State of the Bay

Water Quality Indicator Update

Nutrient Monitoring in the Georgian Bay Biosphere Reserve

Photo credit: thom morrissey photography

Final version, October 2015

Prepared by:
Bev Clark
David Bywater
Becky Pollock
Greg Mason

Government of Canada / Gouvernement du Canada

With support from Environment Canada's Lake Simcoe/South-eastern Georgian Bay Clean-Up Fund (LSGBCUF)

Table of Contents

List of Figures

List of Tables

I – Background

Along eastern Georgian Bay, water quality monitoring programs are conducted by: all levels of government, from federal to municipal; first nations; non-governmental organizations (NGO); and volunteers / citizen scientists. The scope of these monitoring programs differs depending on scale, objectives, parameters, and monitoring frequency.

Given the diversity of individuals, organizations, and entities involved in water quality monitoring, assessment and management, there is an identified need for both (a) better coordination and (b) more monitoring activities at the local level to complement the work of other partners. Overall goals are therefore to: improve the coordination of existing water quality monitoring programs in order to enhance monitoring at a local scale, eliminate redundancies, and ensure that programs use regionally comparable protocols and methodologies. First steps towards these goals are to examine existing nutrient monitoring programs and their outcomes in detail. Only then can we identify gaps, opportunities, redundancies and ways to better harmonize the current suite of tiered nutrient monitoring programs (programs that involve different levels of administrative oversight).

Essentially, we are working with water quality monitoring partners to make existing programs complementary and to avoid redundancy.

The Need for Nutrient Monitoring

Early in the 1970s the scientists at the Experimental Lakes Area (ELA) proved that phosphorus (P) was the nutrient controlling algal growth in most temperate lakes. At that time there was evidence that anthropogenic phosphorus additions to surface water were causing increased phosphorus concentrations (eutrophication) which in turn led to algal blooms and decreased oxygen concentrations in bottom waters. This was due in part to phosphates in detergents, poor phosphorus removal in sewage treatment facilities and improper watershed land use practices. Phosphorus reductions were required to mitigate water quality problems that had developed in the Great Lakes (Lake Erie, Severn Sound, Bay of Quinte, and St. Lawrence River) (Beeton, 1965) and in several inland lakes including Lake Simcoe. In Lake Simcoe it was shown that increased productivity due to P loading had degraded the oxygen climate in bottom waters which resulted in a loss of optimal habitat for Lake Trout and other cold water stenotherms (e.g. Lake Trout and Whitefish).

Programs to reduce phosphorus loads to surface water have been implemented since the 1970s which has led to improvements in many water bodies although problems have returned to some areas (Lake Erie) in recent years. Generally the loads from sewage treatment plants have been greatly reduced and there are fewer point sources of phosphorus compared to those noted prior to the 1970s.

Diffuse loads from agriculture and stormwater sources remain, but are also improved in many areas compared to the past. Much progress has been made to reduce phosphorus inputs to surface water in Ontario but it is important to continue to work towards established targets.

There is some evidence that phosphorus concentrations in inland lakes have decreased in recent years for reasons other than those attributed to reduced anthropogenic loads. The concentrations of P in the open water areas of Georgian Bay are also presently very low (Howell, pers. comm.) and this may be reason to believe that there is P limitations beyond background levels. In a draft report (2014) Dove and Chapra make the following observation:

> *"The significant decline of total phosphorus in all the Great Lakes is an important finding. Others have noted oligotrophication for lakes Michigan and Huron (e.g., Evans et al., 2011; Barbiero et al., 2011, 2012) and Lake Ontario (e.g., Dove, 2009), but this is the first evidence of the gradual ultraoligotrophication of Lake Superior. We have previously noted other significant long-term water quality changes in Lake Superior, including strongly increasing trends in calcium, sodium and sulfate (Chapra et al., 2012). Increasing trends of nitrate have also been previously noted (Bennett 1986; Sterner et al., 2007; McDonald et al., 2010). However, a significant decline in total phosphorus is a new and surprising finding."*

The reasons for P declines however are poorly understood and further research is necessary before an informed management direction can be recommended.

Finally, it should be noted that nutrient monitoring in almost all cases refers to phosphorus monitoring. Although nitrogen plays a role in ecosystem productivity there is rarely a case where it is shown to control the growth of algae and fewer still are examples of eutrophication problems that have been solved through nitrogen controls (Shindler, 2015).

II – The Georgian Bay Biosphere Reserve

Description

The Georgian Bay Biosphere Reserve (GBBR) is a large parcel of land and water that encompasses the eastern Georgian Bay shoreline including the watersheds, lakes, islands, enclosed bays and both nearshore and offshore open water areas (Figure 1).

Designated by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2004, the Georgian Bay Biosphere Reserve is an area of 347,000 hectares that stretches 200 km along the eastern coast from Port Severn to the French River, in the world's largest freshwater archipelago, also known as the 30,000 Islands. The unique geography and geology of the area create more than 1,000 distinct habitat types which support a variety of rare species, including plants, mammals, birds, reptiles and amphibians. Visitors can explore a mosaic of open waters, sheltered bays, coastal wetlands, exposed

bedrock shores, sand and cobble beaches, riparian vegetation and upland forests.

The Georgian Bay Biosphere Reserve model aims to integrate core protected areas (such as provincial and national parks), surrounding buffer areas (mostly Crown Lands) and an outer transition area of communities that support sustainable development. The biosphere reserve does not affect existing jurisdictions but creates a forum for cooperation and operates through community partnerships.

Following the mandate of UNESCO World Biosphere Reserves, the GBBR Inc. is a non-profit organization based in Parry Sound, Ontario whose vision is to be an international model of sustainability for eastern Georgian Bay, while protecting the ecological values of the region. The mission is to facilitate cooperative action in support of the conservation of biodiversity and sustainable development through education and public outreach that will foster a shared responsibility for the Georgian Bay Biosphere Reserve for the next seven generations. [www.gbbr.ca]

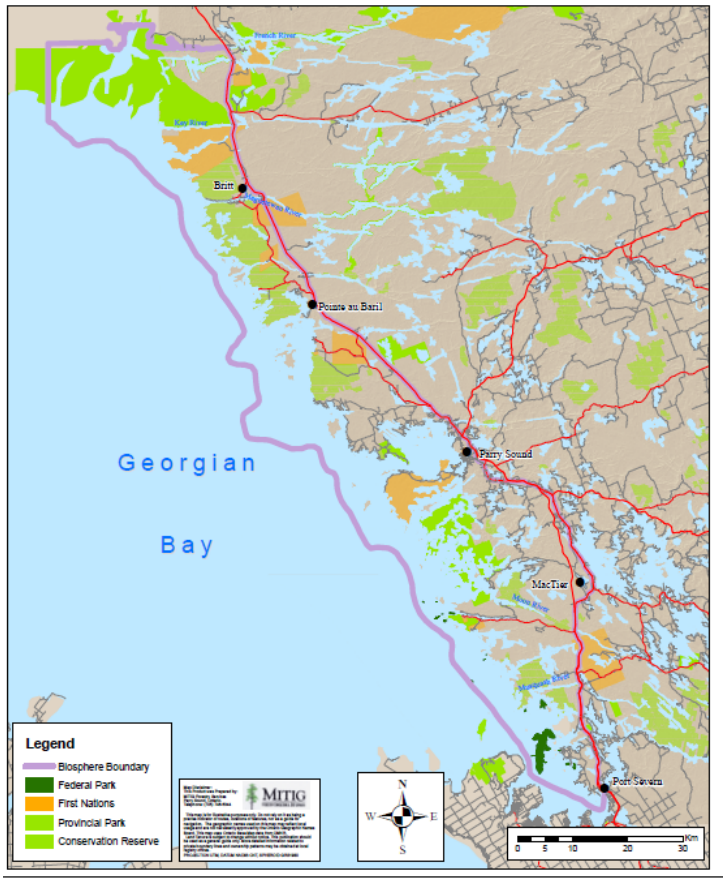


Figure 1 – Georgian Bay Biosphere Reserve

Priorities for Nutrient Monitoring in the GBBR

Nutrient (phosphorus) monitoring requirements in the GBBR are complex. In the past, phosphorus (P) monitoring meant measuring concentration over time to detect any increases due to anthropogenic inputs which could lead to eutrophication and the increased likelihood of nuisance algal blooms. In recent decades there is evidence that P concentrations in inland lakes have been declining for reasons other than a reduction in anthropogenic loads (Eimers, 2009) and it has been shown by Environment Canada that this is occurring in the open waters throughout the GBBR. In addition, the invasion of Dreissenid Mussels in the Great Lakes has led to the removal of nutrients from the centre portions of the lakes which is a result of the filter feeding process of the mussels. In turn, there has been an increase in the nutrients in nearshore areas as the mussels concentrate nutrients as both biomass and waste products in some areas. These multiple stressors require nutrient monitoring for many reasons other than straightforward vigilance with respect to eutrophication. There is now the need to understand complex patterns in nutrient flux and the way these changes in P concentrations affect ecosystem function.

