by invasive alien species affecting forestry and agriculture has been estimated to be $7.5 billion annually (Dawson, 2002).

Invasive alien plants and plant pests can also cause major environmental damage. According to the World Conservation Union invasive alien species are second only to habitat loss as a threat to biodiversity (IUCN, 2000). They alter ecosystem functions such as hydrology and natural succession, displace and reduce populations of native species, modify habitats and hybridize with native species. Their impact on native ecosystems and species is often severe and irreversible. It has been estimated that approximately 24% of the Species at Risk in Canada may be threatened with extinction by invasive alien species (Stronen, 2002).

4.2.3 Climate Change

Climate change is likely to increase the rate of new invasions into Ontario and promote the spread of already-established species (Rahel and Olden, 2008). A warming climate will increase environmental stresses, and may result in less resilient ecosystems that are unable to combat invasive species. MNR's (2012) Strategic Plan presents specific actions that can help Ontario manage and control invasive species in the context of a changing climate. For example, monitoring, eradication and control efforts must consider not only current conditions, but also how the future climate of a region could affect the spread and management of invasive species. Similarly, risk assessments may need to include analyses of our changing climate.

4.3 What is being done?

The ultimate goal of any invasive species plan must be to minimize (and ideally eliminate) both the introduction of new alien invasive species and the spread and impact of those already present in Canada. This includes prevention of unwanted introductions, early detection of potential invaders, rapid response to prevent establishment, and management to contain alien invasive species that have already become established. The basis for a Canadian plan requires a long-term approach that recognizes the relationship between a healthy environment and a sustainable economy (DFO, 2004).

By far the most effective way of controlling invasive species is to prevent their entry into Canada in the first place. This proactive approach will avoid increasing the existing burden of controlling species that have already established themselves, the cost of which is already many millions of dollars. Prevention efforts should address imports, exports and the movement of species within Canada. Specific activities include border control, inspection, enforcement, education and communication, risk analysis, and information management (DFO, 2004).

For species that have already been introduced, the focus turns to eradication, controlling their spread, or adaptive management. While early detection is possible for some species, the lag time between introduction and establishment is often measured in years or even decades. Regardless of when a new species is discovered, the Canadian plan must be able to respond quickly. A rapid response plan assesses all aspects of the introduction, including the potential for successful eradication or control (DFO, 2004).

Once a species becomes established, the task becomes much more challenging. Damage to local ecosystems may already have occurred such that complete eradication may no longer be feasible. Any control measures must be subject to comprehensive analyses in terms of their potential harmful effects on other species or the ecosystem as a whole (DFO, 2004).

The level of intervention should correspond proportionally to the level of threat. Control measures are currently hampered by inadequate resources, lack of coordination, and the absence of suitable control tools or the authority to use them (DFO, 2004).

Any management activities intended to eliminate invasive species must include a restoration component. A damaged ecosystem will not always be able to regenerate itself to its previous state and is more susceptible to subsequent invasion. This may involve taking an active approach in terms of encouraging native species to thrive. The healthier an ecosystem is, the more capable it is of resisting invasions (DFO, 2004).

In 2011, the Canadian Food Inspection Agency (CFIA), Fisheries and Oceans Canada, the Canadian Forest Service and the Ministry of Natural Resources formally agreed to coordinate their efforts to deal with invasive species. A key mechanism for this coordination is the Invasive Species Centre (ISC), a not-for-profit entity established in Sault Ste. Marie by Canada and Ontario. The Invasive Species Centre is a regional centre focusing on Ontario and the Great Lakes, with linkages to adjacent provinces and Great Lakes states. Federal, provincial and local governments currently spend billions of dollars responding to invasive species outbreaks. The role of the ISC is to facilitate and improve coordination, collaboration and decision-making on invasive species issues, so available resources can be used in the most effective and efficient manner (ISC, 2013).

4.3.1 Federal and Provincial Strategic Plans

World leaders have recognized the threat posed by invasive alien species since 1992, when they agreed on the UN Convention on Biodiversity. In response, Canada developed the 1995 Canadian Biodiversity Strategy, which recognized the need to conserve biodiversity and promote the sustainable use of biological resources through increased understanding, legislation, incentives and other means. In it, the federal, provincial and territorial governments expressed a commitment to take all necessary steps to prevent the introduction of harmful alien species and eliminate or reduce their effects on ecosystems (DFO, 2004).

In September 2001, federal, provincial and territorial ministers of forests, fisheries and aquaculture, endangered species and wildlife identified invasive alien species as a priority, calling for the development of a Canadian plan to deal with the threat. Later that year, a national workshop brought together numerous stakeholders to determine the basic approach and underlying principles for the Canadian plan (DFO, 2004).

In 2004, a national strategy called the Invasive Alien Species Strategy for Canada was released. The strategy identified key goals and implementation strategies for addressing the problem. Three thematic working groups undertook the task of producing corresponding action plans in three areas: 1) Aquatic Organisms; 2) Terrestrial Plants and Plant Pests; and 3) Terrestrial Animals and Animal Diseases (MNR, 2012b).

The federal strategy provides a framework under which provincial plans can be developed. The government of Ontario has prepared a provincial level strategic plan that provides details on how Ontario will meet the goals set out in the national strategy and national action plans. It also helps to inform priorities in provincial strategies aimed at control of particular species. Other provincial documents also address invasive species such as, the proposed Ontario Government Plan to

Conserve Biodiversity 2012 and Ontario's Draft Great Lakes Strategy 2012. In addition to these, the renewed Ontario's Biodiversity Strategy, 2011 acknowledges that invasive species are a leading cause of biodiversity loss (MNR, 2012b).

4.3.2 Great Lakes

Inter-jurisdictional discussions on Great Lakes issues, including invasive species, occur in a number of ways. The International Joint Commission (IJC) provides a forum for Canada, the United States and their respective Great Lakes provinces and states to discuss concerns about water quality and quantity in the "boundary waters" – the lakes and rivers shared by Canada and the United States. The IJC has established a number of Advisory Working Groups. One of those groups has produced a report entitled "Binational Aquatic Invasive Species Rapid-response Policy Framework" (MNR, 2012b).

The Great Lakes Water Quality Agreement (GLWQA), first signed in 1972, commits Canada and the United States to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes Basin ecosystem. It includes a number of objectives.

The Great Lakes Protection Act is proposed legislation that, if passed, aims to restore and protect the Great Lakes so they stay drinkable, swimmable, fishable, for present and future generations. Ontario's Draft Great Lakes Strategy is intended to describe how Ontario will focus a variety of tools to take action to achieve Great Lakes goals – through existing laws and programs, the Great Lakes Protection Act, 2012 (if passed), the Canada-Ontario agreement respecting the Great Lakes Basin Ecosystem (COA), and other partnerships and collaboration with many partners across Ontario and across the Great Lakes (MNR, 2012b).

The Canada-Ontario agreement respecting the Great Lakes Basin ecosystem (COA) is an agreement between the governments of Canada and Ontario to restore and protect the Great Lakes Basin ecosystem. COA is the primary mechanism through which Canada meets its obligations and commitments under the GLWQA. Reducing the threat of aquatic invasive species to the Great Lakes is a goal of the current COA (MNR, 2012b).

The Great Lakes Fishery Commission provides a binational forum for fisheries management in the lakes. Its five lake committees contribute to the development of management plans for their respective lakes. Some of these have aquatic invasive species on their agenda; some have aquatic invasive species forums (MNR, 2012b).

