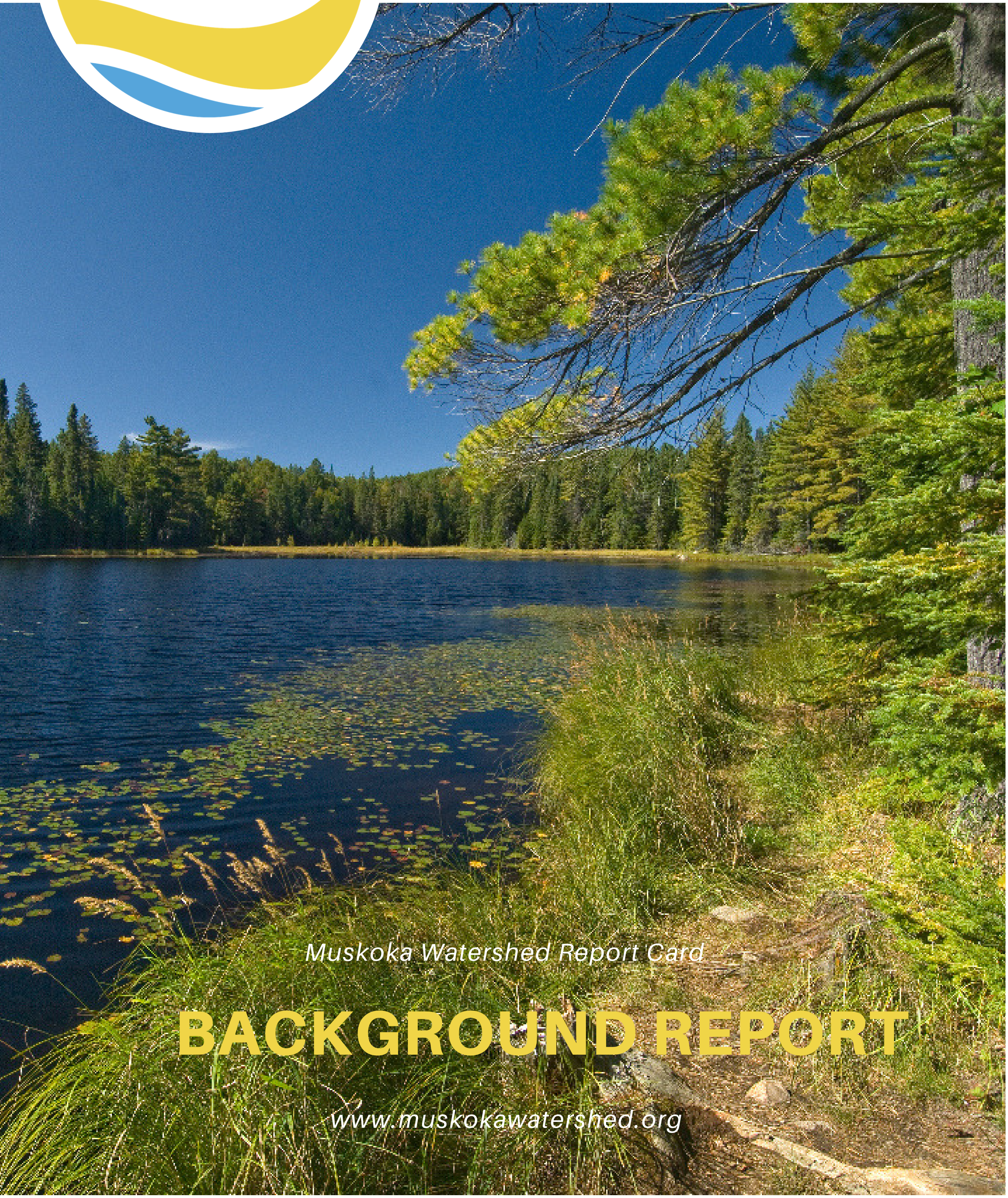
Muskoka Watershed Report Card

July 2018



Muskoka Watershed Report Card

BACKGROUND REPORT

www.muskokawatershed.org

Muskoka Watershed Council

Table of Contents

List of Figures

List of Tables

Acknowledgements

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Letter from the Chair

Kevin Trimble

I am honoured to serve as the current Chair of the Muskoka Watershed Council. I am especially honoured to work alongside the volunteers of MWC, all of whom make projects like the Report Card exciting to develop and deliver.

By offering time, ideas, and expertise, MWC volunteers continue to raise environmental awareness across Muskoka and beyond.

To those taking the time to review this Report Card and learn about the environmental health of your watershed, I sincerely thank you. MWC believes that the health of the watershed lies in the hands of its citizens. Each of us can create and/or contribute to local projects that lead to positive actions. I encourage you to participate in these initiatives, large or small. Not only does our natural environment depend on it, but also our economy and the quality of our communities for future generations.

Glossary of Key Terms

Ecosystem services are the goods and services which the environment produces, such as clean water, timber, habitat for fisheries, and pollination of native and agricultural plants. From Ecological Society of America, "Ecosystem Services: A Primer" http://www.actionbioscience.org/environment/esa.html

Ecosystem functions are the processes by which the environment produces ecosystem services. From Ecological Society of America, "Ecosystem Services: A Primer" http://www.actionbioscience.org/environment/esa.html

Report card is a snapshot of the current conditions of our environment.

A *watershed* is an area of land that drains to a river, lake or stream. What happens in one part of a watershed impacts directly on other parts of that watershed regardless of political boundaries.

Quaternary watershed is a fourth order watershed. Watershed order includes – First order: Great Lakes Basin; Second Order: Georgian Bay; Third Order: Muskoka River; Fourth Order: 19 subwatersheds in Muskoka (Lake of Bays, Lake Rosseau, Big East River, Moon River, etc).

An *indicator* is data that provides information about or predicts the overall health of a portion of the natural environment. An example is total phosphorus as an indicator of recreational water quality.

A *benchmark* is an established guideline against which change in environmental condition can be measured.

Trophic status refers to the amount of productivity in a lake; commonly equated to the amount of phosphorus. The higher the phosphorus level, the more aquatic vegetation will be in the lake.

µg/L means micrograms per litre and is equivalent to parts per billion (ppb).

Climate change is a change in the statistical distribution of weather over periods of time that range from decades to millions of years. It can be a change in the average weather or a change in the distribution of weather events around an average (for example, greater or fewer extreme weather events).

Acid deposition is rain, snow, fog and other forms of precipitation with extremely low pH (acidic).

Biodiversity is a term used to describe the variety of life in a given area. It refers to the wide variety of ecosystems and living organisms: animals, plants, their habitats and their genes.

State of the Muskoka Watershed

The Muskoka Watershed Report Card identifies the environmental health of the ecologically rich and diverse Muskoka Watershed as being very good, overall. Total phosphorus concentrations are stable, benthic macroinvertebrate samples show typical communities, and large, continuous natural areas and interior forest habitats exist for all biota including species at risk.

However, the Report Card also highlights areas in Muskoka that need attention. Invasive species have established in terrestrial and aquatic ecosystems across the entire watershed, and their spread is likely. Calcium concentrations in lakes in the northern watersheds are low, resulting in a decline in key zooplankton species. Climate change is also evident with winter ice coverage on lakes declining and the summer surface water temperatures of lakes increasing.

Armed with this awareness, we can determine what actions we, as a community and as individuals, must do to maintain and enhance Muskoka's environmental health. Many important local initiatives are underway and need support to ensure that our shared watershed remains healthy and can counter environmental challenges with resiliency.

Either as an individual or as part of a larger organization, there are many actions you can undertake to protect what you love about Muskoka's environment.

Introduction

Think Muskoka, and you think water.

We are a region full of water lovers – we play in it, sail on it, paddle it, dive into it, skate on it, fish in it, and of course drink it. However, Muskoka is attracting more and more people each year, and we are all utterly dependent on water for our lives, our livelihoods, our food, and our industry. Muskoka's watershed also provides irreplaceable habitat for aquatic and riparian species. In Muskoka, protecting our watershed is fundamental to our stewardship responsibility and to our overall prosperity. We all have a collective stake in the health of our shared watershed, though as we live, work or travel in this area, we inevitably modify the landscape, impact the plants and animals in their watershed, and alter both ecosystem services and ecosystem functions.

The 2018 Muskoka Watershed Report Card presents the results of monitoring these changes and evaluates the health of the natural features within Muskoka's watersheds. This Muskoka Watershed Report Card is the fifth report card for the area. The content, level of detail, and accuracy of these reports have evolved significantly since 2004 and will continue to evolve as new and better data become available.

The Muskoka Watershed Report Card uses indicators of ecosystem health to identify present and potential environmental stressors and uses data to reveal trends over time. Results are reported on a quaternary watershed basis, of which there are 19 within the Muskoka Watershed.

Goal

The activities of the Muskoka Watershed Council (MWC) are designed to promote a balance between functional human systems and a healthy ecosystem. The Muskoka Watershed Report Card is a tool to educate and promote good stewardship practices with the intent to encourage people to have a positive influence on the ecology of the watersheds.

Using available local data, MWC's Report Card evaluates ecological conditions, general threats, or "drivers" of change, identifies areas of special concern, and highlights emerging issues such as climate change. At the same time, it identifies needed new research. It spotlights the important work being undertaken by various local organizations and offers a pathway for those interested in delving deeper into background information sources.