The needs for nutrient monitoring in the GBBR are typical of monitoring requirements that have been identified elsewhere. These requirements include:

1. Mitigating localised water quality issues.
2. Regional characterisation of water quality.
3. Spatial and temporal trend detection.
4. Identifying the effects of regional drivers and multiple stressors to protect ecosystem function.

Although many of the GBBR monitoring requirements include nutrient monitoring, there are many aspects of ecological monitoring that require the measurement of further parameters to answer compelling questions relating to ecosystem function. The answer to these questions may require the collection of more extensive water and sediment chemistry together with biological data. Many of the monitoring programs listed in subsequent sections of this report collect a suite of parameters in addition to those that would be considered as nutrient monitoring. These data are often collected as part of focused research projects that are conducted through agency research branches or universities. This additional information can be used to fulfil some aspects of the more focused GBBR water quality monitoring priorities identified in the fourth requirement, above.

III – Review of Past Reporting and Monitoring

State of the Bay: an ecosystem health report for eastern & northern Georgian Bay (GBBR, 2013)

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. 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 (i.e. total phosphorus), wetlands, fisheries, and landscape in order to provide a science-based snapshot of conditions from Honey Harbour to Killarney-McGregor Bay.

Science and Monitoring Synthesis for South-Eastern Georgian Bay (Charleton and Mayne, 2012)

Environment Canada's report synthesizes science and monitoring information for south-eastern Georgian Bay with particular emphasis on phosphorus, causes of cyanobacteria and harmful algae blooms and the general condition of aquatic resources within this region. The region includes the nearshore waters and coastal areas west of Hwy 69 extending from the French River to Port Severn, the watersheds and open waters of Severn Sound, eastern Nottawasaga Bay and the watersheds of the Penetang Peninsula and Nottawasaga Valley. The report aims to: summarize current water quality and aquatic habitat conditions; identify and discuss causes and contributing factors; identify priority areas for science and monitoring; and identify unanswered management questions. The report includes an examination of temporal trends in offshore phosphorus concentrations and indicates extremely low P concentrations in these areas.

Data Summary of the 2003-2005 Water Quality Survey (Diep et al., 2007 Draft MOECC)

This monitoring program samples a set of 135 stations in nearshore areas of eastern Georgian Bay on an approximate 10-year cycle. Many sample locations are within enclosed bays but all are not included. The sample cycle was begun again in 2015. The report on the original 2003-5 data is currently in draft. These data agree with the EC data in that all areas where water is inundated by the open water areas of Georgian Bay exhibit extremely low concentrations of P.

Township of Georgian Bay-Coastal Monitoring Program Review (Hutchison Environmental Sciences, 2011)

Georgian Bay Forever (GBF) commissioned Hutchinson Environmental Sciences Limited to conduct a review of the water quality monitoring programs taking place in the Township of Georgian Bay. Their review summarizes nine years of water quality (2001 to 2009) and bacteriology data that was collected by volunteers in numerous sample locations within six large, semi-isolated enclosed bays in

Georgian Bay, including: Twelve Mile Bay, Go Home Bay, Cognashene Lake, Honey Harbour, North Bay, and South Bay. They concluded that the program has collected a set of data that is generally very useful for making water quality characterizations and for screening and describing areas of concern. In most cases the data are not extensive or precise enough to describe trends through time or to differentiate between natural and degraded systems. The dataset provides a great deal of insight into the current water quality conditions that exist throughout the study area.
[www.georgianbayforever.org]

Township of Georgian Bay Water Quality Monitoring Program Synopsis (Georgian Bay Forever, prepared by David Sweetnam, 2014)

This report recommends the ongoing monitoring of conditions at a regular frequency. This ensures that baseline information is available to expose changes or trends in water quality. The report also recommends that the coastal water quality monitoring program is reviewed and modified over time, using a reference to the past and ongoing results, to improve our understanding of the system. It is expected that this adaptive management approach will identify significant pressure from the impacts of climate change and invasive species.

Georgian Bay Forever Causation Study Synthesis (Hutchinson Environmental Sciences, 2014)

This report was a review of water quality problems that have been identified to date in the Severn Sound area. Essentially, the recommendations support a continuation of the SSEA monitoring program.

Note: It should be noted that there is a great deal of past monitoring that has not been summarized in report format (e.g. Lake Partner Program monitoring data). Many of these monitoring activities are ongoing and are described in the current monitoring sections below. SSEA is in the process of summarizing many of these data.

Summary of Past Reporting Recommendations

There are a great number of nutrient monitoring recommendations that have been provided by past reporting. To be properly fulfilled, many of these would require a focused research component. Table 1 shows past reporting recommendations relevant to nutrient monitoring together with the source of the recommendation.

Recommendations from previous studies below are assigned to four categories:
(1) General monitoring;
(2) Monitoring to support research;
(3) Monitoring to address areas susceptible to watershed sourced impacts; and
(4) Monitoring coordination.

Table 1 – Showing relevant past reporting nutrient monitoring recommendations

Recommendation	Source
General monitoring	
Enhance nearshore water quality monitoring	EC
Programs should be coordinated to achieve maximum benefit from volunteer efforts and the expenditure of science program dollars.	HESL - Cause
Monitoring should continue at all of the existing coastal monitoring locations using the new protocol for low level phosphorus analysis for at least 2 years.	HESL-CMP
Reduce the number of sample locations (after 2012) to include only the central deep locations for each enclosed bay. These sites should be the same as those used by the DMM for those bays where DMM collects samples and they should be in central areas for those bays where DMM does not sample. Monitoring should focus on TP and DO during the window 14 days either side of Sept 1st.	HESL-CMP
The Coastal Monitoring Program should begin to collect low level TP data in 2011 following Dorset/Trent University protocols (as suggested previously), with filtration of each sample at the time of collection through an 80 µm mesh to exclude large zooplankton.	HESL-CMP
Development of a P grading System *Note: The updated version of the GLWQA (EC, 2012) states that it will develop substance objectives (including phosphorus) for nearshore waters, including enclosed bays and tributary discharge for each Great Lake.*	SotB-RC
Monitoring to support research	
Research the sources of organic material along the Georgian Bay shoreline and how this contributes to issues with hypoxia and internal phosphorus loading.	EC
Correlative study to see if water quality is related to cottage development.	EC
Examine and confirm the alternative bloom stimulation hypotheses such as the importance of iron (Fe) (Molot et al. 2012).	EC
Compare present day water quality in North Bay with diatom and chironomid-inferred water quality from paleolimnology studies.	EC
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.	SotB-RC
Monitor the spread of attached algae and determine the presence of small nearshore sources of phosphorus; extend studies to bays with eutrophication issues.	EC
Monitoring to address areas susceptible to watershed sourced impacts	
Investigate the sporadic elevated P conditions and sources in the French River	EC
Monitor the total phosphorus contributions and study the associated impacts of sewage and grey water inputs from high density boating	EC
Synthesize and report on temporal trends of TP concentrations for problem Bays mentioned in this report. Investigate causes of oxygen depletion in problem bays.	EC
Investigate and compare nutrient concentrations in streams feeding into problem	EC