A variety of other committees support discussions on Great Lakes issues, including invasive species. These include the Great Lakes Fish Health Committee, the Council of Lake Committees, the Council of Great Lakes Fisheries Agencies, and the Law Enforcement Committee. The U.S. Fish and Wildlife Service, through the Great Lakes Commission (GLC), supports a Great Lakes panel on aquatic nuisance species, a forum to discuss activities (legislation, education, outreach, etc.) regarding aquatic nuisance species by Great Lakes states. Canada, Ontario and Quebec participate on this panel (MNR, 2012b).

Finally, Ontario also works with the federal government through forums such as the Canada-Ontario Fisheries Advisory Board and national bodies such as the Canadian Council of Fisheries and Aquaculture Ministers to address aquatic invasive species issues (MNR, 2012b).

4.3.3 Education to Change Public Attitudes and Behaviours

Since 1992, MNR has partnered with the OFAH to deliver the province-wide Invading Species Awareness Program, focusing on education and outreach, and programs designed to monitor the occurrence and distribution of invasive species. One of the program's key activities is to communicate to anglers the importance of not dumping bait into lakes and rivers. MNR and OFAH have conducted angler surveys every five years since the program was initiated, to determine whether it is having the desired impact. The results of the 2009 survey demonstrated a decline in the number of anglers that dump their bait and an increase in the number of boaters that clean their boat and equipment (MNR, 2012b).

4.3.4 Aquatic Invasive Species

The process of minimizing the effects of invasive species begins with understanding how they get into Canadian waters in the first place and how they spread once they are introduced. DFO's (2004) report on aquatic invasive species identifies and describes the main pathways: shipping, recreational and commercial boating, the use of live bait, the aquarium/water garden trade, live food fish, unauthorized introductions and transfers, and canals and water diversions. Developing a clear picture of the seven key pathways for introduction or spread provides the necessary information for taking effective action. While the seven pathways have been identified as primary sources for the introduction and spread of aquatic invasive species, the report notes that new pathways could be identified in the future, as a result of changing trade patterns or public interest. Readers are referred to DFO's report (listed in Section 4.6) for further information about each pathway.

Ballast water has long been known to be one of the main sources for the introduction and spread of aquatic invasive species in the Great Lakes and St. Lawrence River. In response, Canada and the United States have put in place stringent regulations governing ocean-going vessels and their ballast water. The 2006 regulations enacted by Transport Canada, and the 2008 regulations enacted by the St. Lawrence Seaway Development corporation, require ocean-going vessels to flush their tanks with salt water before entering the St. Lawrence Seaway and the Great Lakes. All vessels entering the seaway are checked through a joint U.S./Canadian inspection program and compliance rates in 2009 were recorded at 97.9% (Great Lakes Ballast Water Working Group, 2010). Any non-compliant vessels are dealt with on a case-by-case basis to ensure that unmanaged foreign ballast water is not released in the Great Lakes. Collectively, the Canadian and U.S. St. Lawrence Seaway regulations, along with monitoring, have significantly reduced the risk of aquatic invasive species entering via ship ballast tanks. If these regulations had been enacted earlier, they might have prevented many aquatic invasive species from entering the Great Lakes basin (MNR, 2012b).

4.3.5 Invasive Plants and Plant Pests

Pathways analysis is the first step in preventing the introduction of invasive alien species, and involves identifying the main pathways that facilitate their movement and dispersal. Studies in the United States and Australia, for example, have shown that most of their invasive plants were originally introduced intentionally, for ornamental or agricultural purposes. Literature on invasive plants introduced in Canada confirms the intentional introduction of plants for agricultural, ornamental or medicinal uses as one source of invasive alien species (Claudi et al., 2002). By contrast, plant pests are seldom intentionally introduced, but instead arrive as contaminants in commodity shipments or hitchhikers on vehicles and shipping containers. Weeds may also be introduced unintentionally, for example as contaminants of seed imported for planting. Pathways analysis is the tool used to identify and assess the different means by which species may be introduced to new areas and the relative likelihood of successful establishment occurring as a result. This allows subsequent pest risk assessments, research, and policy development to focus on priority high-risk pathways (TPPWG, 2004).

A comprehensive pathways analysis has not yet been conducted for invasive alien plants and plant pests in Canada. A preliminary pathways analysis conducted by the CFIA provides a broad overview of the main pathways of entry for plants and plant pests. The most significant pathway categories identified are: 1) live plants and plant parts; 2) viable seed; and 3) wood and forest products. These are primary pathways through which invasive plants or plant pests may be intentionally (though inadvertently) introduced and through which other plant pests may be accidentally introduced as contaminants. Other pathways by which invasive alien species may be introduced include tissue culture propagules such as potato micro-propagated plantlets and minitubers, and pathogen cultures imported for research, teaching or industrial purposes. Readers are referred to TPPWG's (2004) report for further information about each pathway.

4.4 Invasive Species in Ontario

Ontario has a higher risk of new invasive species entering and becoming established, compared to other regions in Canada. Historical data shows that Ontario has had more non-native species establish within its borders than other provinces and territories. Compared to other provinces, Ontario has the highest number of invasive plant species, with 441. This can be compared to Quebec, with 395; and British Columbia, with 368. The lowest numbers are in Nunavut, with 16 species (CFIA, 2008). Ontario also has the most non-native freshwater fish, with 26 known species. This is approximately twice as many as in each of the Maritimes, Québec, Alberta and Manitoba, and one and a half times as many as in British Columbia (Mills et al., 2000).

Ontario has been and will continue to be susceptible to invasive species arriving and surviving due to the favourable environmental conditions and nature of our society (industrialized, urbanized, locally and globally mobile, and high population density), our economy (large quantities of imports, significant goods-producing industry sector), our geographic location (proximity to a major international shipping channel, the Great Lakes St. Lawrence Seaway, and multiple land and water entry points on Ontario's borders), and the degraded habitat and ecosystems in many of Ontario's ecological regions. Ontario imports more goods, from more places in the world, than any other province or territory, and ships many goods onward to other parts of Canada. This economic activity brings both benefits and risks. More trade increases the chances of invasive species arriving inadvertently, for example in packaging, in containers on ships, or in ballast water. In fact, approximately 64% of the overseas containers that arrive in Canada are opened in the Ontario portion of the Great Lakes basin (MNR, 2012b).

There are a number of invasive alien species that are of concern to Ontario. This list includes species that are present in the province, as well as those that are at risk of being introduced. These invasive species pose a threat to Ontario's environment, economy and/or society. For more information about invasive alien species, please visit the following links:

- Terrestrial Invasive Species: www.mnr.gov.on.ca/en/Business/Biodiversity/2ColumnSubPage/STDPROD_068690.html
- Aquatic Invasive Species: www.mnr.gov.on.ca/en/Business/Biodiversity/2ColumnSubPage/STDPROD_068689.html

A selection of invasive alien species of concern to Georgian Bay is summarized below. To determine what invasive species are present in your region look at the distribution maps, prepared by the Ontario Invading Species Awareness Program, online:

- www.invadingspecies.com/resources/distribution-maps/

4.4.1 Zebra and Quagga Mussels

Since first being discovered in Lake St. Clair in the mid-1980s, the zebra mussel has become one of the most notorious invaders of Canadian waters. Originally from the Black and Caspian Sea area, it has spread throughout the Great Lakes and beyond. Zebra and quagga mussels both arrived in the ballast of ocean-going ships (DFO, 2004).