The Muskoka Watershed Report Card is intended for a wide array of audiences: from individuals and organizations to planners and policy makers. The Report Card draws on existing scientific assessments and uses expert analysis across a range of fields.

The Report Card uses a set of indicators to identify present and potential stressors and to evaluate the health of the terrestrial and aquatic resources in the Muskoka Watershed. The environmental evaluations contained within the Report Card are "made in Muskoka", developed with the help of local scientific and expert advisors and augmented by the work of local citizen scientists and volunteers. The Report Card draws data from various sources. Key contributions are derived from data collected by the District Municipality of Muskoka, the Dorset Environmental Science Centre, and the Ontario Lake Partner Program.

Objective

The mission of the Muskoka Watershed Council is to *champion watershed health*. One way MWC accomplishes this is through the development of Muskoka Watershed Report Cards, which evaluate the ecological health of the watershed and, in turn, foster awareness and participation in maintaining and hopefully enhancing Muskoka's environmental health.

Rationale

Muskoka Watershed Council supports the Muskoka District Council Strategic Priorities approved in October 2016, including the overall Council Mission Statement:

> *"Working together through sound governance to manage the legacy of a healthy Muskoka by protecting the natural environment, driving a vibrant economy and enhancing the inclusiveness of our caring community"*

Muskoka District Council's first goal states:

> *"Continue the stewardship of our natural environment - especially water and natural areas – so that they are protected for the values they provide including support for resilient, diverse ecosystems and a vibrant economy."*

The District Municipality of Muskoka and all six Area Municipalities expressly state in their Official Plans that protection of the natural environment is paramount. Neighbouring municipalities, including the Township of Seguin and the Township of Algonquin Highlands, also express their interests in protecting the natural values of the watershed.

Muskoka Watershed Council recognizes the importance of healthy natural areas for all residents of the watershed and has developed the Muskoka Watershed Report Card to assist decision makers in monitoring the success of policies and gauging progress with regard to overall goals of environmental management.

The Report Card is an important management tool because what gets measured gets managed. It also fosters public awareness of environmental issues – an important aspect of rallying support for efforts designed to address then. People will sympathize with a cause only when they understand the problems being faced and the value of what is at stake. The Report Card provides an evaluation of whether the vision of maintaining functioning natural ecosystems is being achieved and identifies where vulnerabilities exist. It may also focus management actions where needed and track progress over time.

The 'Muskoka Watershed'

The term 'Muskoka Watershed' refers to all quaternary watersheds either lying totally or partially within The District Municipality of Muskoka and includes areas in Algonquin Provincial Park and the Townships of Seguin and Algonquin Highlands. At a tertiary watershed level, it includes all of the Muskoka River Watershed (2EB) as well as portions of the Black-Severn River Watershed (2EC) (Figure 1).

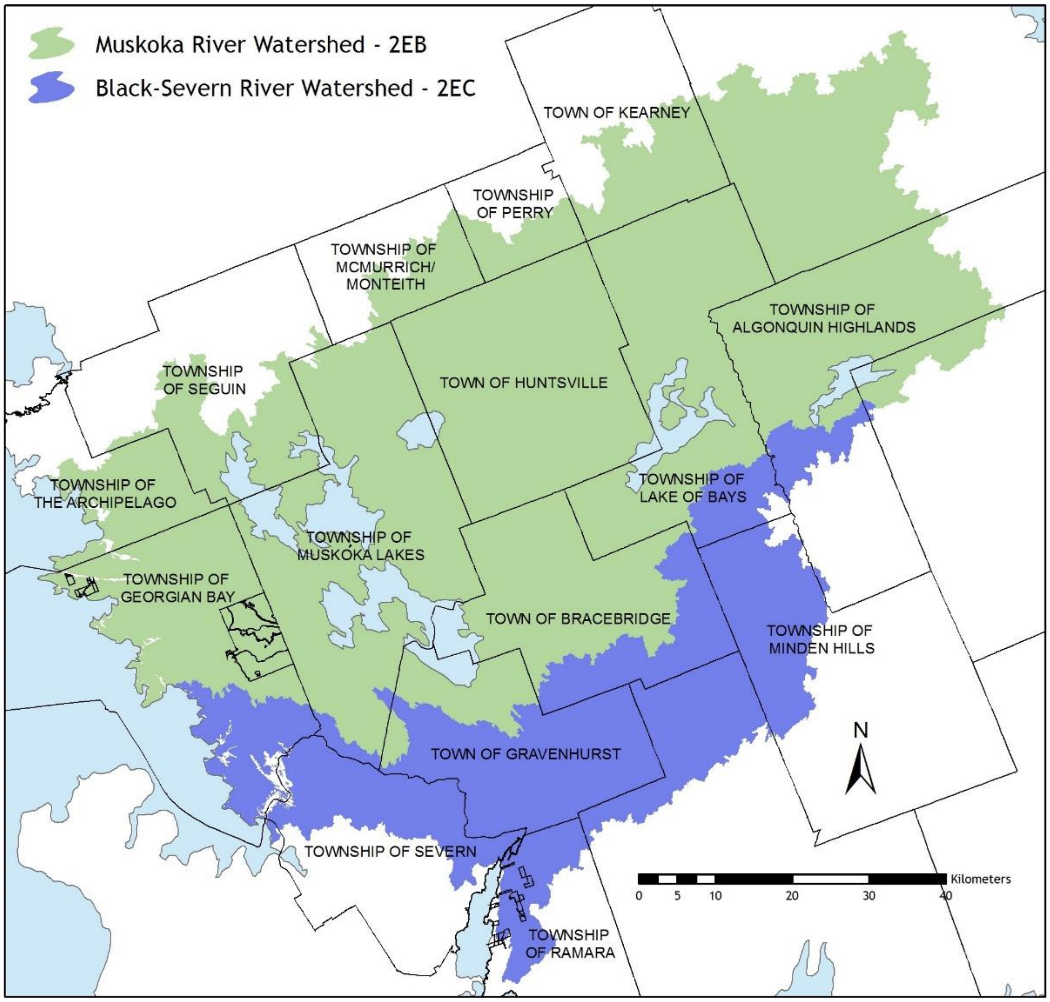


Figure 1. Tertiary-level watersheds that make up the 'Muskoka Watershed' included in the Muskoka Watershed Report Card.

These tertiary watersheds are subdivided into 19 quaternary watersheds (also called subwatersheds), as defined by the Ministry of Natural Resources and Forestry (Table 1 & Figure 2). The Muskoka Watershed Report Card examines environmental health at the scale of quaternary watersheds and the name of the quaternary watershed will be referred to throughout this document.

The quaternary watersheds have been graded using a conservative approach in order to highlight potential issues and raise awareness of the need to be good stewards of our shared watersheds. Effective action can be undertaken at a very local, or even lake-specific, level.

Table 1. Quaternary watersheds, or subwatersheds, of the Muskoka Watershed.

Quaternary Watershed Number	Quaternary Watershed Name
2EB-02	Moon River
2EB-03	Gibson River
2EB-04	Lake Muskoka
2EB-05	Lake Rosseau
2EB-06	Rosseau River
2EB-07	Skeleton River
2EB-08	Dee River
2EB-09	South Muskoka River
2EB-10	Lake of Bays
2EB-11	Oxtongue River

Quaternary Watershed Number	Quaternary Watershed Name
2EB-12	Hollow River
2EB-13	Mary Lake
2EB-14	North Muskoka River
2EB-15	Big East River
2EB-16	Little East River
2EC-14	Lower Black River
2EC-15	Upper Black River
2EC-16	Kahshe River
2EC-17	Severn River

Figure 2. Quaternary-level watersheds included in the Muskoka Watershed Report Card, which are also referred to as subwatersheds.

Environmental management is more effective when management actions are applied at ecologically appropriate scales and with respect to ecological boundaries. These boundaries are not jurisdictional boundaries, such as the boundaries of municipalities, but boundaries built by the topography and the nature of ecological processes. Borders of watershed are good examples of natural or ecological boundaries.

The Muskoka Watershed, in general, is a high-value natural environment. Approximately 82% of the watershed retains natural cover, which supports high biodiversity and functional ecological systems that support a number of species at risk. Only 18% has been extensively modified for human uses. Phosphorus levels are stabilizing across the watershed because of sustained improved management of fertilizers and waste water. Benthic communities are typical of unpolluted water bodies. However, some environmental stressors warrant attention within the Muskoka watershed. For instance, low calcium levels in the northeastern area of the watershed are reducing the growth rate of our forests and altering the composition of our aquatic fauna. Climate change is altering Muskoka's climate in several ways, with run-on impacts on our lakes and waterways. Slow but profound changes in terrestrial and aquatic ecosystems are now underway, new demands are being placed on our built infrastructure, fire prevention and road management, and threats to human health are also being changed. Across Muskoka, invasive species populations are spreading and choking out native species.

Only by monitoring and reporting change can we understand human impacts and environmental sensitivities affecting the watershed. Local stewardship programs are key to addressing these issues and protecting watershed health. Careful monitoring and local benchmarking will assist in understanding how human activities impact natural processes and encourage modified behaviour before significant environmental damage is done.

The Muskoka River Watershed (2EB)

The Muskoka River Watershed (2EB) is located in central Ontario's lake country. The main population centres are Huntsville, Bracebridge and Gravenhurst. Both Highway 400 and Highway 11 bisect the Watershed in a north/south direction. The physical characteristics of the Muskoka River Watershed are provided in Table 2.