areas such as Sturgeon Bay, Cognashene Bay, and Twelve Mile Bay.	
Determine the significance of Sturgeon Bay's north basin watershed as a source of elevated phosphorus during late summer and establish a phosphorus budget. Investigate the cause(s) of the phosphorus concentration gradient from south to north	EC
Monitor and confirm the relatively high phosphorus concentration in streams and in Cranberry Lake are due to natural causes.	EC
Investigate the causes of low dissolved oxygen and increasing P in Little GoHome Bay and Baxter Lake and their relationship to the South Bay of Honey Harbour.	EC
Continue the investigations into the relationships between the Chrysosphaeralla peak and phosphorus and micronutrient availability in North Bay.	EC
That the accumulated state in the Areas of Concern has been well described such that no additional monitoring programs are required other than those currently being conducted by the SSEA.	HESL-Cause
For each perceived problem there must be a method devised to confirm whether the problem exists and if so, outline the extent of the problem, and identify the driver or drivers responsible for the problem.	HESL-Cause
Paleolimnological surveys, especially in South Bay and North Bay are recommended to establish the past history of water quality and incidence of algal blooms	HESL-Cause
Review mixed layer and the hypolimnetic waters at 1 meter above bottom to determine the presence of any internal loading.	HESL-CMP
Survey Parry Sound to establish background conditions in bays and population centres	EC
Monitoring coordination	
The GBF should attempt to collect spring TP each year in each of the central representative locations. If DMM is collecting data in a given year it will not be necessary to collect additional samples. Spring samples should be collected by either DMM or the Coastal Monitoring Program or by the Lake Partner Program each year. These sampling efforts should be coordinated by one person to ensure that there is continuous spring data available that can characterize nutrient status over time.	HESL
The use of volunteers over a wide area could possibly be put to better use by collecting data that could augment those collected by other programs such as the SSEA. In some cases more frequent data or data that is not otherwise being collected could be gathered by volunteers.	HESL-CMP
GBF / Lake Partner Program testing should continue in years between the District testing programs.	HESL-TGB-WQMP
Efforts to co-ordinate scientific and monitoring programs with government agencies, such as Environment Canada, MOE and MNR, should continue to determine what government research activities are underway, to assess if any useful data will be available for the Township to use.	TGB-WQMPS

Source:

EC	Environment Canada, Science Synthesis
HESL-Cause	Hutchison Environmental Sciences, Causation Study

HESL-CMP	Hutchison Environmental Sciences, Coastal Monitoring Program review
SotB-RC	State of the Bay, Report Card
TGB-WQMPS	Township of Georgian Bay, Water Quality Program Synopsis

Many of the recommendations in Table 1 have been fulfilled and several of the recommendations especially those that suggest harmony between levels in a tiered monitoring program are carried forward here.

Note: It is not possible (in this report) to determine whether or not the recommended monitoring in many locations (French River, Parry Sound, Cranberry Lake, etc.) have been added to monitoring programs such as the Lake Partner Program (MOECC) in recent years.

IV – Current Nutrient Monitoring Programs within the GBBR

Current monitoring programs that have a nutrient monitoring component are summarized in detail in the GBBR report *Water Quality Monitoring along Eastern Georgian Bay* (2015). The programs are listed below by agency and summarized in Table 2.

First Nations

1. Magnetawan First Nations – Byng Inlet Monitoring Project

Federal

2. *Environment Canada*- Great Lakes Surveillance Program
3. *Georgian Bay Islands National Park* – Ecological Integrity Monitoring

Provincial

Ontario Ministry of the Environment and Climate Change

4. Lake Huron/Georgian Bay Environment Index Station Program
5. Great Lakes Nearshore Assessment
6. Diver Based Lakebed Surveys of Eastern Georgian Bay
7. Ontario Benthos Biomonitoring Network
8. Lake Partner Program – *volunteer data collection program*

Severn Sound Environmental Association (inter-municipal)

9. Severn Sound Open Water Monitoring Program

Municipal

10. District Municipality of Muskoka – Muskoka Water Strategy
11. Township of Georgian Bay
12. Township of Seguin

Note: Other municipalities are currently considering options for including nutrient monitoring in their programs.

Non-Governmental Organization/Stewardship

13. Georgian Bay Forever

Relevant Regional Monitoring

14. Dorset
15. MNRF Broadscale
16. Laurentian Aquatic Assessment Unit

Table 2 – Current monitoring program characteristics and data coordinates

Note: In many cases there are additional parameters measured to complement the nutrient monitoring.

Project	Description and Rationale	Sites/Parameters	Timeframe/ Datapointer
Magnetawan First Nation	The goal of the Byng Inlet project is to characterize water quality with an emphasis on total phosphorus. There is a lack of water quality data for the Inlet.	5 stations in Byng Inlet - Turbidity, Secchi depth, temp/DO, TP, alkalinity, pH, conductivity, nitrogen, DOC	2014-16
Environment Canada Great Lakes Surveillance Program	Responds to: - Cooperative Science and Monitoring Initiative - Lakewide Management Plans - Binational Toxics Strategy - Integrated Atmospheric Deposition Network. Goal is to ensure compliance with water quality objectives, evaluate water quality trends and identify emerging issues.	26 stations in GB, 8 stations in eastern GB - Full suite of parameters including trace metals, trace organics, pesticides	1962-present, Standardized in 1974, each lake monitored every two years (3 cruises per year)
Georgian Bay Islands National Park – Ecological Integrity	The goal of Ecosystem Indicator Monitoring is to protect natural heritage where the current quality visitor experience will be available for future generations.	The measures are; - Water quality index (WQI), temp, turbidity, pH, conductivity, nitrogen - Aquatic exotic invasive plant species abundance - Frog and toad abundance	Every 3 years at selected wetlands

Project	Description and Rationale	Sites/Parameters	Timeframe/ Datapointer
MOECC – Environment Index Station Program	Goal is to monitor ambient water quality change over time and to identify the onset of anomalous patterns or conditions which may forebode adverse changes due either to stressors where impacts are not known, or where an impact of a stressor was not anticipated. Data used as input to Great Lakes management programs to assess progress in meeting objectives and to assess the success of programs to restore or protect environmental quality in the Great Lakes	8 sites along eastern GB 1. Concentrations of persistent contaminants in surficial sediment and in suspended particulate. 2. Benthic invertebrates. 3. Thermal and optical profiles and physical characterization of the lake bottom. 4. Full suite of water quality parameters including phytoplankton and zooplankton.	6 year cycle in Lake Huron, 3 surveys per sample year
MOECC – Great Lakes Nearshore Assessment	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.	135 sites along EGB (enclosed bays, nearshore, offshore) - Depth, temperature profiles - Secchi depth - TSS, turbidity, colour, TP, phosphate, TN, nitrite, nitrate, ammonium, silicates, sulphates, chloride, alkalinity, pH, conductivity, hardness, Cr, Ca^{2+}, Na^{+}, K^{+}, Mg^{2+}, chl *ab,* DOC, DIC	Sampled 2003-2005 and then roughly every 10 years
MOECC – Diver Based Lakebed Surveys	Diver based surveys of sediment and biota. Goals not summarized.	Qualitative summary of: - Substrate type - Underlying substrate - Benthic algae - Dreissenid Mussels - Round Gobies	- Five sites in 2014 - 60 sites proposed - July-Aug surveys
MOECC – Ontario Benthos Biomonitoring Network	The Ontario Benthos Biomonitoring Network is a multi-stakeholder collaboration established in 2003, in which bottom-dwelling aquatic (benthic) invertebrates are used to monitor the ecological condition of lakes, streams, and wetlands.	- Extensive sampling in lakes and rivers in the Muskoka River watershed in 2012. - No OBBN monitoring along eastern Georgian Bay.	http://desc.ca/programs/obbn