Significant changes to aquatic ecosystems have been documented as a result of the introduction of zebra and quagga mussels (as discussed in Section 2.1.3). These mussels filter out large amounts of phytoplankton. This filtering causes the water to become clearer allowing more sunlight to penetrate the water column. Changes in weed growth patterns occur and force some fish, such as walleye that are light sensitive, to find new habitat. In addition, when these mussels die and decompose, they add nutrients to the nearshore areas and this can cause nuisance algae blooms. These ecosystem alterations have caused problems for those who live in the coastal communities as well as industries and businesses that depend on these ecosystems (MNR, 2012b).

Zebra and quagga mussels also directly threaten native mussels by colonizing their shells and smothering them. The impacts are particularly pronounced in the lower Great Lakes. Zebra and quagga mussels have virtually eliminated native mussels from Lake Erie, Lake St. Clair, and the Detroit River, leaving only small populations in a few refuges (MNR, 2012b).

In addition to habitat changes and threats to native species, these invaders cause significant damage to human infrastructure by fouling water intake pipes or attaching themselves to other structures. Although there are ongoing efforts to find a mechanism to control zebra mussels, it is unlikely that this species will be completely eradicated from Ontario's waters due to its wide distribution. The zebra mussel invasion has had serious economic consequences:

- The total impact of Zebra Mussels in Ontario is estimated to be between $75–91 million per year (Marbek, 2010).
- The city of Windsor has spent between $400,000 to $450,000 per year for activated charcoal treatment to eliminate taste and odour problems from municipal water supplies after Zebra Mussels invaded lake St. Clair, upstream of the city's water intake line (Colautti et al., 2006).
- Zebra Mussels have cost Ontario power producers $6.4 million per year in increased control/operating costs and about $1 million per year in research costs (Colautti et al., 2006).

4.4.2 Sea Lamprey

Sea lamprey are considered a significant factor in the collapse of the lake trout and whitefish fisheries in the mid-1940s and 50s (as discussed in Section 2.2.6). Prior to sea lamprey entering the Great Lakes, Canada and the US harvested close to 6.8 million kgs (15 million lbs) of lake trout in Lakes Huron and Superior each year. By the early 1960s the annual catch was about 136,077 kgs (300,000 lbs), a significant 98% decrease. The sea lamprey control program, implemented in 1955, has successfully resulted in reducing sea lamprey populations by 90%. The combined average annual investment by Canada and the US in the sea lamprey control program is $22 million. Although this program has led to increased employment and growth in commercial fish stocks, the ongoing expense underscores the fact that the cost of prevention is far less than the cost of control and mitigation. If sea lamprey had been prevented from entering Canadian waters in the early 20th century, these annual, continuing costs would never have materialised. The combined economic value (in Canada and the US) of recreational and commercial fishing on the Great Lakes is currently estimated at about $4.5 billion (DFO, 2004).

4.4.3 Round Goby

The round goby is a small, bottom-dwelling invasive fish. Native to the Black and Caspian seas in eastern Europe, it was first found in North America in 1990 in the St. Clair River north of Windsor, Ontario. Researchers believe the fish was brought to North America in the ballast water of ships from Europe. In less than a decade the round goby has successfully spread through all five Great Lakes and has begun to invade inland waters. In some areas the fish has reached densities of more than 100 fish per square metre (MNR, 2012d).

Impacts of Round Goby (MNR, 2012d):

- The fish compete with and prey on native bottom-dwelling fish such as mottled sculpin (*Cottus bairdii*) and logperch (*Percina caprodes*). Round goby also threaten several species at risk in the Great Lakes Basin, including the northern madtom (*Noturus stigmosus*), the eastern sand darter (*Ammocrypta pellucida*), and several species of freshwater mussels.

- Round goby have reduced populations of sport fish by eating their eggs and young, and competing for food sources.
- Researchers believe the round goby is linked to outbreaks of botulism type E in Great Lakes fish and fish-eating birds. The disease is caused by a toxin that may be passed from zebra mussels, to goby, to birds, resulting in large die-offs of fish and birds.

4.4.4 Asian Carps

Asian carps were brought from Asia to North America in the 1960s and 70s. Since then they have migrated north through U.S. waterways towards the Great Lakes. Preventing Asian carps from spreading into the Great Lakes is the best way to prevent harm to Ontario's native fish species (MNR, 2011).

Asian carps prefer cool to moderate water temperatures, like those found near the shores of the Great Lakes. The Department of Fisheries and Oceans in collaboration with U.S. authorities, has recently completed a risk assessment affirming that all five Great Lakes are hospitable to Asian carp and that, if established, they will likely disrupt the native fishery, alter the ecosystem and create another food web. If Asian carps become established in Ontario waters, they would likely eat the food supply that our native fish depend on and crowd them out of their habitat. The decline of native fish species could damage sport and commercial fishing in Ontario, which brings millions of dollars a year into the province's economy (MNR, 2011).

The term "Asian carps" includes four species: Bighead, Silver, Grass and Black carp. Bighead carp and Silver carp are the species that have spread the most aggressively and can be considered one of the greatest threats to the Great Lakes. Silver carp are a hazard for boaters. The vibration of boat propellers can make Silver carp jump up to three metres out of the water. Boaters and water-skiers in areas of the Mississippi and Illinois rivers have been seriously injured by jumping fish (MNR, 2011).

In 2012, DNA from Asian carp species was found in the waters of Lake Erie. Environmental DNA extracted from water samples can be used to determine if a target species has been in the vicinity. The discovery was made by researchers with Notre Dame University's Environmental Change Initiative in Indiana. Genetic material was discovered at two locations: at the mouth of Maumee Bay in Michigan, and in Sandusky Bay in Ohio. The source of the DNA is unknown; it could have come from a live or dead fish, from the digestive system of a bird, or a rotting fish. Following this discovery (of the DNA), MNR conducted sampling on the Canadian side of the lake and the results were negative (no DNA of Asian carp was found) (Raveena, 2013).

In May 2013, an angler caught a grass carp (weighing 18.5 kg) close to the mouth of the Grand River, near Lake Erie. Lab tests revealed that the fish was sterile. According to Fisheries and Oceans Canada, several U.S. states allow the stocking of grass carp in order to control aquatic plants. The states also require the fish to be sterilized in order to prevent them from reproducing (CBC News, 2013).

Asian carps (Silver carp, Bighead carp, Grass carp, and Black carp) (MNR, 2011):

- Are successful invaders that have replaced native species in areas of the Mississippi River and its tributaries
- Make up more than 50 per cent of the fish by weight in some parts of the Illinois River
- Can grow more than 25 centimetres in their first year
- Typically weigh two to four kilograms, but can weigh up to 40 kilograms and reach more than a metre in length
- Can eat up to 20 per cent of their body weight in plankton each day
- Reproduce rapidly.

In May 2012, the federal government announced that it would allocate $17.5 million over the next five years to address prevention, early warning, rapid response, and management and control of this invasive species. In August 2012, MRN and the federal government announced they are joining the U.S. Asian Carp Regional Coordinating Committee, which brings together U.S. federal, state and local agencies to coordinate short-term action to stop Asian carp from migrating into the Great Lakes. Despite this progress, several organizations and agencies are concerned about the possibility of Asian carp entering the Great Lakes via the Chicago sanitary and ship canal. The Great Lakes Commission and Great Lakes-St. Lawrence Cities Initiative issued recommendations last January regarding the permanent separation of the Mississippi and Great Lakes basins. The propose creating this separation by upgrading the sewage, flood control and waterborne transportation infrastructure in the Chicago area. The estimated cost for this separation solution is between $3.2 and $9.5 billion. The proposal notes that the long-term benefits outweigh these initial costs; by preventing the migration of invasive species, there will be significant long-term savings in improved water quality, strengthened flood protection, and modernized shipping facilities. For example, approximately $500 million is spent annually to address zebra mussels (GBF, 2012).