Table 2. Watershed characteristics of the Muskoka River Watershed (2EB).

Characteristic	Value
Watershed Area	7,638 km^2
Approximate Permanent Population	61,200
Approximate Seasonal Population	82,300
Number of Major Towns	3 (Bracebridge, Gravenhurst, Huntsville)
Number of Villages and Hamlets	11
Number of Quaternary Watersheds	16
Number of Lakes	Over 1,000
Number of Municipal Wastewater Systems	8
Number of Water Control Structures	42
Number of Navigation Locks	3
Number of Hydro Generating Stations	10

From its headwaters in Algonquin Provincial Park, the Muskoka River flows 210 km through a series of connecting lakes to two outlets in Georgian Bay. The watershed is 62 km at its widest point, encompasses an area of approximately 7,638 km^2, and includes about 780 km^2 of lakes. The watershed is divided into three distinct sections: the north and south branches of the Muskoka River, and the lower Muskoka River. The north and south branches of the Muskoka River comprise approximately the eastern two-thirds of the watershed, originating in the highlands of Algonquin Provincial Park. They flow south-westerly until converging in Bracebridge and then flow into Lake Muskoka. The lower portion of the watershed covers approximately the western one-third of the watershed and receives the inflow from the north and south branches of the Muskoka River as well as Lakes Muskoka, Joseph and Rosseau. This combined flow passes through the Moon and Musquash Rivers and discharges into Georgian Bay.

The Black-Severn River Watershed (2EC)

The Black-Severn River Watershed (2EC) encompasses an area from Newmarket in the south to Minden in the north and Honey Harbour in the west. It includes all of Lake Simcoe in addition to the Black and Severn Rivers. The portion of the Black-Severn River Watershed that is dealt with in this Report Card is limited to the northern portions of the watershed only and encompasses 2,538 km^2.

The headwaters of the Black River are in the Township of Algonquin Highlands. From there, the river flows in a south-westerly direction through the southern portion of the District of Muskoka and northern portions of the Township of Minden Hills, City of Kawartha Lakes, and Ramara Township to Lake Couchiching. From Lake Couchiching, it enters the Severn River and flows to Georgian Bay. Most of the land area in the Black River Watershed is Crown land, with the upper reaches being part of the old Leslie M. Frost Centre.

The portion of the Severn River Watershed that flows through the southern portion of Muskoka is the very bottom section of the Trent/Severn Waterway. The water flows from Lake Couchiching into the lower Severn River and out to Georgian Bay at lock 45 at Port Severn. The Kahshe River Quaternary Watershed flows into the Severn River.

The portion of the Black-Severn River Watershed included in the Report Card is sparsely populated (less than 54,000 residents) with few large urban or agricultural areas. The land use tends to be a blend of rural residential and Crown land settings where population dramatically increases for the summer months as a result of a vibrant tourism industry and seasonal residents. The characteristics of the Black-Severn River Watershed are outlined in Table 3.

Table 3. Watershed characteristics of the Black-Severn River Watershed (2EC).

Characteristic	Value
Watershed Area	22,770 km^2 (only 1,212 km^2 in study area)
Approximate Permanent Population	54,000
Approximate Seasonal Population	Unknown
Upper Tier Municipalities	3
Lower Tier Municipalities	9
Number of Quaternary Watersheds	8 (only 4 in study area)
Number of Lakes	Over 500

The Black-Severn River Watershed flows through portions of three upper tier municipalities (Simcoe, Muskoka, and Haliburton), one single tier municipality (City of Kawartha Lakes) and nine lower tier municipalities (Gravenhurst, Bracebridge, Lake of Bays, Muskoka Lakes, Georgian Bay, Minden, Algonquin Highlands, Severn and Ramara).

The Black-Severn River Watershed is part of the Trent-Severn Waterway. As such, water levels and water flows throughout the Severn River Watershed, including portions of the Lower Black River Watershed, are managed by Parks Canada, which is an Agency of Environment Canada.

Watershed use

The Muskoka Watershed supports a wide range of aquatic and terrestrial ecosystems. Numerous human uses, including recreational activities such as swimming, canoeing, boating, angling, hunting and trapping, and industrial uses like waterpower generation, farming, timber, gravel and dimensional stone mining operations occur within these ecosystems. There are over 42 water control structures (dams and/or dam/powerhouse combinations) on the Muskoka River system and three navigation locks.

Past indicators of watershed health

Since the first Muskoka Watershed Report Card was issued in 2004, considerable information about our watershed has been gathered and assessed and environmental knowledge has advanced. Over the years, the Muskoka Watershed Report Card has evolved significantly and, over time, a variety of indicators have been used. Effective indicators are best chosen as a result of data availability, science advancements, and improved methodologies reinforced by expert scientists. Most watershed health indicators used in Report Cards have been modified over time.

For example, in past report cards, total phosphorus was evaluated and reported each time, usually using the provincial guidelines existing at that time. Since then, provincial guidelines have changed, as well as how we analyze the data to determine grades, so while the indicator remains the same, it has been analyzed differently from one report card to the next which in turn may change some of the lake and quaternary watershed grades. Consequently, the grades of the 2014 Report Card are not a continuum of the 2018 Report Card, and should not be compared.

A key difference to note between the 2014 and 2018 Report Cards is that in the earlier Report Card, several indicators were averaged into an overall grade, and the 2018 Report Card instead offers individual indicators. More specifically, in the 2014 Report Card, terrestrial indicators such as large natural areas, interior forest, road density and development were graded and averaged to derive an overall "Land" grade. Similarly, an overall "Water" grade was determined using the total phosphorus, algae, fish habitat and calcium indicators. While some of these indicators continue to be reported in the 2018 Report Card, they are reported individually and are not averaged.

2018 Muskoka Watershed Report Card indicators

Careful consideration was used when determining the indicators for the 2018 Report Card. Eight indicators were chosen based on data availability, recommendations from scientists, and a desire to consider varied and comprehensive aspects of watershed health including water quality, large natural areas, and biodiversity.

The indicators chosen for the 2018 Report Card retain significant continuity with previous Report Cards but also address emerging issues, such as climate change. Indicators were also chosen with the intention of creating a consistent, easily understandable foundation for incorporating new evidence as it emerges, for future reporting. Many of the current methodologies are developed by local scientists and are unique to Muskoka. These "made-in-Muskoka" benchmarks provide a meaningful understanding of environmental health and vulnerabilities and serve to highlight areas of the watershed that most need improvement. Using the current methods, it is possible to see smaller changes in the health of our quaternary watersheds and the functioning of our ecosystems so that we may act accordingly before ecological problems become insurmountable.

Indicators of ecological health are most meaningful and effective if interpreted together because all aspects of the environment are linked (Briggs, 1999). For this reason, these indicators are assessed for their cumulative impacts in the concluding section of this background report.

Two categories of indicators were assessed: key contributors to the health of the Muskoka Watershed, and key threats to the health of the Muskoka Watershed. The indicators assessed in the 2018 Muskoka Watershed Report Card are outlined in Table 4. This year the Report Card has added benthic macroinvertebrates and climate change as indicators.

Table 4. 2018 Muskoka Watershed Report Card indicators to assess environmental health.

Health Indicators	Threat Indicators
Calcium Concentration	Invasive Species
Total Phosphorus Concentration	Spotlight: Species at Risk
Benthic Macroinvertebrates	Fragmentation
Interior Forest	Climate Change

Together, these indicators provide an understanding of the environmental state of the Muskoka Watershed.

Calcium (Ca) is an important nutrient for all organisms and is required for the development of bones and exoskeletons. As a result of acid precipitation, calcium has leached out of the forest soils and is now in decline in many of the lakes in the watershed. In some cases, reduced calcium levels have resulted in increased stress to *Daphnia,* an important zooplankton species at the bottom of the food chain.

Total Phosphorus (TP) is a measure of the amount of the nutrient phosphorus present in a waterbody. Higher amounts of Total Phosphorus increase the likelihood that a waterbody will experience excessive aquatic plant growth and/or a nuisance algal bloom.

Benthic Macroinvertebrates – or benthos – is a group of small animals living in aquatic habitats that are used as biological indicators of water quality and habitat conditions. Different species have different tolerances to pollution or disturbance, so the presence or absence of various benthic species can provide an indication of water quality.

Interior Forest refers to all forest areas at least 100 metres from a forest edge; essentially it is buffered by that 100 metres of undisturbed forest from external disturbances. Interior forest supports a wide variety of forest-dependent wildlife that do not live closer to forest edges, and is an important component in protecting biodiversity. The amount of interior forest is an indicator of the quality of the forest habitat in Muskoka.

Invasive Species are plants, animals and micro-organisms that out-compete native species for habitat and resources when introduced outside their natural range. Invasive species significantly reduce the biodiversity of an area.

Species at Risk are plants and animals that have been evaluated and are declared to be threatened with extinction, extirpation, or endangerment in a region. These species are at risk because of various natural and human-induced threats they may face. These species contribute to biodiversity, which is important for a healthy watershed. Note: we have not provided quaternary watersheds with a grade for this indicator partly because of a lack of data, but also because, unfortunately, some people use information about the presence of rare species to collect them for the (illegal) pet and curio trade. Instead, the status of species at risk in Muskoka is more broadly discussed.