Project	Description and Rationale	Sites/Parameters	Timeframe/ Datapointer
MOECC – Lake Partner Program	The LPP is a volunteer-based, water-quality monitoring program collecting low level total phosphorus and water clarity data from ~800 locations throughout Ontario.	Lakes on the Canadian Shield are sampled for total phosphorus once per year during May, and Secchi disk observations are made, ideally, twice per month from May to October.	Began in 1996 - Low level data since 2002 - Spring sampling for shield lakes, monthly ice free sampling for off shield lakes http://www.ontario.ca/environment-and-energy/lake-partner-program
SSEA – Severn Sound Open Water Monitoring Program	In 2003, restoration targets had been met and Severn Sound was delisted as an AOC. The RAP continued under the Severn Sound Environmental Association (SSEA). Severn Sound RAP Stage 3 Report called for continued monitoring of open waters of Severn Sound in order to assess changes in trophic status in relation to remedial actions and other ecosystem changes in the area (e.g. invasive species, water level changes).	- Station depth - Secchi disc depth - Vertical profiles (surface to 1m off bottom) - Temperature, dissolved oxygen, and conductivity Ions, conductivity, pH, TP, total ammonia, total nitrate, total Kjeldahl nitrogen, Chlorophyll a, Zooplankton, phytoplankton, heavy metals	~ data since 1973 - sampled biweekly April-Nov
District Municipality of Muskoka – Muskoka Water Strategy	The goal of the Lake System Health Program is to protect lake ecosystems and the social and economic values they provide.	193 sites on 164 lakes (on a rotational basis) - 30 years of data - Secchi depth, Temp/DO, alkalinity, conductivity, pH, nutrients, calcium chloride, colour, Na, S04, Fe, DOC, benthic invertebrates	30 years of data http://muskokawaterweb.ca/water-101
Township of Seguin	- To establish a historical record of water quality parameters to identify trends in water quality - To collect TP data to determine shoreline development capacity of recreational lakes.	120 lakes on a rotating basis - Secchi, temp/DO - Spring TP - DOC	2008 - present

Project	Description and Rationale	Sites/Parameters	Timeframe/ Datapointer
Township of Georgian Bay – Georgian Bay Forever	Water quality monitoring program is coordinated by Georgian Bay Forever. The program has been funded by the Township and coordinated and delivered through a network of amateur and professional volunteers. GBF leveraged additional funding to conduct supplemental water quality studies, such as paleolimnological and causation studies. Objectives include: • Describing water quality conditions in the Township of Georgian Bay. • Identification of areas where further monitoring or remediation are necessary. • Creation of a long-term database. • Development and fostering of volunteer support and program awareness. • Assessment of impacts of septic systems and improvement of re-inspection programs. • Provision of technical input for planning at three levels of government. • Coordination with universities and other research agencies.	Twelve Mile Bay – 6 stations, Go Home Bay – 6 stations, Cognashene Lake – 5 stations, Honey Harbour –unknown, North Bay – 7 stations, and South Bay – 8 stations. The water quality monitoring program collects water samples for analysis of TP and makes in situ measurements of temperature, DO, and water clarity in September of each year Additional measurements include conductivity, pH, water clarity and depth including sonar imaging to observe the presence/absence of fish Water chemistry analysis related to eutrophication concerns (TP, water clarity, DO, coldwater fish community).	1999-present http://www.gbtownship.ca/content/water-quality-reports-information

V – Review of Existing Data

Offshore

The offshore data collected by Environment Canada is excellent in its ability to describe both spatial and temporal changes through time in the open water areas of Georgian Bay. This is important because the water chemistry in the open water areas will influence the water chemistry in nearshore areas to a large extent and may also have an impact on enclosed bays' water quality.

Without a firm understanding of offshore water chemistry it would be extremely difficult to assess the results of analyses in nearshore areas. This is the most important dataset available because it shows the spatial variation that can be expected in offshore nutrient concentrations in any given year (Figure 2) and demonstrates considerable trends through time (Figure 3).

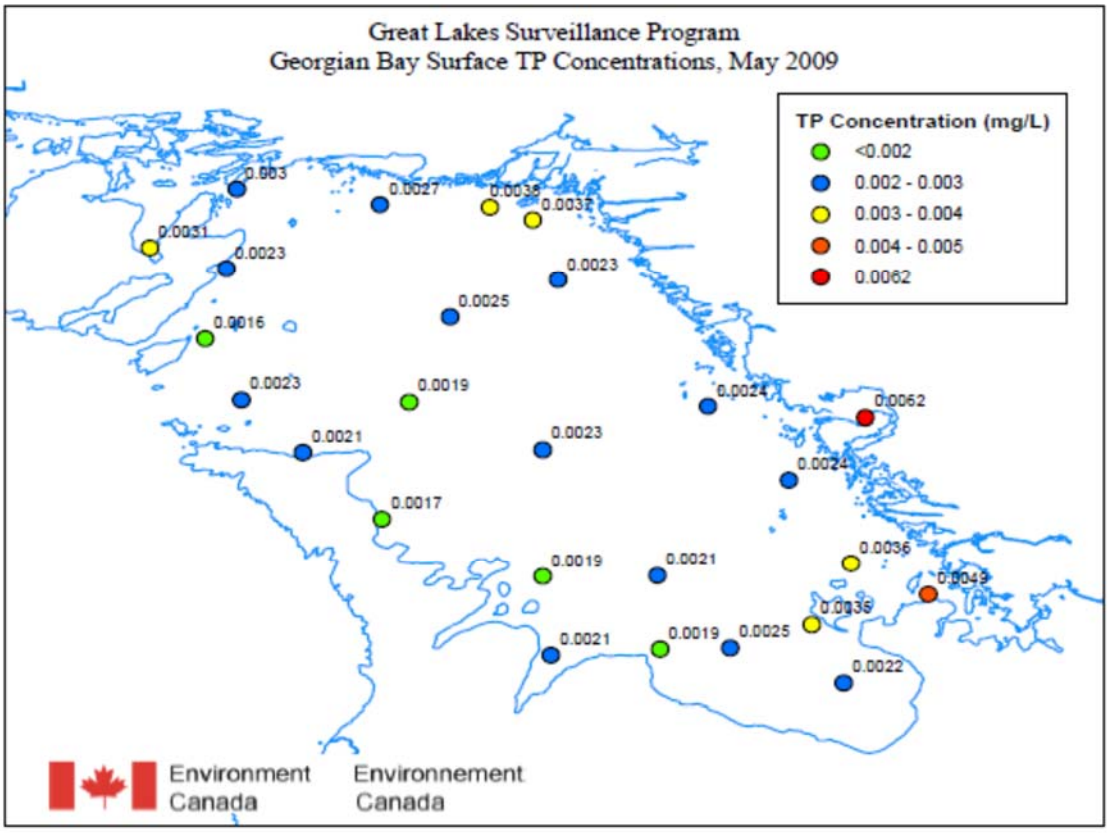


Figure 2 – Environment Canada Great Lakes Surveillance Program sample locations on Georgian Bay showing total phosphorus concentrations

Note: These data show considerable declines in TP concentrations in offshore water over the past few decades (Figure 3) to levels that are in ultra-oligotrophic

ranges. This is certainly alarming and there are, no doubt, serious consequences for offshore biota as a result of this loss in productivity.