4.4.5 Spiny and Fishhook Waterfleas

Spiny and fishhook waterfleas are small aquatic predators native to Eurasia. The first reports of spiny and fishhook waterfleas in North America were both in Lake Ontario – spiny waterflea in 1982 and fishhook waterflea in 1998. Both species were introduced to the Great Lakes in ballast water from ocean-going ships (MNR, 2012e).

Both waterfleas are species of zooplankton – small animals that rely on water currents and wind to move long distances. Spiny and fishhook Waterfleas prefer large, deep, clear lakes, but can also be found in shallower waters. Spiny waterfleas move to deeper, cooler waters during the day and swim towards the water surface at night to feed, while fishhook waterfleas stay near the surface (MNR, 2012e).

Impacts of spiny and fishhook waterfleas (MNR, 2012e):

- Researchers believe that spiny waterfleas are the greatest threat to the biodiversity and structure of native zooplankton communities on the Canadian Shield since acid rain.
- Because their main diet is zooplankton, they reduce food supplies for small fish and the young of sport fish such as bass, walleye and yellow perch.
- A few animals can quickly multiply into a large population.
- They are easily spread between waterbodies on angling equipment and bait buckets, and in live wells and bilge waters.
- Spiny waterflea introductions result in an average 30 to 40 per cent decline in native populations of zooplankton.
- Spiny and fishhook Waterfleas can affect recreational angling and commercial fishing. Their tail spines catch on fishing equipment, making it difficult to reel in lines, and clogging commercial nets and trawl lines.

4.4.6 Giant Hogweed

A large perennial native to the Caucasus Mountains in southwest Asia, giant hogweed has been widely introduced in Europe and North America as a garden curiosity. Present in Canada since at least the 1940's but currently expanding its range, it has spread widely and become a problematic weed in Ontario and B.C., and has recently been reported in Quebec, New Brunswick, Nova Scotia and Newfoundland. A serious weed that can out-compete native plant species, giant hogweed is difficult to control; in part because it produces a sap increases the sensitivity of the skin to sunlight. Contact with the sap can cause severe burns that blister and scar and sensitivity to sunlight may continue for years (MNR, Date unknown b).

4.4.7 Eurasian Water Milfoil

Eurasian water-milfoil is an invasive aquatic plant native to Europe, Asia and northern Africa. Introduced to North America in the 19th century, it is now one of the most widely distributed invasive aquatic plants on the continent. It may have been introduced through the aquarium trade or the ballast water of ships (MNR, Date unknown a).

Eurasian water-milfoil prefers shallow water one to three metres deep, but can root in up to 10 metres of water. A fast-growing perennial, it forms dense underwater mats that shade other aquatic plants. When large stands begin to die off in the fall, the decaying plants can reduce oxygen levels in the water (MNR, Date unknown a).

Impacts of Eurasian water milfoil (MNR, 2012b):

- The plant reduces biodiversity by competing aggressively with native plants.
- Reduced oxygen levels in the water caused by decomposing plants can kill fish.
- Thick mats of Eurasian water-milfoil can hinder recreational activities such as swimming, boating, and fishing.

- Dense stands can create stagnant water, which is ideal habitat for mosquitoes.
- Invasive species can also have an economic impact on individual landowners. A recent study shows that property values were depressed by as much as 16.4% for shoreline residences in Vermont affected with Eurasian water milfoil.

4.4.8 Phragmites

Invasive phragmites is an aggressive plant that spreads quickly and out-competes native species for water and nutrients. It releases toxins from its roots into the soil to hinder the growth of and kill surrounding plants. While it prefers areas of standing water, its roots can grow to extreme lengths, allowing it to survive in relatively dry areas (MNR, Date unknown c). Invasive Phragmites (MNR, Date unknown c):

- Crowds out native vegetation, thus resulting in decreased plant biodiversity.
- Generally provides poor habitat and food supplies for wildlife, including several Species at Risk.
- Grows very quickly thereby causing lower water levels as water is transpired faster than it would be with native vegetation.
- Increases fire hazards as stands are composed of a high percentage of dead stalks.
- Can affect agriculture, cause road safety hazard and impact recreational activities such as swimming, boating and angling.

Invasive phragmites has resulted in significant habitat losses for several species of wetland-dependent wildlife. Without effective control programs, declines are expected to continue to occur at an exponential rate (Bolton and Brooks, 2010).

MNR has been involved in invasive phragmites control pilot projects since 2007. This work focuses on the investigation of effective and efficient control options within sensitive coastal habitats such as wetlands and dunes. Projects are ongoing and some progress has been made within small, targeted, dry sites. Work to date demonstrates that control costs range between $865 and $1,112 per hectare (Gilbert et al., 2009a, Gilbert et al., 2009b).

4.4.9 Japanese Knotweed

Japanese Knotweed is an aggressive semi-woody perennial plant that is native to eastern Asia. In the 1800's it was introduced to North America as an ornamental species and also planted for erosion control. It has since spread throughout the United States and Canada (Ontario's Invading Species Awareness Program, Date unknown).

Japanese Knotweed is often mistaken for bamboo; however it is easily distinguished by its broad leaves and its ability to survive Ontario winters. Japanese Knotweed is especially persistent due to its vigorous root system, which can spread nearly 10 metres from the parent stem and grow through concrete and asphalt. This invader is very persistent and once it becomes established, is incredibly difficult to control (Ontario's Invading Species Awareness Program, Date unknown).

Impacts of Japanese Knotweed (Ontario's Invading Species Awareness Program, Date unknown):

- Spreads quickly, creating dense thickets that degrade wildlife habitats.
- Reduces plant biodiversity by competing with other native vegetation. Thick layers of decomposing stems and leaves on the ground make it difficult for native plant species to establish.
- Aggressive plant with a strong root system that has been known to break through asphalt and concrete.
- Plant populations are extremely persistent. Plants are able to survive severe floods and re-colonize areas.
- It can establish along riverbanks, where pieces of roots can break off and float downstream to start new populations.

4.4.10 Purple Loosestrife

Purple loosestrife arrived in Canada in the early 19th century. It is considered invasive as it forms dense monocultural stands over very large areas, threatening wetland habitat and communities. In 1992 the Canadian and U.S. governments approved the release of leaf-feeding beetles, galerucella calmariensis and g. pusilla, to control this invasive plant. Although purple loosestrife will never be eradicated, these insects have been effective in reducing loosestrife populations and enabling native vegetation to become re-established. Despite this successful control program, purple loosestrife is still considered invasive (MNR, 2012c).

4.4.11 Asian Long-horned Beetle

The Asian long-horned beetle is a forest pest native to several Asian countries that attacks and kills a wide range of hardwood trees. This invasive insect was found in an industrial park bordering Toronto and the city of Vaughan in 2003. Upon discovery of the beetle, the CFIA immediately initiated efforts to eradicate the insect, in partnership with several other agencies (MNR, 2010a).