Fragmentation refers to the breaking apart of large natural areas into smaller and smaller pieces, such as when a new road or hydro corridor cuts through a forest. As development occurs, fragmentation increases. As patches of habitat become smaller, biodiversity declines because many species lack adequate space to carry out their lives. How our watersheds are developed will dictate their health in the future and determine the legacy left for future generations.

Climate Change will have significant impacts on the Muskoka Watershed over the next 50 years and beyond. The climate change indicator is based on the duration of winter ice cover on lakes and surface water temperatures of lakes in the summer. Because climate change is a broad-scale impact across the Muskoka region, the indicator is applied for the entire area rather than for each quaternary watershed.

Watershed grades

The Muskoka Watershed Report Card assesses the health of our watersheds. It establishes benchmarks based on the best available science to provide a snapshot of the current condition of our quaternary watershed. Muskoka's benchmarks are typically higher than those used in southern Ontario, to reflect the condition of our watershed in contrast with more developed areas to the south.

Overall, Muskoka's environment is in very good condition. However, this high level of ecological health will not be maintained without continued management effort. Settlement and development often come with environmental costs and local stewardship programs are needed to mitigate these impacts and protect watershed health. Long-term data sets are required to identify and understand environmental changes. Monitoring across the watershed makes it possible both to detect changes and to act as needed, sooner, where necessary.

Our understanding of the health of our watershed is improving as more data become available. Grades are presented as:

- Not Stressed (green)
- Vulnerable (yellow)
- Stressed (red), and
- Insufficient Data/Not Applicable (gray)

Where data for individual lakes is available, the grade for each quaternary watershed is based on the number of lakes in each category (i.e. stressed, vulnerable, not stressed), such as for the calcium, total phosphorus, and benthic macroinvertebrate indicators. The category for each lake was determined using the criteria outlined in Table 5.

Table 5. Criteria for categorizing lakes for those indicators with lake specific data.

Indicator	Category	Criteria
Calcium	Not Stressed	Concentration above 2.0 mg/L
	Vulnerable	Concentration between 1.5 and 2.0 mg/L
	Stressed	Concentration less than 1.5 mg/L
Total Phosphorus	Not Stressed	Long-term trend is decreasing, or, if increasing, the p-value of the regression is greater than or equal to 0.10
	Vulnerable	Long-term trend is increasing at a significance between 0.10 and 0.05
	Stressed	Long-term trend is increasing at a significance equal to or less than 0.05
Benthic Macroinvertebrates	Typical	%EOT* is between the 10th and 90th percentile
	Atypical	%EOT* is between either the 5th and 10th percentile or the 90th and 95th percentile
	Extremely Atypical	%EOT* is less than the 5th percentile or greater than the 95th percentile

* EOT = *Ephemeroptera* (mayflies), *Odonata* (dragonflies), and *Trichoptera* (caddisflies)

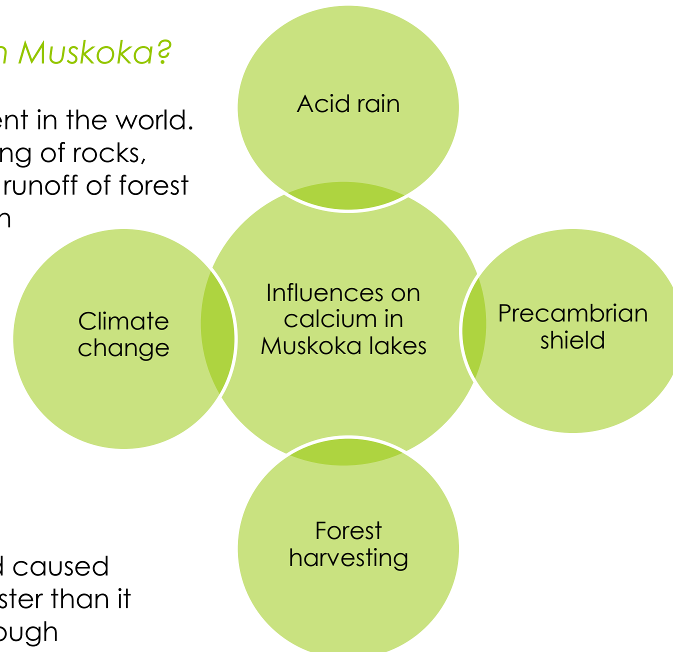
Each quaternary watershed grade was determined using the criteria outlined in Table 6.

Table 6. Criteria for determining the grade for each quaternary watershed by indicator.

Indicator	Grade	Criteria
Calcium	Not Stressed	50% or more of the lakes in the quaternary watershed have a calcium concentration above 2.0 mg/L
	Vulnerable	50% or more of the lakes in the quaternary watershed have a calcium concentration between 1.5 and 2.0 mg/L
	Stressed	50% or more of the lakes in the quaternary watershed have a calcium concentration less than 1.5 mg/L
Total Phosphorus	Not Stressed	Less than 25% of the lakes in the quaternary watershed are vulnerable or stressed
	Vulnerable	Between 25% and 50% of lakes in the quaternary watershed are vulnerable or stressed
	Stressed	More than 50% of the lakes in the quaternary watershed are vulnerable or stressed
Benthic Macroinvertebrates	Typical	50% or more of the lakes in the quaternary watershed are classified as typical
	Atypical	50% or more of the lakes in the quaternary watershed are classified as atypical
	Extremely Atypical	50% or more of the lakes in the watershed are classified as extremely atypical
Interior Forest	Not Stressed	More than 50% of the quaternary watershed is comprised of interior forest
	Vulnerable	Between 20% and 50% of the quaternary watershed is comprised of interior forest
	Stressed	Less than 20% of the quaternary watershed is comprised of interior forest
Invasive Species	Not Stressed	Total score of the quaternary watershed (Invasiveness Ranking System X abundance) is less than 5,000
	Vulnerable	Total score of the quaternary watershed (Invasiveness Ranking System X abundance) is between 5,000 and 10,000
	Stressed	Total score of the quaternary watershed (Invasiveness Ranking System X abundance) is greater than 10,000
Fragmentation	Not Stressed	More than 90% of the quaternary watershed is comprised of natural areas greater than 200 ha in size
	Vulnerable	60% to 90% of the quaternary watershed is comprised of natural areas greater than 200 ha in size
	Stressed	Less than 60% of the quaternary watershed is comprised of natural areas greater than 200 ha in size
Climate Change	All quaternary watersheds are considered vulnerable	
Species at Risk	Not graded	

Calcium Concentrations in Muskoka's Lakes

What is calcium and why is it important in Muskoka?



Calcium is the fifth most abundant natural element in the world. It enters freshwater systems through the weathering of rocks, especially limestone, and from the leaching and runoff of forest soils (Day, 1963). Further, calcium in lakes plays an important role in buffering against acid rain. Calcium is also an essential nutrient for every living plant and animal species while some species, including freshwater mussels, crayfish and *Daphnia*, require more calcium (The District Municipality of Muskoka, 2018).

Acid rain and calcium

Between 1960 and 1970, acid rain intensified and caused calcium to leach from watershed soils to lakes faster than it could be replenished through weathering, or through atmospheric inputs such as dust. As a result, calcium levels in lakes initially increased because of the increased transfer of calcium from watershed soils to lakes. However, as acid rain continued to fall, the available pool of calcium in soils slowly depleted, as did the pool of calcium in lakes (Dorset Environmental Science Centre, 2015).

Lakes in Muskoka are especially vulnerable to the effects of acid rain because the majority of them are located in the Precambrian Shield, where the bedrock is resistant to weathering and the calcium levels in the bedrock are very low, resulting in little leaching of calcium. These low calcium concentrations, in addition to bicarbonate associated with the calcium, made lakes vulnerable to acid rain because they are less able to neutralize or "buffer" against acids (Yan & Jeziorski, 2011). This is not as big of an issue in the Black-Severn River Watershed as its lakes are off the Shield and on limestone – calcium carbonate.

While efforts to reduce acid deposition, such as the revision of the United States' *Clean Air Act* and similar regulations in Canada, have stopped further calcium decline due to acid precipitation, past and current land use practices have also removed calcium from the environment, leaving both forests and lakes increasingly calcium-deficient in Muskoka. These include the historical unsustainable use of forest resources, the export of forest products from the watershed, and land clearing for colonization and agriculture. Modern day development of the shoreline coupled with forest fire suppression reduces the input of calcium into rivers and lakes.

Ecological impacts of low calcium

Scientists are only just beginning to understand the impacts of low calcium on aquatic biota. In lakes with less than 1.5 milligrams of calcium per litre, *Daphnia* die. *Daphnia* are tiny zooplankton that require calcium in the water to build their carapaces. As keystone herbivores in lake food webs, *Daphnia* provide food to many fish and help keep lakes clear by eating algae (Yan & Jeziorski, 2011).

Across the Muskoka Watershed, 56%, or 187 of the lakes sampled for this Report Card, have an average calcium concentration below the threshold of 2.5 milligrams of calcium per litre, a level at which *Daphnia* populations in laboratories become stressed (Ashforth & Yan, 2008). There are many other aquatic animals that need calcium, such as clams, amphipods, and crayfish, and their populations are also declining in low calcium lakes (Yan & Jeziorski, 2011). However, naturally low calcium concentrations across the Muskoka Watershed have also limited the spread and colonization of invasive zebra mussels, as they require higher calcium levels to survive.