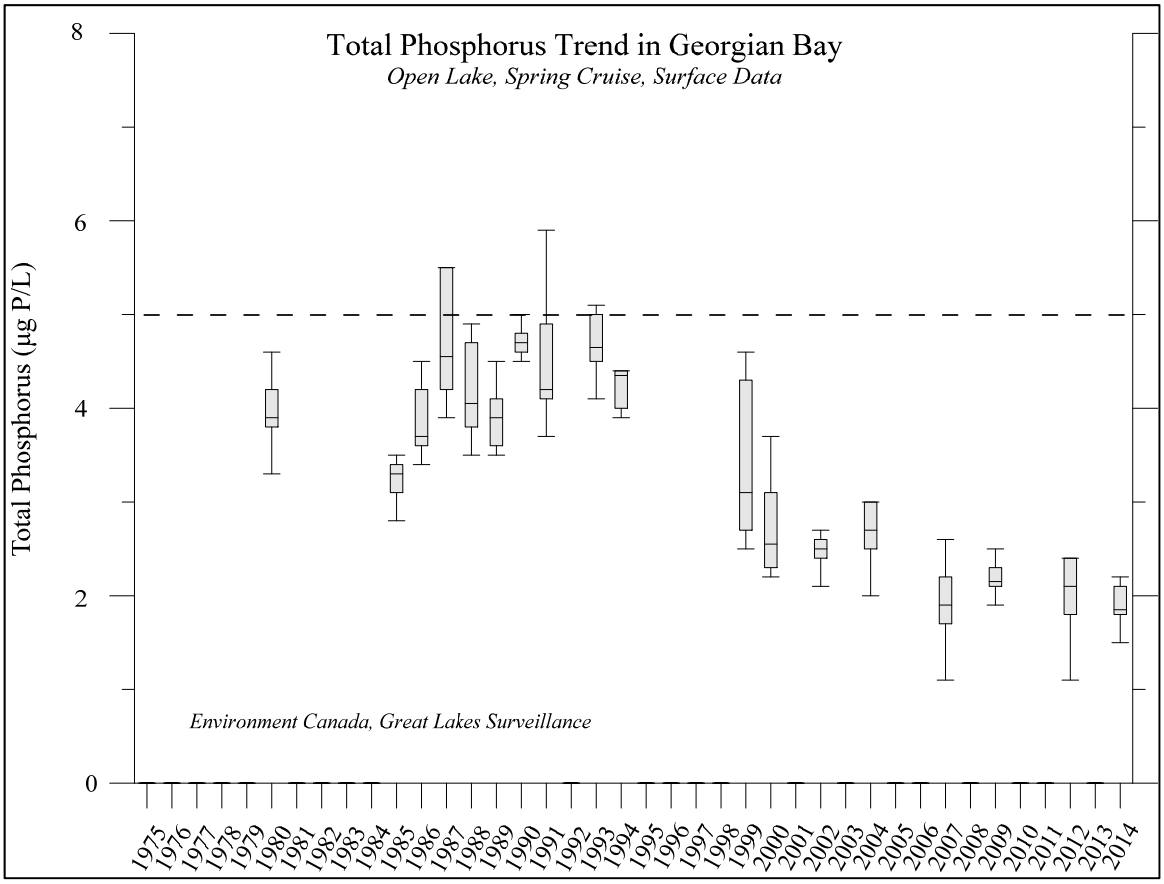


Figure 3 – Trends in total phosphorus concentrations (mg/L) between 1975 and 2014 in open water areas of Georgian Bay

The characteristics of offshore water must be considered when any evaluation of nearshore water quality is attempted. It should be noted that declines in offshore concentrations of P in some areas, especially in the southern portions of eastern Georgian Bay, are due in part to the filtering of particulates by dreissenid mussels.

Note: Considering the EC-GLSP dataset, there is no requirement for additional offshore nutrient monitoring.

Nearshore and Enclosed Bays

A draft report by the MOECC (Diep et al., 2007) describes the water quality data collected in nearshore areas and enclosed bays of eastern Georgian Bay between 2003 and 2005 (Figure 4). These surveys provide a detailed characterization of water quality between Killarney in the north and Honey

Harbour in the south. The report noted a range in water quality parameters between 135 sites with an offshore to nearshore gradient characterized by lower conductivity, alkalinity, and pH. Higher nutrients and chlorophyll a were observed at the more inland embayed locations. In addition they noted that areas close to watershed sources of runoff had softer water with lower ion concentrations while open water areas have harder water with higher conductivity.

Seasonal differences in water quality indicate a larger range in observed values, lower conductivity, alkalinity and pH together with higher nutrients in the spring.

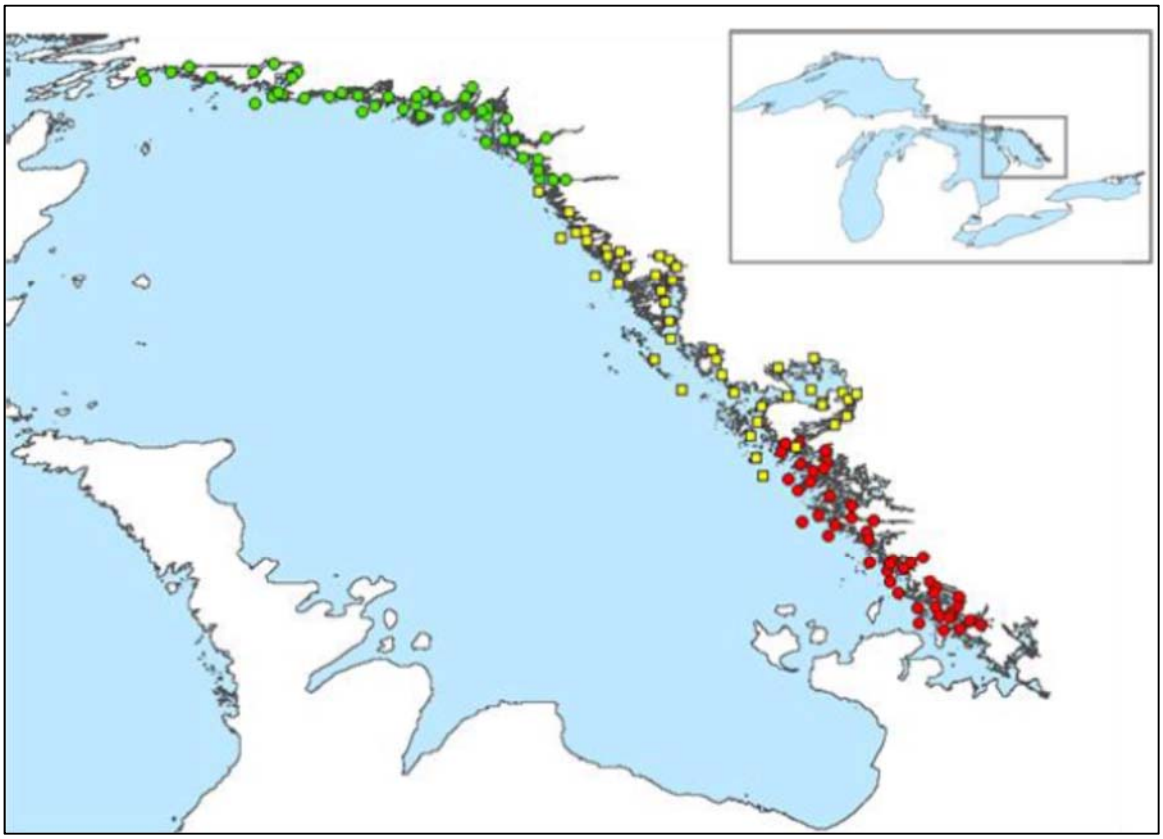


Figure 4 – Sample locations for the MOECC 2003-2005 water quality survey. Green circles are 2003 sample locations with yellow locations sampled in 2004 and red in 2005

These results indicate extremely low phosphorus concentrations in open water areas with a corresponding low concentration in those nearshore areas that are inundated by offshore water. Offshore areas had generally less than 5 µg/L TP. Nearshore areas have concentrations between 5-15 µg/L which indicates a watershed influence. Only three areas had 15-20 µg/L TP which is still within the Provincial Water Quality Objective (PWQO) for phosphorus and Sturgeon Bay was the only area with >20 µg/L TP (Figure 5).

Note: These results indicate that current monitoring has been sufficient to characterize water quality in most areas (for the 2003-2005 time period). There was very little evidence for water quality problems at this time with respect to nutrients except for in a few areas which are discussed in detail in the following section Areas Susceptible to Watershed Impacts. It is important to note that these ongoing surveys do not include the numerous enclosed bays where nutrient monitoring has not been conducted.