- The majority of Canadian broadleaf trees are at risk from the Asian long-horned beetle, including all species of maple.
- They do not attack conifers.
- Canada 's temperate climate is well suited for the establishment of the insect as the larva spends winters deep within the wood protected from harsh winter conditions.
- The beetle has no known natural enemies within Canada's forests.
- Insecticides do not protect infested trees and only kill some beetles when applied to uninfested trees before attack.
- The only way to combat the beetle is to identify, cut down, and burn or chip the infested tree.
- Infested trees are also prone to secondary attack from other insects and diseases.
- The estimated potential economic impact to Canada is $9 billion in wood products and $100M in maple syrup products annually.

The CFIA lists certain areas as 'regulated' in order to slow the spread of the emerald ash borer. As of May 2013, there are two regulated areas in Ontario; Bruce County and Frontenac County. The movement of all ash tree materials and all firewood out of the regulated areas will be restricted. Updates to regulated areas are provided at this website:

- http://www.inspection.gc.ca/plants/plant-protection/insects/emerald-ash-borer/latest-information/eng/1337287614593/1337287715022?utm_source=FOCA+Elert+May+2013&utm_campaign=FOCA+Elert+16May2013&utm_medium=email

4.4.12 Emerald Ash Borer

Emerald Ash Borer is a highly destructive insect pest of ash trees Native to Asia, it was accidentally introduced to North America on imported wood packaging or crating material. Little information was known about the beetle at the time. Despite substantial research and control efforts, the beetle has continued to spread to new areas. Some of this spread has been natural dispersal, but the long distance spread has been helped by people, especially through the movement of nursery stock or infested firewood from infested areas (MNR, 2010b).

- The emerald ash borer is able to attack and kill healthy trees.
- All native ash species are at risk.
- Ash trees of all sizes are susceptible to attack, from 5 cm DBH (diameter at breast height) to 90 cm DBH or greater. Larvae have been found in branches as small as 1.1 cm in diameter.
- Ash trees are widespread in Canada and the United States, both in natural and urban settings, and green ash is one of the most commonly planted species in the urban forest.

It poses a major economic and environmental threat to urban and forested areas of Canada and the U.S containing ash trees. During the short time that it has been in North America, the emerald ash borer has killed over one million trees in southwestern Ontario. The City of Toronto estimates it will cost $37 million over five years to cut and replace the city-owned trees that are killed by the emerald ash Borer (MNR, 2012b). The Canadian Food inspection Agency has spent over $30 million and cut over 130,000 trees to slow the spread of the beetle (MNR, 2012c).

4.4.13 Pine Shoot Beetle

The pine shoot beetle is native to Europe, North Africa and Asia. It was first found in Ohio in 1992. Subsequent surveys since then have found the insect in 26 counties in southern Ontario, several locations in Quebec and over 180 counties across 8 states in the northeastern United States. Although the pine shoot beetle was first found in Ontario in 1992, it has probably been present for 10 or more years (MNR, 2010d).

Originally the pine shoot beetle was thought to be mostly a benign pest, causing limited damage to pines, primarily Scots pine. In 1998 the situation changed in Ontario; the pine shoot beetle was found to be attacking Scots pine and native pines in high numbers, resulting in tree mortality in several stands. Like many other introduced organisms it is thought to have arrived in North America through imports shipped using wooden crates, wooden pallets, or with logs used to brace loads (MNR, 2010d).

- This pest attacks both healthy and stressed trees.
- All native pines in Ontario are at risk, as well as Austrian, Scots and Mugo pines.
- Some current harvesting practices provide an excellent environment for this pest to reproduce.
- No practical insecticide treatment exists.
- The beetle attacks trees in 2 ways:
    - Adults attack 1-3 year old healthy shoots by tunneling in the pith towards the tip, resulting in shoot death.
    - Adults bore under the bark of the main stem of the tree, construct a brood chamber, mate and lay eggs. Developing larvae then feed on the cambium resulting in tree death by girdling.

4.4.14 Beech Bark Disease

Beech bark disease is currently spreading along eastern Georgian Bay, with recent outbreaks occurring in Killbear Provincial Park and Wasausking. The disease results from the combined action of the beech scale insect and a pathogenic fungus, Nectria coccinea. Most affected beech end up succumbing to the disease, either directly or as a result of being attacked by other pathogens. The beech scale insect is part of the scale family. In mid-summer, the female deposits her eggs (asexual reproduction) in the bark fissures. The larva hatches and stays in the same place or migrates to other cracks. In fall, the nymph becomes stationary again and secretes a woolly envelope. This woolly envelope makes the tree look like it is covered with snow. The scale insect over winters in the bark of the tree. The fungal spores are disseminated by rain splash or by the wind and penetrate into the tree through wounds created by the scale insect. The fungus first causes a depression in the bark of the affected region and cankerous blisters of various sizes also form. On severely affected trees, there are so many cankers that they end up merging. Tree mortality is often caused by other pathogens, such as Hypoxylon fungi, for example, or other insects (Forest Invasive Alien Species, 2011).

4.4.15 White Nose Syndrome

The condition has been dubbed "white nose syndrome" because some affected bats have visible rings of white fungus around their faces. The cause of the syndrome is believed to be *Geomyces destructans*, a fungus that grows in the skin of the bat, producing a white, fuzzy appearance on the muzzle, wings and ears. Infected bats emerge from torpor (the state of low physical activity characteristic of hibernating animals) more frequently than normal during winter hibernation, exhausting their energy reserves before food becomes available in the spring (MNR, 2012f).

White nose syndrome has killed more than five million bats in the northeastern U.S. It was first identified in a cave near Albany, New York, in 2006. Cases have also been found in more than a dozen American states as well as Quebec, New Brunswick and Nova Scotia. In March 2010, white nose syndrome was confirmed for the first time in Ontario (MNR, 2012f).

The ministry is concerned about the potential impact of white nose syndrome on Ontario's bat populations. Although the condition is not well understood, it is believed that human activity in caves is contributing to its spread. Therefore, the public is urged to refrain from entering non-commercial caves and abandoned mines where bats may be present. The public is also urged to refrain from entering any caves or abandoned mines in the United States or Canada where white nose syndrome has been identified (MNR, 2012f).

4.5 What can I do to help?

4.5.1 Aquatic invasive species

Here are a few ways you can help stop the spread of invasive species in Ontario:

- Inspect your boat, trailer and equipment after each use. Remove all plants, animals and mud before moving to a new waterbody.
- Drain water from your motor, live well, bilge and transom wells while on land.
- Rinse all recreational equipment with high pressure (>250 psi) or hot (50°C / 122°F) water OR let it dry in the sun for at least five days.
- Don't release any live fish into Ontario lakes, rivers or streams.
- Don't import live fish into Ontario.
- Learn how to identify invasive aquatic species and how to prevent the spread of these unwanted species. If you've seen an Asian carp or other invasive species in the wild please contact the toll free Invading Species Hotline at 1-800-563-7711.
- Never buy or use round goby as bait. It is against the law to use round goby as bait or to have a live round goby in your possession.
- If you catch a fish with a sea lamprey attached, do not return the sea lamprey to the water. Kill it and put it in the garbage.
- Don't help sea lampreys pass over dams and culverts that block their spawning migration.
- Have a fish pet that is no longer wanted? Don't release it into the wild and don't flush dead fish down the toilet. Put them in the garbage or compost.