Overall, declining calcium levels have led to the increased abundance of a jelly-clad water flea called *Holopedium* (left), which is replacing calcium rich species of *Daphnia*. This water flea has the potential to clog water filters for residents drawing their water from lakes (Jeziorski, et al., 2008). These jelly-clad water fleas are now found in many parts of Muskoka.

Climate change is likely to further contribute to calcium decline. A recent study examined 29 years of calcium data from three lakes in Muskoka and found that calcium decline has worsened with recent warming (Yao, et al., 2011). In addition, mean calcium concentrations in 104 lakes across the watershed have decreased by 30% since the 1980's (Reid, 2015). Muskoka's changing climate has led to decreased water flow, resulting in less calcium being exported from the land to lakes (Yao, et al., 2011).

How is calcium measured in Muskoka?

The calcium indicator is based on data collected through the District of Muskoka's Lake System Health Water Quality Monitoring Program, the Province's Lake Partner Program, and the Dorset Environmental Science Centre. The District Municipality of Muskoka has monitored over 160 lakes across the District for almost 40 years, assessing many water quality parameters including calcium concentrations in lakes. The Provincial Lake Partner Program is a volunteer based initiative that was established in 1996. Through this program, more than 600 volunteers have sampled more than 800 sampling locations in 550 inland lakes across Ontario. These data are complementary with the District's data because they include lakes that lie within the Muskoka River Watershed, but outside the District's boundaries. Scientists at the Dorset Environmental Science Centre provided additional data collected through the long-term ecosystem science program, which focuses on headwater lakes and streams located in south-central Ontario that are representative of tens of thousands of lake catchments on the Canadian Shield. Through these three datasets, the Report Card assessed 187 lakes for the calcium indicator.

The average calcium concentration for each lake was calculated using data collected from 2014 to 2017 and then categorized based on the following criteria:

- **Not stressed**: average lake calcium concentration is greater than 2.0 mg/L
- **Vulnerable**: average lake calcium concentration between 1.5 and 2.0 mg/L
- **Stressed**: average lake calcium concentration less than 1.5 mg/L

Quaternary watersheds grades were then determined based on the categories of lakes within each watershed as follows:

- **Stressed**: 50% or more of the lakes in the quaternary watershed have a calcium concentration less than 1.5 mg/L
- **Vulnerable**: 50% or more of the lakes in the quaternary watershed have a calcium concentration between 1.5 and 2.0 mg/L
- **Not Stressed**: 50% or more of the lakes in the quaternary watershed have a calcium concentration above 2.0 mg/L

Results

See Table 7 for the average calcium concentration and category for each lake assessed for the Report Card.

Table 7. Average calcium concentrations (mg/L) for lakes sampled from 2014 to 2017.

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Big East River	Bella Lake	2.62	Not Stressed
Big East River	Camp Lake	1.34	Stressed
Big East River	Foote Lake	1.96	Vulnerable
Big East River	Little Clear Lake	2.70	Not Stressed
Big East River	Mansell Lake	1.71	Vulnerable
Big East River	Oudaze Lake	2.31	Not Stressed
Big East River	Rebecca Lake	2.43	Not Stressed
Big East River	Solitaire Lake	2.09	Not Stressed
Big East River	Tasso Lake	1.54	Vulnerable
Dee River	Camel Lake	1.86	Vulnerable
Dee River	Longs Lake	3.54	Not Stressed
Dee River	Mainhood Lake	1.72	Vulnerable
Dee River	Three Mile Lake	4.45	Not Stressed
Gibson River	Bastedo Lake	2.62	Not Stressed
Gibson River	Gibson Lake	2.26	Not Stressed

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Gibson River	Long Lake	5.20	Not Stressed
Gibson River	Nine Mile Lake	1.60	Vulnerable
Gibson River	Webster Lake	6.34	Not Stressed
Hollow River	Fletcher Lake	1.75	Vulnerable
Hollow River	Kawagama Lake	1.80	Vulnerable
Hollow River	Livingstone Lake	1.89	Vulnerable
Hollow River	Lower Fletcher Lake	1.99	Vulnerable
Hollow River	Troutspawn Lake	1.85	Vulnerable
Kahshe River	Bass Lake (GR)	2.47	Not Stressed
Kahshe River	Ben Lake	2.02	Not Stressed
Kahshe River	Doeskin Lake	2.52	Not Stressed
Kahshe River	Gartersnake Lake	1.28	Stressed
Kahshe River	Kahshe Lake	2.09	Not Stressed
Kahshe River	Prospect Lake	2.10	Not Stressed
Kahshe River	Ryde Lake	2.06	Not Stressed
Kahshe River	Sunny Lake	2.22	Not Stressed
Kahshe River	Three Mile Lake (GR)	3.18	Not Stressed
Kahshe River	Weismuller Lake	2.96	Not Stressed
Lake Muskoka	Black Lake	2.54	Not Stressed
Lake Muskoka	Brandy Lake	3.14	Not Stressed
Lake Muskoka	Clear Lake (ML)	3.69	Not Stressed
Lake Muskoka	Dark Lake	3.46	Not Stressed
Lake Muskoka	Deer Lake	1.52	Vulnerable
Lake Muskoka	Gull Lake	5.12	Not Stressed
Lake Muskoka	Gullwing Lake	2.20	Not Stressed
Lake Muskoka	Lake Muskoka	3.77	Not Stressed
Lake Muskoka	Leonard Lake	2.16	Not Stressed
Lake Muskoka	Medora Lake	1.20	Stressed
Lake Muskoka	Mirror Lake	3.69	Not Stressed
Lake Muskoka	Neilson Lake	0.97	Stressed
Lake Muskoka	Pigeon Lake	1.60	Vulnerable
Lake Muskoka	Pine Lake (GR)	1.90	Vulnerable
Lake Muskoka	Silver Lake (GR)	2.64	Not Stressed
Lake Muskoka	Silver Lake (ML)	6.05	Not Stressed
Lake Muskoka	Thinn Lake	3.20	Not Stressed

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Lake of Bays	Axle Lake	1.10	Stressed
Lake of Bays	Buck Lake	2.12	Not Stressed
Lake of Bays	Cooper Lake	1.84	Vulnerable
Lake of Bays	Fifteen Mile Lake	1.83	Vulnerable
Lake of Bays	Hardup Lake	1.92	Vulnerable
Lake of Bays	Lake of Bays	2.12	Not Stressed
Lake of Bays	Longline Lake	3.06	Not Stressed
Lake of Bays	Menominee Lake	2.16	Not Stressed
Lake of Bays	Paint Lake	2.79	Not Stressed
Lake of Bays	Pell Lake	1.30	Stressed
Lake of Bays	Shoe Lake	1.94	Vulnerable
Lake of Bays	Sixteen Mile Lake	1.83	Vulnerable
Lake of Bays	Tooke Lake	4.67	Not Stressed
Lake of Bays	Wolfkin Lake	3.66	Not Stressed
Lake Rosseau	Ada Lake	5.59	Not Stressed
Lake Rosseau	Bass Lake (ML)	2.33	Not Stressed
Lake Rosseau	Bruce Lake	3.59	Not Stressed
Lake Rosseau	Brush Lake	1.78	Vulnerable
Lake Rosseau	Butterfly Lake	4.35	Not Stressed
Lake Rosseau	Hamer Lake	2.17	Not Stressed
Lake Rosseau	Henshaw Lake	5.86	Not Stressed
Lake Rosseau	Lake Joseph	4.00	Not Stressed
Lake Rosseau	Lake Rosseau	3.44	Not Stressed
Lake Rosseau	Little Lake Joseph	3.61	Not Stressed
Lake Rosseau	Pickering Lake	1.39	Stressed
Lake Rosseau	Rickett's Lake	6.84	Not Stressed
Lake Rosseau	Stewart Lake	8.65	Not Stressed
Little East River	Arrowhead Lake	3.40	Not Stressed
Little East River	Bay Lake	2.17	Not Stressed
Little East River	Bing Lake	1.40	Stressed
Little East River	Clark Lake	1.74	Vulnerable
Little East River	Emsdale Lake	2.09	Not Stressed
Little East River	Jessop Lake	1.54	Vulnerable
Little East River	Lake Waseosa	2.29	Not Stressed
Little East River	Palette Lake	4.20	Not Stressed

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Little East River	Perch Lake	2.68	Not Stressed
Little East River	Ripple Lake	2.61	Not Stressed
Lower Black River	Riley Lake	2.18	Not Stressed
Mary Lake	Bittern Lake	1.74	Vulnerable
Mary Lake	Buck Lake (HT)	1.96	Vulnerable
Mary Lake	Chub Lake (HT)	2.54	Not Stressed
Mary Lake	Fairy Lake	2.41	Not Stressed
Mary Lake	Fox Lake	1.86	Vulnerable
Mary Lake	Golden City Lake	0.68	Stressed
Mary Lake	Harp Lake	2.34	Not Stressed
Mary Lake	Lake Vernon	2.05	Not Stressed
Mary Lake	Mary Lake	2.67	Not Stressed
Mary Lake	Otter Lake	2.17	Not Stressed
Mary Lake	Penfold Lake	5.58	Not Stressed
Mary Lake	Peninsula Lake	3.80	Not Stressed
Mary Lake	Rose Lake	1.00	Stressed
Mary Lake	Siding Lake	1.72	Vulnerable
Mary Lake	Tucker Lake	2.67	Not Stressed
Mary Lake	Walker Lake	2.83	Not Stressed
Moon River	Blackstone Lake	3.82	Not Stressed
Moon River	Burnt Lake	7.65	Not Stressed
Moon River	Cassidy Lake	2.92	Not Stressed
Moon River	Crane Lake	3.50	Not Stressed
Moon River	Flatrock Lake	3.07	Not Stressed
Moon River	Galla Lake	2.00	Not Stressed
Moon River	Go Home Lake	3.45	Not Stressed
Moon River	Haggart Lake	3.78	Not Stressed
Moon River	Healey Lake	1.82	Vulnerable
Moon River	Hesner's Lake	2.80	Not Stressed
Moon River	Horseshoe Lake	3.34	Not Stressed
Moon River	McRey Lake	1.62	Vulnerable
Moon River	Moon River	3.22	Not Stressed
Moon River	Myers Lake	2.63	Not Stressed
Moon River	Silver Sand Lake	2.14	Not Stressed
Moon River	Tadenac Lake	1.68	Vulnerable