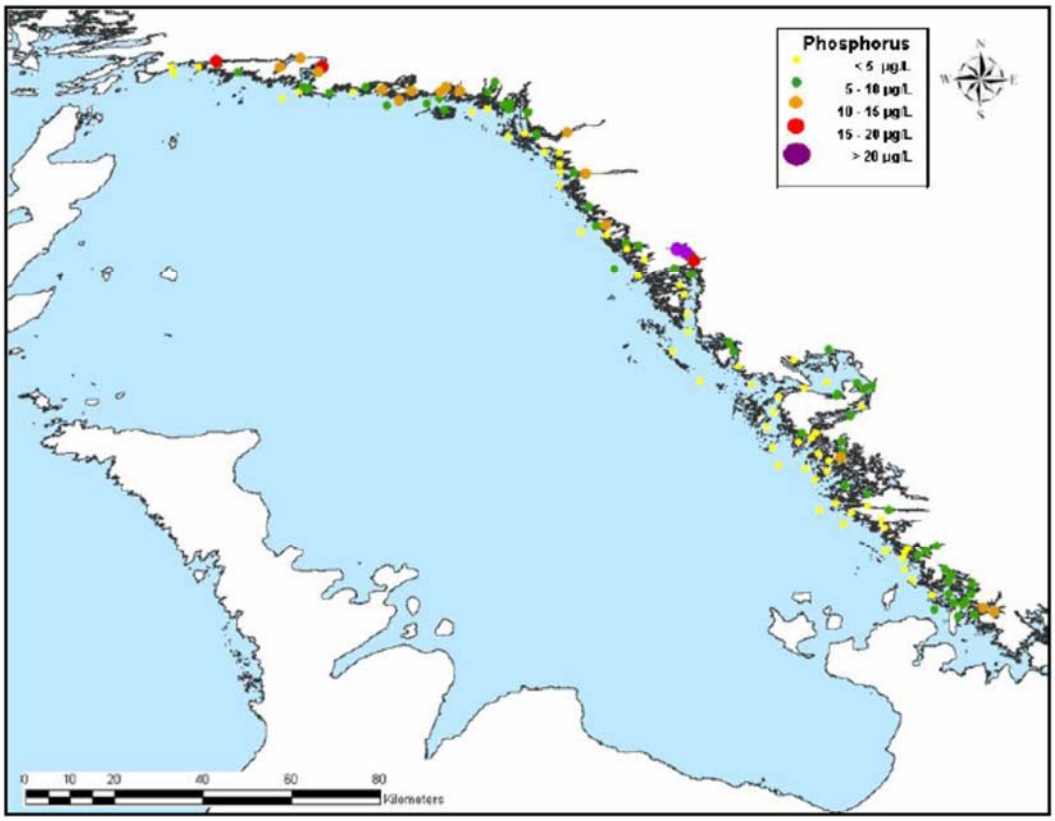


Figure 5 – Total phosphorus concentrations measured at the MOECC survey locations between 2003 and 2005

Many enclosed bays have been monitored in other studies either as part of a regional monitoring initiative or as part of a focused research project. There have been enclosed bay measurements conducted by all tiers of monitoring effort from federal agencies to citizen stewards.

Most of these efforts are suitable to characterize current water quality conditions with respect to nutrients but there are fewer datasets where trends through time can be assessed. The exception to this is the work conducted by the Severn Sound Environmental Association. [www.severnsound.ca]

Areas Susceptible to Watershed Impacts

Considering that open water areas are characterized by extremely low phosphorus concentrations, it is likely that only those areas that are isolated from the main body of Georgian Bay will have the potential to be impacted by local watersheds.

The MOECC 2003-2005 survey reported annual mean TP concentrations for each survey site. There were 20 of the 135 sites with TP over 10 µg/L and 5 of these had concentrations >15 µg/L (Table 3). If the MOECC surveys were used to identify problem areas with respect to nutrients it would identify only one location where PWQOs were exceeded (Sturgeon Bay) and then only by 2 µg.

Table 3 – MOECC 2003-2005 survey sites with total phosphorus concentrations greater than 10 µg/L

Site	Description	Latitude	Longitude	DOC	TP
934	Sturgeon Bay N	46 36 47.88	80 25 51.84	6.1	22
935	Sturgeon Bay Mid	45 36 23.93	80 24 43.77	5.5	21.9
872	Beaverstone R.	45 58 53.85	81 09 17.79	6.6	20
936	Pte-au-Baril Ch.	45 35 30.44	80 23 50.85	5	15.7
876	Collins Inlet W Keyhole	45 59 39.93	81 22 16.52	5.7	15.4
925	Naiscoot R. CL Ch.	45 39 48.37	80 34 40.76	5.4	14.1
873	Beaverstone Bay	45 59 18.34	81 09 48.31	5	13.6
844	Henvey Inlet A	45 50 57.53	80 39 24.38	6	12.8
861	Bad R. CH.	45 56 02.97	80 58 24.12	5.8	12.8
675	South Bay	44 52 36.00	79 47 10.99	5.2	12.7
858	French R. Main Outlet	45 56 29.90	80 54 06.13	5.4	12.3
838	Byng Inlet (mag R.)	45 46 03.24	80 37 03.57	5.2	12.2
857	French R. Outlet	45 55 57.39	80 52 31.04	5.2	12.1
864	Fort Channel	45 56 08.08	81 01 59.93	5.2	12.1
862	Lodge CH at Brad R	45 54 47.92	80 59 54.47	5.2	11.6
875	Mill Lake	45 58 52.22	81 14 30.05	4.6	11.4
674	North Bay	44 53 04.82	79 48 29.89	4.4	11.3
643	Jenner Bay	45 11 23.76	80 05 58.00	3.3	10.2
859	Sand Bay 2	45 55 54.85	80 54 55.87	4.4	10.2
874	Collins Inlet E Mill Lake	45 59 55.90	81 11 58.09	5	10.2

Note: Yellow rows indicate river influence sample sites

The magnitude of the TP concentrations, of course, cannot be strictly used to identify areas where nutrients are a problem because PWQOs now limit TP increases to background concentrations plus 50%. For example, an area with a

background concentration of 4 µg/L would be considered to have a problem once concentrations reached 6 µg/L (background plus 50%).

We can gain some insight into whether or not the phosphorus is from natural sources by observing the relationship between dissolved organic carbon (DOC) and TP. If there is a strong relationship then it is reasonable to assume that much of the TP measured is natural with watershed sources linked to the export of DOC. This is in fact the case for the MOECC data which show a strong relationship between DOC and TP (Figure 6).

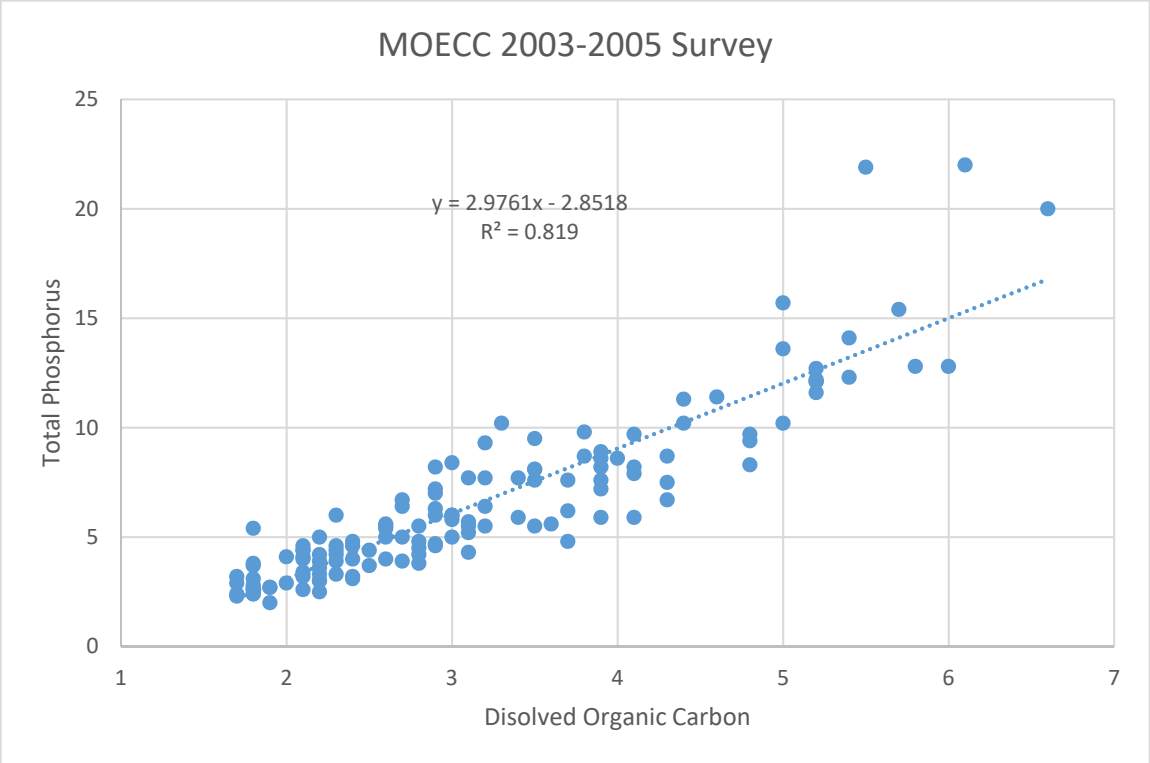


Figure 6 – Showing the relationship between DOC and TP for the 135 survey sites in Eastern Georgian Bay

Areas with water quality or biota related concerns that have been mentioned or identified in previous reports/studies are shown in Table 4 together with an assessment as to whether these areas have been or are currently being adequately monitored.