4.5.2 Invasive plants and plant pests

- Gardeners should use only native plants and are encouraged to ask garden centres for plants that are not invasive. For helpful suggestions see:
    - www.invadingspecies.com/download/publications/brochures/Northern%20Grow%20me%20Instead%20ENG.pdf
    - www.evergreen.ca
- Learn how to properly identify invasive plants, such as Japanese knotweed, and how to effectively manage invasive plants on your property.

- www.invadingspecies.com/download/publications/Guides/Landowners%20Guide%20to%20Controlling%20Invasive%20Woodland%20Plants.pdf
- www.invadingspecies.com/download/publications/Guides/Quick%20Reference%20guide%20to%20Invasive%20plant%20species.pdf

- Already have an invasive species on your property? To learn about what to do if you find an invasive species on your property, read the species fact sheets available online:
  - www.ontario.ca/invasivespecies
- Do not dispose of invasive plants in the compost pile – discard them in the regular garbage or check with your municipality for disposal information.
- When hiking, prevent the spread of invasive plants and seeds by staying on trails and keeping pets on a leash.
- Going camping? Don't transport firewood. Buy it locally; leave what you don't use there.
- Learn how to identify Phragmites or common reed grass, and if found, follow the Best Management Practices to remove it:
  - www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@biodiversity/documents/document/stdprod_089643.pdf

4.6 Resources and Further Reading

1. Ontario's Invading Species Program
   - www.invadingspecies.com
2. Ontario Invasive Plant Council
   - www.ontarioinvasiveplants.ca
   - www.youtube.com/user/Oninvasives
3. Invasive Species Centre
   - www.invasivespeciescentre.ca
4. Government of Ontario
   - www.ontario.ca/invasivespecies
5. DFO's (2004) report on Aquatic Invasive Species
   - www.dfo-mpo.gc.ca/science/enviro/ais-eae/plan/plan-eng.htm

5 Species at Risk

5.1 What is a Species at Risk?

A "species at risk" is any naturally-occurring plant or animal in danger of extinction or of disappearing from the province. Species can become at risk due to a number of reasons. These include habitat fragmentation and loss, changing land use activities, persecution, as well as the spread of invasive species. For example, the creation of roads (as discussed in Section 2.4.3) along eastern Georgian Bay has resulted in habitat fragmentation and species mortality.

For the purposes of this report there are two acts that govern species at risk: 1) the federal Species at Risk Act (SARA); and 2) the provincial Endangered Species Act (ESA).

5.1.1 SARA

In 1992 the UN Conference on Environment and Development (the Earth Summit) was held in Rio de Janeiro, Brazil. The international community sought to address the problem of species loss and decline by passing the United Nations Convention on Biological Diversity (the "Rio Convention"). Article 8 of the Convention, which addresses "in situ" or "on the ground" conservation, includes the specific commitment to pass legislation for the protection of species at risk (Smallwood, 2003).

Although Canada was the first industrialized nation to ratify the Rio Convention, it took Canada nearly a decade to address this commitment. Bill C-5, the Species at Risk Act ("SARA"), was the government's fourth attempt at passing endangered species legislation. SARA passed through the Senate without amendment on December 12, 2002 and received Royal Assent the same day (Smallwood, 2003).

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other design designatable units that are considered to be at risk in Canada. COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees (MNR, 2013b).

SARA is a law that is largely restricted to federal lands, aquatic species and migratory birds under the Migratory Birds Convention Act. The majority of species listed under the Act will only be protected if they are found on federal land – a mere 5% of Canada outside the territories. Therefore the jurisdiction of species at risk in Ontario is via the ESA administered by the Ministry of Natural Resources (Smallwood, 2003).

5.1.2 ESA

Ontario's original Endangered Species Act (ESA) was written back in 1971. Since then there have been changes in the province; changes in land and resource use, planning processes, and increasing threats to native species. Therefore it was deemed to be time for updated legislation and the new

Endangered Species Act was passed on May 16, 2007. The ESA is binding on everyone including individuals, businesses, municipal governments and the provincial government (MNR, 2013b).

The purposes of the ESA are to (MNR, 2013b):

- Identify species at risk based on the best available scientific information, including information obtained from community knowledge and Aboriginal traditional knowledge.
- Protect species that are at risk and their habitats, and promote the recovery of species that are at risk.
- Promote stewardship activities to assist in the protection and recovery of species that are at risk.

In Ontario, species that may be at risk are reviewed by a team of experts known as the Committee on the Status of Species at Risk in Ontario (COSSARO). COSSARO can be made up of people with expertise in certain scientific disciplines, or Aboriginal Traditional Knowledge. COSSARO has been around since 1995, but under the new ESA it is now a legally recognized committee. COSSARO is an independent body that can be made up of up to 11 members from both the public and private sectors. At least 5 members must be from outside of the Ontario Government. The Minister of Natural Resources may make recommendations on committee members, but the final decision on who can be a member is made by the Lieutenant Governor in Council. Once classified as "at risk", they are added to the Species at Risk in Ontario (SARO) list (MNR, 2013b).

The four categories, or classes, of "at risk" are (MNR, 2013b):

- Extirpated - a native species that no longer exists in the wild in Ontario, but still exists elsewhere (e.g. greater prairie chicken).
- Endangered - a native species facing extinction or extirpation (e.g. spotted turtle).
- Threatened - a native species at risk of becoming endangered in Ontario (e.g. massasauga rattlesnake).
- Special Concern - a native species that is sensitive to human activities or natural events which may cause it to become endangered or threatened (e.g. monarch butterfly).

If a species is listed on the SARO list as an extirpated, endangered or threatened species, it receives protection under section 9 of the ESA. If a species is listed as an endangered or threatened species, its habitat also receives protection under section 10 of the ESA (MNR, 2013b).

Recovery strategies identifying steps to protect and restore populations are developed within one year for endangered species and within two years for threatened species. A recovery strategy provides the best available scientific knowledge on what is required to achieve recovery of a species. A recovery strategy outlines the habitat needs and the threats to the survival and recovery of the species. It also makes recommendations on the objectives for protection and recovery, the approaches to achieve those objectives, and the area that should be considered in the development of a habitat regulation. Species-specific habitat regulations that describe an area to be protected are developed one year after the recovery strategy (MNR, 2013b).

5.2 What is at risk in eastern Georgian Bay?

There are over 200 species at risk are in Ontario and one fifth of those species are found in Parry Sound and Muskoka. Eastern Georgian Bay supports a rich variety of wildlife. This is a reflection of the varied types and quality of habitats available on the shoreline. The combination of wetlands, lakes, rock barrens and mixed forests support many species of breeding birds, unique plants and the greatest diversity of viable reptile populations in Ontario. For example, eastern Georgian Bay is one of a few areas in North America where the threatened eastern foxsnake and massasauga rattlesnake find refuge. Furthermore, the entire Ontario population of a threatened plant called branched bartonia is found in local wetlands.

There are 43 species at risk in the *State of the Bay* report card area (the total is calculated using both COSSARO and COSEWIC listings). These species are listed in Table 13 and Figure 70 illustrates the breakdown of these species by taxonomic group.