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Moon River	Toronto Lake	1.44	Stressed
North Muskoka River	Atkins Lake	3.32	Not Stressed
North Muskoka River	Bonnie Lake	2.12	Not Stressed
North Muskoka River	Clearwater Lake (HT)	2.81	Not Stressed
North Muskoka River	Devine Lake	1.51	Vulnerable
North Muskoka River	Fawn Lake	1.80	Vulnerable
North Muskoka River	Gilleach Lake	1.41	Stressed
North Muskoka River	Halfway Lake	2.74	Not Stressed
North Muskoka River	Moot Lake	1.11	Stressed
North Muskoka River	Stoneleigh Lake	1.43	Stressed
Oxtongue River	Brooks Lake	2.78	Not Stressed
Oxtongue River	Dotty Lake	1.50	Vulnerable
Oxtongue River	Oxbow Lake	1.75	Vulnerable
Oxtongue River	South Nelson Lake	1.29	Stressed
Oxtongue River	Westward Lake	1.48	Stressed
Rosseau River	Cardwell Lake	1.34	Stressed
South Muskoka River	Bigwind Lake	1.79	Vulnerable
South Muskoka River	Chub Lake (LOB)	1.42	Stressed
South Muskoka River	Dickie Lake	2.44	Not Stressed
South Muskoka River	Echo Lake	2.18	Not Stressed
South Muskoka River	Grandview Lake	4.42	Not Stressed
South Muskoka River	Heney Lake	1.39	Stressed
South Muskoka River	Leech Lake	2.89	Not Stressed
South Muskoka River	McKay Lake	2.24	Not Stressed
South Muskoka River	Pine Lake (BR)	2.58	Not Stressed
South Muskoka River	Ridout Lake	1.63	Vulnerable
South Muskoka River	Ril Lake	2.17	Not Stressed
South Muskoka River	Spence Lake	1.97	Vulnerable
South Muskoka River	Spring Lake	2.67	Not Stressed
South Muskoka River	Tackaberry Lake	1.10	Stressed
South Muskoka River	Wildcat Lake	1.22	Stressed
South Muskoka River	Wood Lake	2.42	Not Stressed
Severn River	Barron's Lake	7.06	Not Stressed
Severn River	Baxter Lake	21.00	Not Stressed
Severn River	Bearpaw Lake	2.72	Not Stressed

Quaternary Watershed	Lake Name	Average Ca (mg/L)	Category
Severn River	Clearwater Lake (GR)	2.61	Not Stressed
Severn River	Cornall Lake	3.92	Not Stressed
Severn River	Jevins Lake	6.87	Not Stressed
Severn River	Loon Lake	6.20	Not Stressed
Severn River	McCrae Lake	19.80	Not Stressed
Severn River	McDonald Lake	20.80	Not Stressed
Severn River	Morrison Lake	3.49	Not Stressed
Severn River	North Muldrew Lake	3.53	Not Stressed
Severn River	Six Mile Lake	15.55	Not Stressed
Severn River	South Bay	15.50	Not Stressed
Severn River	South Muldrew Lake	3.53	Not Stressed
Severn River	Sparrow Lake	24.35	Not Stressed
Severn River	Turtle Lake	5.80	Not Stressed
Skeleton River	High Lake	2.79	Not Stressed
Skeleton River	Little Long Lake	7.09	Not Stressed
Skeleton River	Nutt Lake	8.28	Not Stressed
Skeleton River	Skeleton Lake	3.73	Not Stressed
Skeleton River	Young Lake	2.02	Not Stressed
Upper Black River	Blue Chalk Lake	2.15	Not Stressed
Upper Black River	Cinder Lake East	1.33	Stressed
Upper Black River	Clear Lake (BR)	1.62	Vulnerable
Upper Black River	Crosson Lake	1.22	Stressed
Upper Black River	Grindstone Lake	2.27	Not Stressed
Upper Black River	Margaret Lake	1.36	Stressed
Upper Black River	Mouse Lake	1.27	Stressed
Upper Black River	Poker Lake	1.63	Vulnerable
Upper Black River	Porcupine Lake	1.80	Vulnerable
Upper Black River	Raven Lake	1.91	Vulnerable
Upper Black River	Red Chalk Lake	1.82	Vulnerable

BR (Bracebridge) GR (Gravenhurst) GB (Georgian Bay) HT (Huntsville)
LOB (Lake of Bays) ML (Muskoka Lakes)

The number of lakes by quaternary watershed that fall into the Not Stressed, Vulnerable and Stressed categories based on the criteria provided above is presented in Table 8.

Table 8. Quaternary watershed grades for the calcium indicator.

Quaternary Watershed	Number of Lakes			Grade
	Not Stressed	Vulnerable	Stressed	
Big East River	5	3	1	Not Stressed
Dee River	2	2	0	Not Stressed
Gibson River	4	1	0	Not Stressed
Hollow River	0	5	0	Vulnerable
Kahshe River	9	0	1	Not Stressed
Lake Muskoka	12	3	2	Not Stressed
Lake of Bays	7	5	2	Not Stressed
Lake Rosseau	11	1	1	Not Stressed
Little East River	7	2	1	Not Stressed
Lower Black River	1	0	0	Insufficient Data
Mary Lake	10	4	2	Not Stressed
Moon River	13	3	1	Not Stressed
North Muskoka River	4	2	3	Not Stressed
Oxtongue River	1	2	2	Vulnerable
Rosseau River	0	0	1	Insufficient Data
South Muskoka River	9	3	4	Not Stressed
Severn River	16	0	0	Not Stressed
Skeleton River	5	0	0	Not Stressed
Upper Black River	2	5	4	Stressed

What do the results mean?

Most sampled lakes in the Muskoka Watershed have calcium concentrations above the threshold at which *Daphnia* populations suffer. There are insufficient data to demonstrate trends over time in calcium concentrations for individual lakes. However, the lakes graded as vulnerable or stressed are likely to experience declines, or may have already done so. These changes likely mean lower *Daphnia* and higher *Holopedium* abundances, and, in turn, modifications in the aquatic food web. Such food web changes may result in changes in fish populations that rely on zooplankton as a food source, and may also alter the frequency of algal blooms. Continued monitoring on these lakes is important to detect further declines of calcium.

It is difficult to compare the results for this indicator between the 2014 and 2018 Report Cards as the sources of data are not consistent (Table 9), particularly in the upper reaches of the Muskoka River Watershed where calcium concentrations are known to be low (Figure 3). For example, in the 2014 Report Card, the Big East River Watershed grade of 'vulnerable' was based on data from 45 lakes (20 stressed, 16 vulnerable and 9 not stressed), while the 2018 Report Card grade of 'not stressed' is based on data from only nine lakes (1 stressed, 3 vulnerable and 5 not stressed).

This discrepancy highlights the need for more consistent and broader sampling of lakes in the Big East River, Oxtongue River and Hollow River Watersheds to ensure that a more representative sample of lakes form the basis for grading the calcium indicator. The good news is that the lakes included in the 2018 dataset are likely to be sampled long-term (either as part of the Lake Partner Program or the District of Muskoka's Lake System Health Water Quality Monitoring Program) so trends in these sampled lakes can be seen in the future.

Table 9. Comparison of datasets used for the calcium indicator in the 2014 Report Card and the 2018 Report Card.