Note: Volunteers associated with monitoring programs may have additional sites of concern that will be documented in a future report. It will be important to communicate with members of the active public to capture their concerns, particularly around tributaries. The Eastern Georgian Bay Stewardship Council is

currently developing a fish habitat assessment protocol for tributaries, and some of these results may inform future studies on water quality.

Table 4 – Areas with water quality or biota related concerns that have been mentioned or identified in previous reports/studies

Area	Problem(s)	Source	Status
Cognashene Bay	Phosphorus from the sediment, low conductivity, and anoxia.	1,2,3,	Monitored TGB/GBF TP=5-10 (anoxia)
Go Home Bay	Reduced clarity within the inner bay due to elevated phosphorus.	1,2,3	Monitored TGB/GBF TP=4-8 (anoxia)
Severn Sound	Remedial Action Plan	MOECC	Well studied, research continues
North Bay	Increase in rooted aquatic plants and periphyton over past 10-15 years, and anoxia.	2,3	Well studied, research continues
South Bay	Degradation of water quality between inflow from Baxter Lake and outflow, periphyton, and anoxia.	2,3	Well studied, research continues
Sturgeon Bay	Eutrophication and excessive cyanobacteria blooms, and low DO.	1	Well studied
Twelve Mile Bay	Elevated phosphorus and anoxia.	1,2,3	Monitored TGB/GBF TP=5-10 (anoxia)
Honey Harbour	Decreased water clarity, elevated bacteria and phosphorus.	1,2	Well studied, research continues
Church Bay	Changing invertebrate and phytoplankton communities; aquatic plants and periphyton.	1,2	some studies, degradation links to sedimentation
Severn River	Elevated phosphorus and macrophytes.	1	Unknown
French River	Elevated phosphorus levels, and cyanobacteria blooms.	1	Unknown
Parry Sound (Deep Bay)	Algal blooms.	1	Unknown

Source code:
1. EC science and monitoring synthesis
2. TGB/GBF 2011 WQ program report
3. GBF coastal monitoring review 2011

VI – Assessing the Adequacy of Current Monitoring Programs

Harmony with GBBR Monitoring Requirements

The value of current monitoring programs (conducted within the biosphere reserve) is assessed here relative to GBBR monitoring priorities, namely:

1. Mitigating localised water quality issues.
2. Regional characterisation of water quality.
3. Spatial and temporal trend detection.
4. Identifying the effects of regional drivers and multiple stressors to protect ecosystem function.

The current programs are assessed in Table 5 and are represented numerically in the column headings as follows:

1. Magnetawan First Nations – Byng Inlet Monitoring Project
2. Environment Canada – Great Lakes Surveillance Program
3. Georgian Bay Islands National Park – Ecological Integrity Monitoring
4. MOECC Lake Huron/Georgian Bay Environment Index Station Program
5. MOECC Great Lakes Nearshore Assessment
6. MOECC Diver Based Lakebed Surveys of Eastern Georgian Bay
7. MOECC Ontario Benthos Biomonitoring Network
8. MOECC Lake Partner Program
9. SSEA – Severn Sound Open Water Monitoring Program
10. District Municipality of Muskoka – Muskoka Water Strategy
11. Township of Georgian Bay
12. Township of Seguin
13. Georgian Bay Forever
14. MOECC Dorset
15. MNR Broadscale
16. Laurentian Aquatic assessment Unit

Table 5 – Assessing the ability of current programs to support GBBR monitoring priorities

- Green = Capable of supporting the four monitoring priorities in the GBBR.
- Red = Not currently capable of supporting the four monitoring priorities in the GBBR.
- Yellow = Partially capable of supporting the four monitoring priorities in the GBBR.

Priority	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mitigating localised water quality issues	G	R	R	G	G	G	Y	G	G	G	G	G	G	Y	Y	Y
Regional characterisation of water quality	R	G	R	G	G	R	Y	G	G	G	Y	G	G	G	G	G
Spatial and temporal trend detection	R	G	R	G	G	R	Y	G	G	G	G	Y	G	G	G	G
Regional drivers multiple stressors	R	G	G	G	G	G	Y	G	G	G	G	G	G	G	G	G

The GBBR benefits from a number of ongoing comprehensive water quality monitoring programs. It should be noted that the potential for each of these monitoring programs to fulfil monitoring priorities has been assessed here in a very subjective manner and is intended to show that each priority is being addressed by a number of programs. Some research programs conducted by government or university facilities that are outside of the biosphere (eg.14, 15, 16) have the potential to provide insight into those problems or processes that involve regional drivers such as climate change.

Gaps and Opportunities

The main need with respect to nutrient monitoring within the GBBR is to ensure that the enclosed bays are being sufficiently monitored. This is required for reasons beyond the detection of problem areas in a traditional sense whereby the *end-of-pipe* condition is measured. Multiple stressors such as climate change, invasive species and the long range transport of pollutants are regional in nature such that they impact undeveloped areas. In addition, many processes that are currently impacting the aquatic environment are poorly understood which requires the collection of data that can detect trends within a wide suite of parameters.

Finally there is a general lack of synthesis or reporting for many of the data that are being collected in the biosphere.

Tiered Monitoring

Effective and comprehensive tiered monitoring will help to provide answers to both current and future questions that concern nutrients in the environment.

Smaller local or regional monitoring programs conducted by First Nations, Municipalities or by citizen scientists can help to fill gaps between program years in the larger Provincial or Federal monitoring programs.

VII – Nutrient Monitoring Protocols

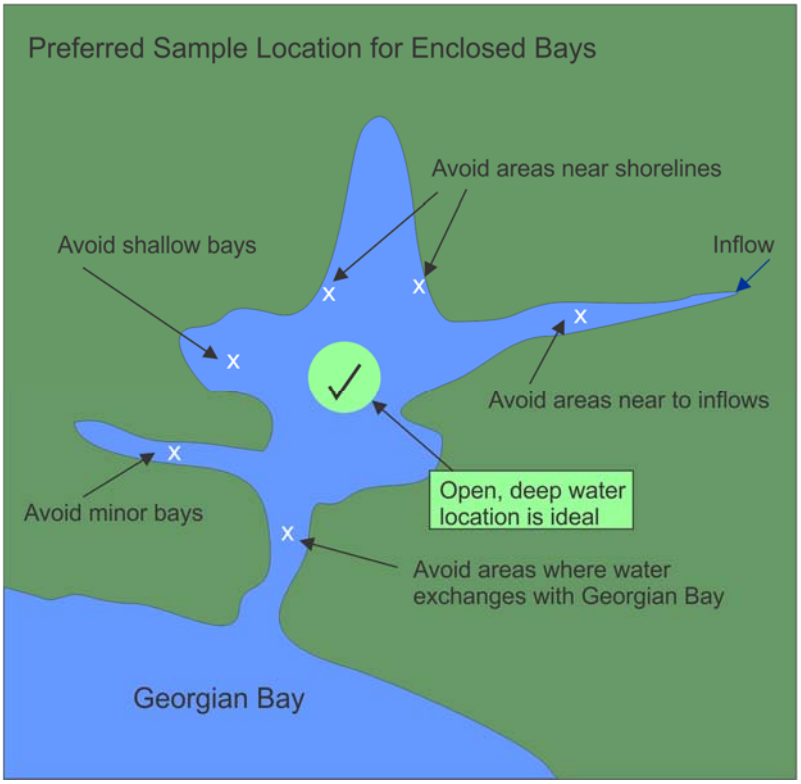
In this case *nutrient monitoring* refers primarily to total phosphorus (TP) monitoring. This is the nutrient that controls the growth of algae and most living biota in the aquatic environment.