Table 13: Species at risk in the *State of the Bay* report card area

Taxonomic Group	Common Name	Latin Name	COSSARO	COSEWIC
Amphibians	Western Chorus Frog	*Psuedacris triseriata*	-	THR
Birds	Bald Eagle	*Haliaeetus leucocephalus*	SC	-
	Barn Swallow	*Hirundo rustica*	THR	THR
	Black Tern	*Chlidonias niger*	SC	-
	Bobolink	*Dolichonyx oryzivorus*	THR	THR
	Canada Warbler	*Wilsonia Canadensis*	SC	THR
	Cerulean Warbler	*Dendroica cerulean*	THR	END
	Chimney Swift	*Chaetura pelagic*	THR	THR
	Common Nighthawk	*Chordeiles minor*	SC	THR
	Eastern Meadowlark	*Sturnella magna*	THR	THR
	Eastern Wood-Pewee	*Contopus virens*	-	SC
	Golden-winged Warbler	*Vermivora chrysoptera*	SC	THR
	Least Bittern	*Ixobrychus exilis*	THR	THR
	Olive-sided Flycatcher	*Contopus cooperi*	SC	THR
	Red-headed Woodpecker	*Melanerpes erythrocephaleus*	SC	THR
	Rusty Blackbird	*Euphagus carolinus*	-	SC
	Whip-poor-will	*Caprimlugus vociferus*	THR	THR
	Wood Thrush	*Hylocichla mustelina*	-	THR
Fish	Lake Sturgeon	*Acipenser fulvescens*	THR	THR
	Northern Brook Lamprey	*Ichthyomyzon fossor*	SC	SC
	Silver Lamprey	*Ichthyomyzon unicuspis*	-	SC
Insects	Monarch	*Danaus plexippus*	SC	SC
	West Virginia White Butterfly	*Pieris virginiensis*	SC	-
Mammals	Eastern Wolf	*Canis lupus lycaon*	SC	SC
	Little Brown Myotis	*Myotis lucifugus*	END	END
	Northern Myotis	*Myotis septentrionalis*	END	END
	Tri-colored Bat	*Perimyotis subflavus*	-	END

Taxonomic Group	Common Name	Latin Name	COSSARO	COSEWIC
Plants	Branched Bartonia	*Bartonia paniculata*	THR	THR
	Broad Beech Fern	*Phegopteris hexagonoptera*	SC	SC
	Butternut	*Juglans cinerea*	END	END
	Engelmann's Quillwort	*Isoetes engelmannii*	END	END
	Forked Three-awned Grass	*Aristida basiramea*	END	END
Reptiles	Blanding's Turtle	*Emydoidea blandingii*	THR	THR
	Common Map Turtle	*Graptemys geographica*	SC	SC
	Common Snapping Turtle	*Chelydra serpentine*	SC	SC
	Eastern Foxsnake	*Pantheropis gloydi*	THR	END
	Eastern Hog-nosed Snake	*Heterodon platirhinos*	THR	THR
	Eastern Milksnake	*Lampropeltis triangulum*	SC	SC
	Eastern Musk Turtle	*Sternotherus odoratur*	THR	SC
	Five-lined Skink	*Plestiodon fasciatus*	SC	SC
	Massasagua Rattlesnake	*Sistrurus catenatus*	THR	THR
	Northern Ribonsnake	*Thamnophis sauritus*	SC	SC
	Spotted Turtle	*Clemmys quattata*	END	END

END = Endangered, THR = Threatened, SC = Special Concern, - = Not listed

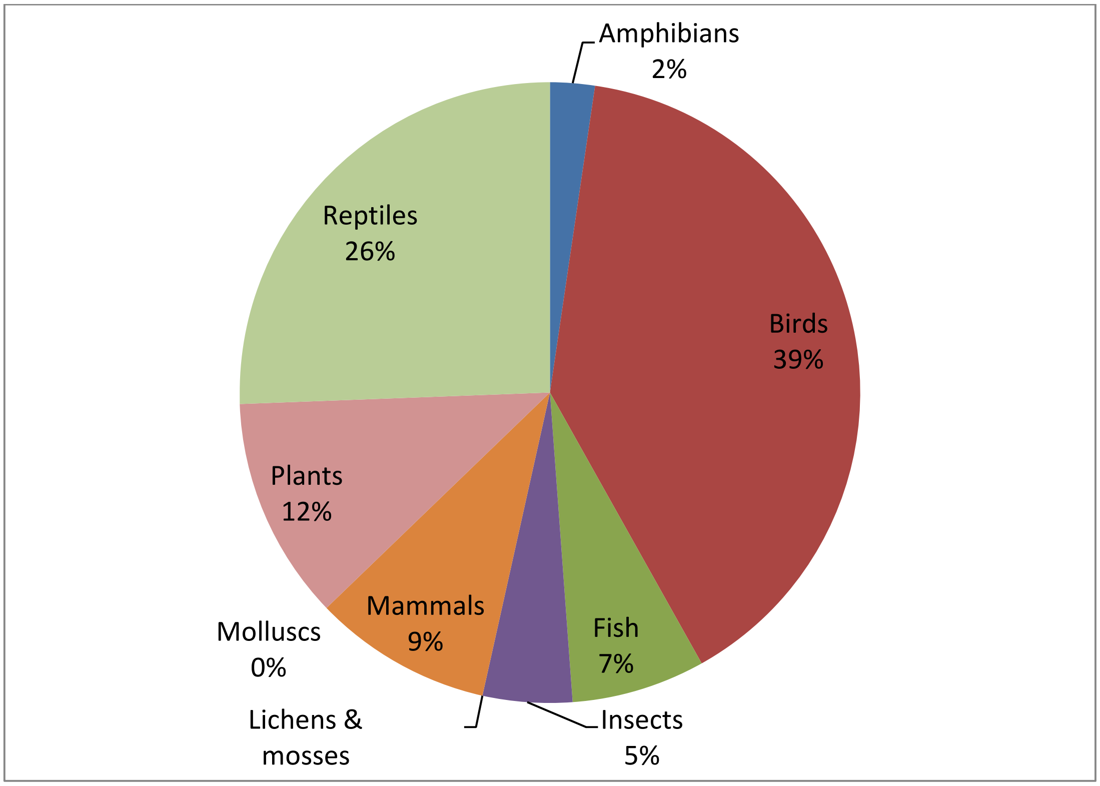


Figure 70: Breakdown of species at risk by taxonomic group

5.3 What can I do to help?

Here are a few ways you can help species at risk in Ontario:

- Learn more about SAR in eastern Georgian Bay.
  - www.gbbr.ca/our-environment/species-at-risk/
- Report your sightings of at-risk species to improve knowledge of species range.
  - www.gbbr.ca/our-environment/species-at-risk/report-a-sighting/
- Download Ontario Nature's Reptile & Amphibian Atlas App that identifies Ontario's reptiles and amphibians, lets you submit sightings to the Reptile and Amphibian Atlas, and also stores a record of your sightings.
  - www.ontarionature.org/protect/species/app.php
- Create habitat for wildlife on your property – plant a butterfly or wildflower garden with native plants and trees, maintain brush piles, let some grass grow uncut, or participate in a local habitat restoration project. Check out the *Life on the Bay Stewardship Guide* for more information on natural landscaping.
  - www.gbbr.ca/our-environment/life-on-the-bay-guide/
- Watch out for wildlife on roads and waterways. If safe to do so, please move a turtle off the road and try to place them in the direction they were traveling.
- Keep your cat indoors. Feral and domestic cats roaming outside kill more birds than any other human activity!
- Become knowledgeable of invasive species and act to limit their spread.
  - www.invadingspecies.com