	2014 Report Card	2018 Report Card
Data Sources	• District Municipality of Muskoka • Yan: 300 lakes study	• District Municipality of Muskoka • Lake Partner Program • Dorset Environmental Science Centre
# of lakes included	415	190
Years of data included	10 (2004-2013)	4 (2014-2017)

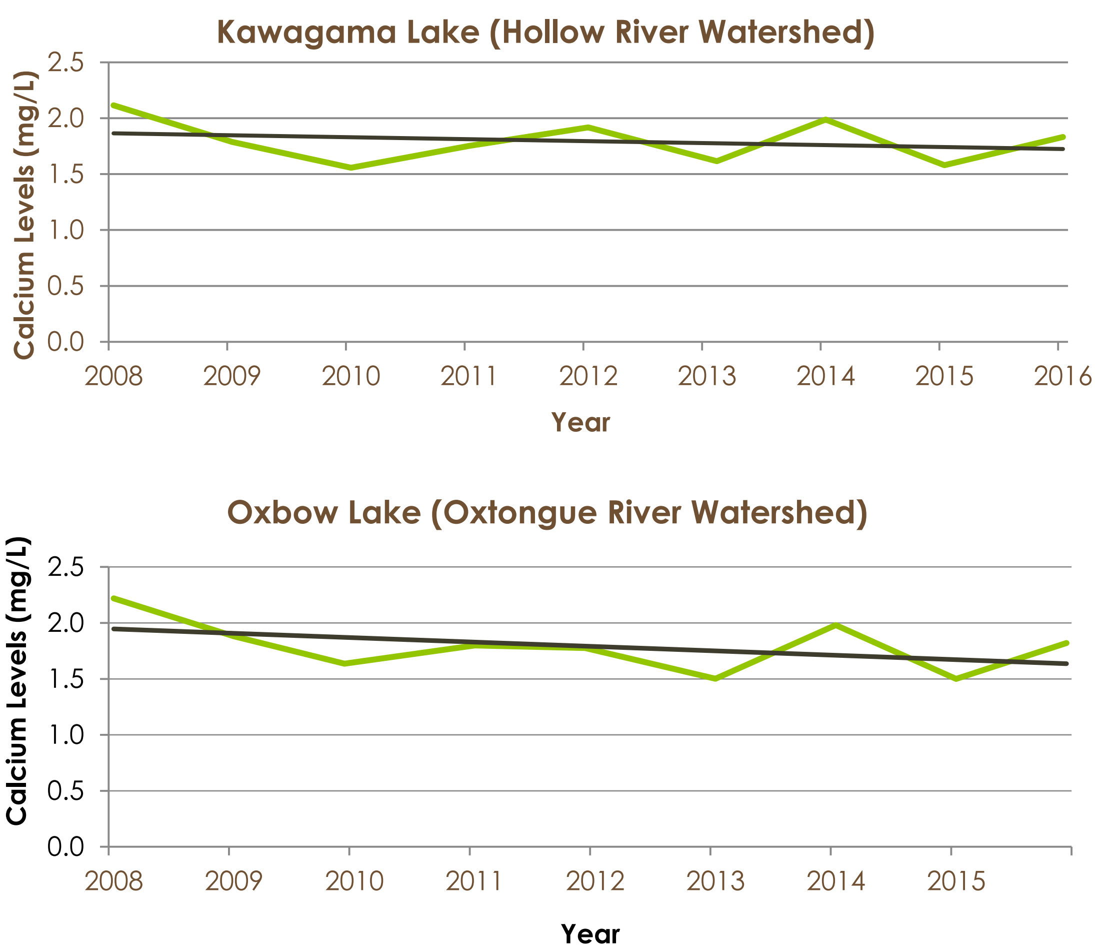


Figure 3. Calcium decline in two lakes in the northeastern portion of the Muskoka River Watershed.

It's your turn!

Although the process of supplying calcium to soils by weathering bedrock is a slow one, you can help reduce the potential impacts of calcium decline by:

- Supporting governmental efforts to reduce SO_2 and NO_X emissions to reduce acid deposition rates;
- Participating in the Province's public consultation for forest management of the French-Severn Forest in Muskoka; and
- Joining Ontario's Lake Partner Program to help monitor Ontario's lakes. Check out http://desc.ca/programs/LPP for more information.
- Participating in Friends of the Muskoka Watershed's Residential Wood Ash Recycling Program.

Local Spotlight: Friends of the Muskoka Watershed

Friends of the Muskoka Watershed are encouraging public participation in their Residential Wood Ash Recycling Program, which is aimed to help stop the calcium decline in Muskoka's lakes. This program encourages Muskokans to become "gardeners of the forest". As gardeners, participants can use wood ash – the residue remaining after the burning of wood – to return calcium to forest soils where it originated. Wood ash contains many elements, of which calcium is the most abundant, forming between 15% and 50% of total ash weight. Applying wood ash to forests or soil is already being used in the northeast United States of America, Sweden, Finland, United Kingdom, and several provinces in Canada including Alberta, British Columbia, New Brunswick, Nova Scotia and Quebec. However, wood ash in Ontario is not regularly used as a soil amendment on agricultural or forest soils, and there are currently no guidelines for such uses on private land. With enough participants, wood ash could help solve the calcium decline problem in Muskoka. Learn more about this program at www.friendsofthemuskokawatershed.org.

Phosphorus Concentrations in Lakes

Water quality is one of the fundamental components of a healthy watershed. As people live and work around lakes, they may impact and change lake ecosystems. One change that may be seen as a result of human influences is an increase of phosphorus concentration in lakes.

What is phosphorus and why is it important in Muskoka?

Phosphorus occurs naturally in the environment and is an essential nutrient that plants and animals need to grow. However, too much phosphorus can impact the amount and types of algae found in a waterbody, and may contribute to the development of algal blooms (Hutchinson, Köster, Karst-Riddoch, & Parsons, 2016). Algae blooms can detract from the recreational use of water and, in some cases, can affect the habitat of coldwater fish species such as Lake Trout.

Phosphorus has many pathways of entry to a waterbody, both from natural processes and human activities. Natural processes include weathering of rocks, erosion of soil, decay of organic material, and deposition from the atmosphere through pollen and dust (Ministry of the Environment, Conservation and Parks, 2010). Human-driven activities can include erosion due to vegetation removal; runoff from urban stormwater and/or agricultural lands fertilized with products containing phosphorus or manure; discharge from sewage treatment plants and septic systems; and atmospheric deposition from the burning of fossil fuels (Ministry of the Environment, Conservation and Parks, 2010).

Excessive phosphorus loading can degrade water quality and disrupt the balance in aquatic ecosystems (Ministry of the Environment, Conservation and Parks, 2010). When excessive phosphorus loading is a result of human activities, it is called eutrophication or nutrient enrichment. Without clean and safe water, many of our favourite summer recreational activities may be jeopardized and our sense of enjoyment from being in a natural and relatively pristine environment can be lost (Schiefer, 2008).

Phosphorus levels in a lake will naturally vary from year to year due to factors such as amount of precipitation, wind, and levels of sunlight (Hutchinson, Köster, Karst-Riddoch, & Parsons, 2016). Climate change may also affect phosphorus levels. In order to understand trends in phosphorus concentrations, scientific investigations that relate all these factors to variables such as development, invasive species and other human impacts are necessary (Hutchinson, Köster, Karst-Riddoch, & Parsons, 2016).

Trophic status in Muskoka's lakes

In any watershed, there is natural variation in phosphorus concentrations among lakes because of differences in lake size, amount of wetland, and characteristics of water flow. Lakes are generally classified into one of three categories in regards to their nutrient status. Lakes with less than 10 µg/L of total phosphorus are called oligotrophic lakes. These lakes have low primary productivity as a result of low nutrient content, and are generally considered desirable for

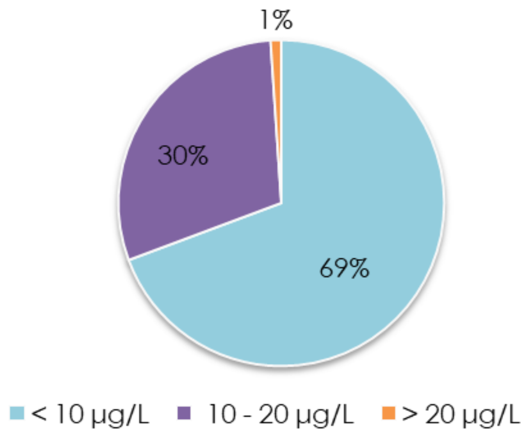


Figure 4. Distribution of sampled lakes by trophic status (2001-2017).

recreational activities and cottage development. 69% of sampled lakes in Muskoka from 2001-2017 are oligotrophic.

Lakes with moderate total phosphorus concentrations are called mesotrophic lakes, which have between 10 and 20 µg/L of total phosphorus. These lakes tend to be smaller and support warm water fish species and more diverse shoreline habitat. 30% of sampled lakes in Muskoka *from 2001-2017 are mesotrophic*. Lakes with greater than 20 µg/L of total phosphorus are called eutrophic lakes. These lakes are enriched with phosphorus and are considered to be highly productive. They may show signs of persistent and nuisance algal blooms. Approximately 1% of lakes sampled in Muskoka from 2001-2017 are eutrophic. Figure 4 shows the variation in trophic status or productivity of lakes in Muskoka.

Lakes in Muskoka, like others on the Canadian Shield, are naturally low in surface water total phosphorus concentrations due to geology, vegetation cover, and smaller human influence from sources like agriculture, industry and large urban centres. Long-term monitoring carried out at the Dorset Environmental Science Centre over a 40-year period has shown an overall decline in total phosphorus concentrations in both developed and undeveloped lakes. Eimers (2016) suggested that possible drivers of this decline may include a decrease in atmospheric deposition to lake surfaces and a decrease in phosphorus inputs to lakes from their watershed (potentially as a result of recovering from past disturbances such as cottage development and logging). Research is ongoing to investigate these hypotheses.

This trend of decreasing phosphorus concentrations is also seen in the District of Muskoka's dataset. Figure 5 shows the average spring turnover phosphorus concentrations for a range of lakes across Muskoka for three consecutive time periods (1988-1997, 1998-2007, and 2008-2017). Lower phosphorus concentrations are seen in the more recent time periods.