Sample Location

Sample locations to characterize water quality in enclosed bays should be in open, deep-water areas. Sample locations near to inflows, close to shore, in shallow areas or in areas where there is significant water exchange with Georgian Bay should be avoided (Figure 1Figure 7). Further protocols should be developed to help identify those areas that are likely to be influenced by watershed processes.

Tools to help identify areas that would be more or less influenced by open water or watershed processes are being developed by SSEA.

Figure 7 – Diagram to illustrate preferred sample locations for enclosed bays



Sample Timing

Spring turnover is the period when lake water is well mixed from the surface to the bottom such that samples will be representative of the entire water body. Samples taken a bit later in the season after the water has stratified will still be acceptable since the water, which is now thermally stratified, will not begin immediately to show variations in chemistry with depth. Samples taken in the month of May are preferred (Clark et al., 2010).

Sample Methods

Composite samples are collected and coarse filtered directly into the same borosilicate sample tubes that will be used to digest the samples for analysis. The key aspect of low level phosphorus analysis is to collect the samples into the same container that will be used to digest the sample. This eliminates problems associated with transfer between sample containers and eliminates sample perishability problems. The Lake Partner Program and the Trent University Lab provide 35mL borosilicate glass tubes for sample collection.

There are many protocols for mixed layer sampling that include composite bottles or bottles that are simply held below the surface to fill. Most protocols suggest a composite whereby a bottle fills as it is being lowered and sample bottom depths are often specified as the Secchi depth or 5m. LPP volunteers collect a composite sample from the surface down to the Secchi depth using a weighted plastic drinking water bottle. Studies by Clark to assess differences in sample methods found no difference in results for samples collected by a wide range of protocols. Only the samples collected to 2x the Secchi depth showed some difference. The key is to avoid getting surface material into the sample and to avoid contact with the water by any foreign material other than the sample bottle, the filter and the borosilicate tube. Sampling directions are provided by the LPP for those participating in that program.

Sample Analysis

Much of the TP data collected historically has been affected by poor precision in analysis but these problems have been corrected since circa 2002 when low level analysis was adopted by the MOECC Lake Partner Program and other groups. The most important aspect of a TP monitoring program is to ensure that samples are submitted to a lab that can conduct precise, low-level analysis. Specifically, it is important to maintain detection limits around 0.1 µg/L and standard deviation between duplicate analyses of less than 1 µg/L in order to detect change at the extremely low ambient concentrations that are currently being observed in Georgian Bay. These methods are currently being used by the MOECC labs at the Dorset Environmental Science Centre (DESC) to analyse samples from the Lake Partner Program and by the Trent University Lab at the DESC to analyse fee for service samples for many groups.

VIII – Summary

Nutrients are being monitored with ongoing programs by Environment Canada (open water) and the Ontario Ministry of the Environment and Climate Change (nearshore) to characterize spatial variation and to detect trends through time. These programs sample some enclosed bays but further monitoring may be required in areas that are enclosed and thereby susceptible to watershed influences. Very few of these areas currently show evidence of water quality problems in the traditional sense (eutrophication, algal blooms etc.) but the list of potential regional stressors such as climate change, long range transport of materials, invading species, etc. require vigilance and these stressors may have impacts that directly affect the concentrations of nutrients available in the environment. Indeed, it may be that a low nutrient environment may represent a current stress in many areas. It would be useful under these circumstances to develop long term nutrient monitoring strategies for as many enclosed bays as possible in areas along eastern Georgian Bay.

A tiered monitoring approach would help to provide monitoring in areas where upper tier, especially provincial monitoring programs do not have sample sites. This is required in many of the enclosed bays and in areas further to the north where LPP monitoring is sparse. Additional monitoring in these areas could be accomplished by municipal or citizen science groups. Increased harmonization between programs could provide monitoring at many MOECC sample locations between program survey years.

IX – Recommendations

1. *Enhance the current tiered monitoring framework*

It is recommended that municipal and citizen monitoring component of a tiered monitoring program be further developed to enhance monitoring in enclosed bays throughout the biosphere. Tiered monitoring currently exists (e.g. District of Muskoka and Township of Georgian Bay monitoring programs) but the extent of the lower tier could be further developed. Several municipalities do not undertake nutrient monitoring.

2. *Harmonized monitoring*

Although there does not seem to be an unreasonable degree of overlap with any of the current monitoring programs, it is important to harmonize monitoring efforts wherever possible. This is already a well-established practice in the District of Muskoka and Township of Georgian Bay programs. These practices could be transferred to other jurisdictions especially into the more northern areas of the biosphere reserve.

3. *Reporting and Synthesis*

All programs that collect nutrient data in the GBBR should report these data in a timely manner so that the monitoring program's adequacy can be evaluated on a timely and ongoing basis. Ongoing synthesis of multiple program results would be valuable, as would publicly accessible data and reports.

References

Beeton, A.M. 1965. Eutrophication of the St. Lawrence Great Lakes. Limnol. Oceanogr. 10(2): 240–254.

Charleton and Mayne, 2012. Science and Monitoring Synthesis for South-Eastern Georgian Bay Prepared for Environment Canada

Clark, B.J., A.M. Paterson, A. Jeziorski, and S. Kelsey. 2010. Assessing variability in total phosphorus measurements in Ontario lakes, Lake and Res. Man. 26(1): 63-72

Diep, N., Howell, T., Benoit, N., and Boyd, D. 2007. Limnological conditions in eastern Georgian Bay: Data summary of the 200/-2005 water quality survey. Water Monitoring and Reporting Section, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment.

Dove, A. and Steven C. Chapra - Long-term trends of nutrients and trophic response variables for the Great Lakes Dramatic Changes in the Long-Term Nutrient Record for the Great Lakes Indicate Increasing Phosphorus Limitation, Water Quality Monitoring and Surveillance, Environment Canada, Burlington, ON L7S 1A1, Canada

Eimers, M.C., Shaun A. Watmough, Andrew M. Paterson, Peter J. Dillon, and Huaxia YaoCan 2009. Long-term declines in phosphorus export from forested catchments in south-central Ontario. J. Fish. Aquat. Sci. 66: 1682–1692

Georgian Bay Forever 2013. State of the Bay: an ecosystem health report for eastern & northern Georgian Bay

Georgian Bay Forever, 2014. Township of Georgian Bay Water Quality Monitoring Program Synopsis - (prepared by David Sweetnam)

Hutchison Environmental Sciences, 2014. Georgian Bay Forever Causation Study Synthesis.

Hutchison Environmental Sciences, 2011. Township of Georgian Bay-Coastal Monitoring Program Review.

Shindler, D.W. 2015. The shootout at the N-P lagoon, plenary presentation ASLO conference 2015.

Acronyms & Abbreviations

Acronym / Abbreviation	Description
AOC	Area of concern
DESC	Dorset Environmental Science Centre
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EC	Environment Canada
EGB	Eastern Georgian Bay
ELA	Experimental Lakes Area
GB	Georgian Bay
GBBBR	Georgian Bay Biosphere Reserve
GBF	Georgian Bay Forever
GLSP	Great Lakes Surveillance Program
LPP	Lake Partner Program
MOECC	Ministry of the Environment & Climate Change
NGO	Non-governmental organizations
OBBN	Ontario Benthos Biomonitoring Network
P	Phosphorus
PWQO	Provincial water quality objective
RAP	Restoration action plan
SSEA	Severn Sound Environmental Association
Temp	Temperature
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UNESCO	United Nations Educational, Scientific and Cultural Organization
WQI	Water quality index