5.4 Resources and Further Reading

- Species at Risk in the Georgian Bay Biosphere Reserve:
    - www.gbbr.ca/our-environment/species-at-risk/
- Species at Risk (SARA) Public Registry:
    - www.sararegistry.gc.ca/default_e.cfm
- MNR's Ontario Species at Risk Program:
    - www.mnr.gov.on.ca/en/Business/Species/index.html
- DFO's Aquatic Species at Risk:
    - www.dfo-mpo.gc.ca/species-especes/index-eng.htm
- COSWEIC
    - www.cosewic.gc.ca/eng/sct5/index_e.cfm
- ROM's Ontario Species at Risk:
    - www.rom.on.ca/ontario/risk.php

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7 Acronyms and Abbreviations

Acronym / Abbreviation	Definition
BMP	Best management practices
CCA	Canonical correspondence analysis
CCGCM	Canadian Coupled Global Circulation Model
CFIA	Canadian Food Inspection Agency
cfs	Cubic feet per second
cms	Cubic metres per second
CO_2	Carbon dioxide
COA	Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COSSARO	Committee on the Status of Species at Risk in Ontario
CPUE	Catch per unit effort
DFO	Department of Fisheries and Oceans
DO	Dissolved oxygen
EC	Environment Canada
EGBSC	Eastern Georgian Bay Stewardship Council
ESA	Endangered Species Act
ESTN	Early Spring Trap Netting
FRI	Forest Resources Inventory
GBA	Georgian Bay Association
GBBR	Georgian Bay Biosphere Reserve
GBF	Georgian Bay Forever
GBINP	Georgian Bay Islands National Park
GBLT	Georgian Bay Land Trust
GIS	Geographic Information System
GLC	Great Lakes Commission
GLCWC	Great Lakes Coastal Wetland Consortium
GLERL	Great Lakes Environmental Research Laboratory
GLNA	Great Lakes Nearshore Assessment
GLNS	Great Lakes Navigation System
GLWQA	Great Lakes Water Quality Agreement
ha	Hectare
HM	High marsh
IAS	Invasive alien species
IGLD	International Great Lakes Datum
IJC	International Joint Commission
IKONOS	IKONOS is a commercial earth observation satellite, and was the first to collect publicly available high-resolution imagery at 1- and 4-meter resolution
ISC	Invasive Species Centre
LM	Low marsh
LPP	Lake Partner Program

Acronym / Abbreviation	Definition
MCWI	McMaster Coastal Wetland Inventory
MHF	Muskoka Heritage Foundation
MNR	Ontario Ministry of Natural Resources
MoE	Ministry of the Environment
MTA	metric tonnes per annum
MWC	Muskoka Watershed Council
NCC	Nature Conservancy of Canada
OBM	Ontario Base Map
ppmv	parts per million by volume
RAP	Remedial Action Plan
RES	Riverstone Environmental Solutions Inc.
SARA	Species at Risk Act
SotB	State of the Bay
TP	Total phosphorus
UN	United Nations
UNESCO	United Nations Scientific, Educational and Cultural Organization
UP	Upstream wetland
USACE	United States Army Corp of Engineers
VAPS	Volunteer Aquatic Plant Survey
WMI	Wetland Macrophyte Index
WQI	Wetland Quality Index
µg/L	micro gram per litre

8 Glossary

Word	Definition
Advection (in a water context)	Horizontal movement of water.
Alkalinity	Acid neutralizing or buffering capacity of water; a measure of the ability of water to resist changes in pH caused by the addition of acids or bases.
Ambient	Of or relating to the immediate surroundings of something: "ambient temperature".
Anoxia	Condition of being without dissolved oxygen (O_2).
Anoxic	Completely lacking in oxygen.
Atmospheric deposition	Sedimentation of solids, liquids, or gaseous materials from the air.
Benthic	Refers to being on the bottom of a lake.
Biodiversity	The number and variety of organisms in a particular habitat or ecosystem.
Chlorophyll	A green pigment, present in all green plants and in cyanobacteria, responsible for the absorption of light to provide energy for photosynthesis.
Cladophora	Scientific term for green algae (non-toxic).
Coastal wetland	Wetlands that occur within 2 km of the 1:100 year floodline of the Great Lake/channel shoreline, and include all four wetland types (bog, fen, swamp, and marsh) identified in the Ontario Wetland Evaluation System.
Conductivity	The degree to which a specified material conducts electricity, calculated as the ratio of the current density in the material to the electric field that causes the flow of current.
Cyanobacteria	Scientific term for blue-green algae (toxic).
Dimictic lake	Lakes with a pattern of two mixing periods.
Dissolved organic carbon	Dissolved organic carbon (DOC) is a broad classification for organic molecules of varied origin and composition within aquatic systems.
Dissolved oxygen	The concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odors.
Dreissenid mussels	Zebra and quagga mussels (both of which are invasive species).
Ecosystem	A system that includes all living organisms in an area as well as its physical environment functioning together as a unit.
Ecosystem resilience	Ecosystem resilience is the ability of the ecosystem to recover from negative impacts.
Ecosystem resistance	Ecosystem resistance is the ability of a given ecosystem to withstand negative impacts.

Word	Definition
Embayment	A recess in a coastline forming a bay.
Epilimnion	The upper layer of water in a stratified lake.
Eutrophic lake/water body	A very biologically productive type of lake due to relatively high rates of nutrient input.
Eutrophication	A process by which a body of water acquires a high concentration of nutrients, especially phosphorus and nitrogen.
Evapotranspiration	Evaporation from plant leaves.
Hypolimnion	The layer of water in a thermally stratified lake that lies below the thermocline, is non-circulating, and remains perpetually cold
Invasive alien species	Invasive alien species are species of plants, animals, and microorganisms introduced by human action outside their natural past or present distribution.
Isostatic rebound	The 'bounce back' of the earth's crust following the retreat of the glaciers during the last ice age.
Limnology	The study of the biological, chemical, and physical features of lakes and other bodies of fresh water.
Littoral	Nearshore out from shore to the depth of the euphotic zone where it is too dark on the bottom for macrophytes to grow.
Macrophyte	A member of the macroscopic plant life especially of a body of water.
Median	Denoting or relating to a value or quantity lying at the midpoint of a frequency distribution of observed values or quantities.
Mesotrophic	Moderately productive; relating to the moderate fertility of a lake in terms of its algal biomass.
Metalimnion	The middle layer of a thermally stratified lake or reservoir.
Morphometry	The quantitative measurement of the form especially of living systems or their parts.
Net basin supply	Net water supply in the basin resulting from precipitation on the lakes' surfaces, runoff from their tributary drainage areas, groundwater flow into or out of the lakes, and evaporation.
Oligotrophic	Having a deficiency of plant nutrients that is usually accompanied by an abundance of dissolved oxygen.
Pelagic	Of, relating to, or living or occurring in the open water.
pH	Potential hydrogen: negative 10-base log (power) of the positive hydrogen ion concentration; measure of acidity.
Phytoplankton	Photosynthetic or plant constituent of plankton; mainly unicellular algae.
Secchi disk	A circular disk used to measure water transparency.
Seiche	A temporary disturbance or oscillation in the water level of a lake, esp. one caused by changes in atmospheric pressure.
Species at Risk	Species at Risk refers to any naturally-occurring plant or

Word	Definition
	animal in danger of extinction or of disappearing from the province. Once a species is classified as “at risk”, it is added to the Species at risk in Ontario list
Thermal stratification	A process whereby layering occurs in the water column due to temperature-dependent density gradients.
Thermocline	The middle layer of a thermally stratified lake or reservoir.
Trophic	Of or relating to nutrition.
Watershed	A region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water.
Wetland	Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface.

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