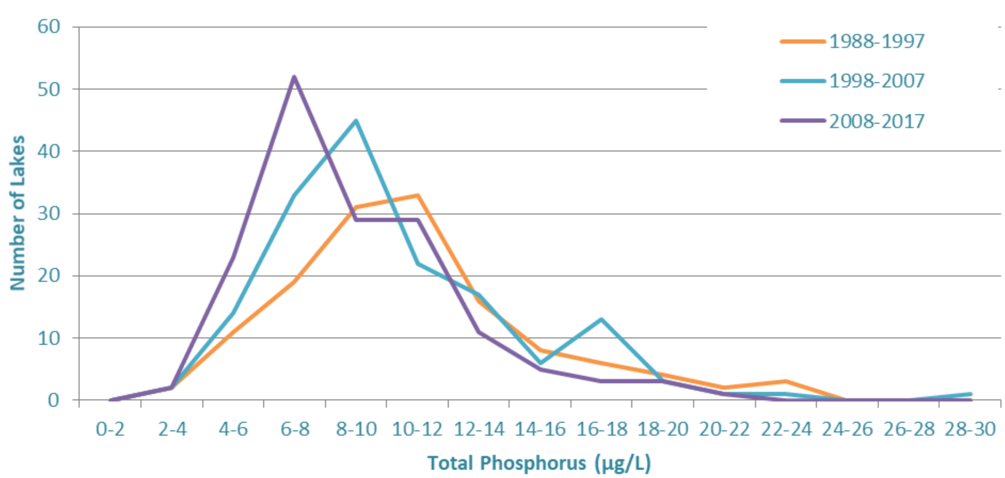


Figure 5. Distribution of sampled lakes in Muskoka based on 10-year average phosphorus concentrations for three time periods: 2008-2017, 1988 to 1997 and 1998 to 2007.

How is Phosphorus measured in Muskoka?

Datasets were obtained from The District Municipality of Muskoka (Lake System Health Water Quality Monitoring Program) and the Ministry of the Environment, Conservation and Parks (Ontario Lake Partner Program and Dorset Environmental Science Centre Dorset-A and Dorset-B Lakes) and analyzed for the phosphorus indicator in the Report Card.

The District Municipality of Muskoka has monitored over 160 lakes across the District for almost 40 years, assessing many water quality parameters including phosphorus. The Ontario Lake Partner Program is a volunteer based initiative established in 1996 and has more than 600 volunteers sampling over 800 sampling locations in 550 inland lakes across Ontario. The District of Muskoka dataset was used for lakes within the District and the Lake Partner Program dataset was used for lakes within the watershed but outside of the District. Additional data was acquired from the Dorset Environmental Science Centre, which has monitored specific sets of lakes (Dorset-A Lakes and Dorset-B Lakes) since the mid-1970's. In total, 188 lakes were assessed for the phosphorus indicator.

The 2018 Muskoka Watershed Report Card assesses long-term trends of Total Phosphorus concentrations in individual lakes since 2001. Only data since 2001 were included as this is when collection methodology and laboratory and data analysis methods were standardized and remain fairly consistent to this day.

Linear regressions were carried out for each lake that had a minimum of three years of data. The following steps were used to determine the grade of each lake:

1. Individual lake data collected between 2001 to 2017 was plotted on a line graph.
2. A trend line was added to the graph, and
    a. If the trend line was decreasing, the lake is deemed not stressed as total phosphorus concentrations are not increasing
    b. If the trend line was horizontal, the lake is deemed not stressed as total phosphorus concentrations are not increasing
    c. If the trend line was increasing, the R^2 value of the trend line was calculated. If the R^2 value was less than 0.1, the lake is deemed not stressed because the increasing trend is not significant. If the R^2 was greater than 0.1, the p-value of the trend was calculated to determine the significance of the increasing trend and subsequently the category, as follows:

        - **Not Stressed:** the p-value of the regression is greater than or equal to 0.10
        - **Vulnerable**: The p-value of the regression is between 0.10 and 0.05
        - **Stressed**: The p-value of the regression is equal to or less than 0.05

Quaternary watersheds grades were then determined based on the categories of lakes within each watershed as follows:

- **Not Stressed**: Less than 25% of the lakes in the watershed are vulnerable or stressed
- **Vulnerable**: Between 25% and 50% of lakes in the watershed are vulnerable or stressed
- **Stressed**: More than 50% of the lakes in the watershed are vulnerable or stressed

The overall results of the quaternary watershed can be seen in Table 11.

About R^2 values, trend lines (linear regression), and p-values

A trend line is a line in a graph that runs through data points that displays the trend of the data. An R^2 value of the line can be calculated, which indicates the goodness of fit of the line, or how close the data points fit the trend line. The closer the R^2 value is to 1, the closer the data points are to the line. For instance, total phosphorus concentrations in Bay Lake in the Little East River Watershed is increasing at a R^2 value of 0.31 (Figure 6). The trend line is going through or close to most of the data points. However, for Lower Fletcher Lake in the Hollow River Watershed, most data points are not in contact with the black trend line. Therefore, the R^2 value is low.

P-values determine the significance of the R^2 value. It determines if the trend line is significantly different from zero.

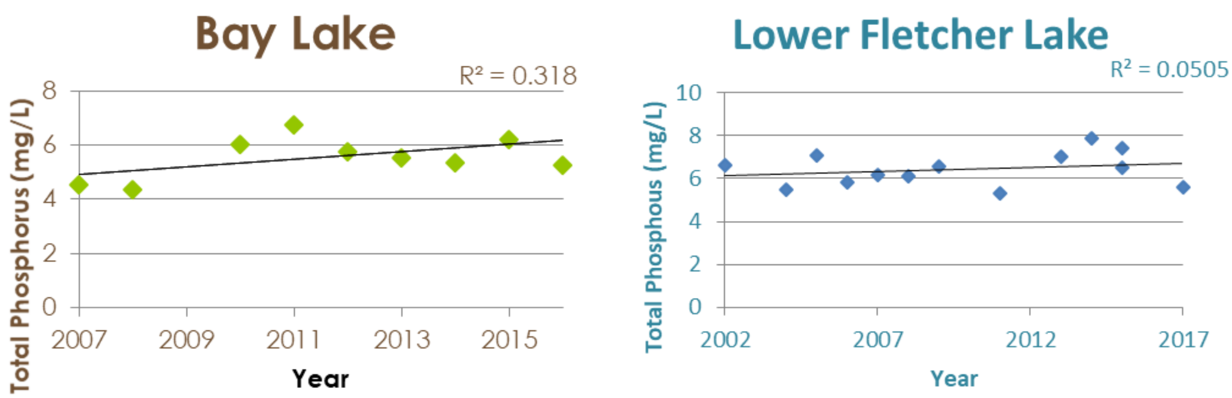


Figure 6. Examples of R^2 values and trend lines.

Results

See Table 10 for the results of the analysis of trends in phosphorus concentrations in lakes sampled between 2001 and 2017 and the category assessed for the Report Card.

Table 10. Trends in phosphorus concentrations in lakes sampled between 2001 and 2017 and the category assessed for the Report Card

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Big East River	Bella Lake	Not Increasing	Not Increasing	Not Stressed
Big East River	Camp Lake	Not Increasing	Not Increasing	Not Stressed
Big East River	Foote Lake	Not Increasing	Not Increasing	Not Stressed
Big East River	Mansell Lake	0.33	0.23	Not Stressed
Big East River	Oudaze Lake	Not Increasing	Not Increasing	Not Stressed
Big East River	Rebecca Lake	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Big East River	Solitaire Lake	Not Increasing	Not Increasing	Not Stressed
Big East River	Tasso Lake	Not Increasing	Not Increasing	Not Stressed
Dee River	Camel Lake	Not Increasing	Not Increasing	Not Stressed
Dee River	Longs Lake	Not Increasing	Not Increasing	Not Stressed
Dee River	Mainhood Lake	0.48	0.19	Not Stressed
Dee River	Three Mile Lake	Not Increasing	Not Increasing	Not Stressed
Gibson River	Bastedo Lake	Not Increasing	Not Increasing	Not Stressed
Gibson River	Gibson Lake	Not Increasing	Not Increasing	Not Stressed
Gibson River	Long Lake (ML)	Not Increasing	Not Increasing	Not Stressed
Gibson River	Nine Mile Lake	Not Increasing	Not Increasing	Not Stressed
Gibson River	Webster Lake	0.92	0.01	Stressed
Hollow River	Fletcher Lake	Not Increasing	Not Increasing	Not Stressed
Hollow River	Kawagama Lake	Not Increasing	Not Increasing	Not Stressed
Hollow River	Livingstone Lake	Not Increasing	Not Increasing	Not Stressed
Hollow River	Lower Fletcher Lake	Not Increasing	Not Increasing	Not Stressed
Hollow River	Troutspawn Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Bass Lake (GR)	0.24	0.35	Not Stressed
Kahshe River	Ben Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Doeskin Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Gartersnake Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Kahshe Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Prospect Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Ryde Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Sunny Lake	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Three Mile Lake (GR)	Not Increasing	Not Increasing	Not Stressed
Kahshe River	Weismuller Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Black Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Brandy Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Clear Lake (ML)	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Dark Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Deer Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Gull Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Gullwing Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Lake Muskoka	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Lake Muskoka	Leonard Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Medora Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Mirror Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Neilson Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Pigeon Lake	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Pine Lake (GR)	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Silver Lake (GR)	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Silver Lake (ML)	Not Increasing	Not Increasing	Not Stressed
Lake Muskoka	Thinn Lake	0.16	0.50	Not Stressed
Lake of Bays	Axle Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Buck Lake (LOB)	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Cooper Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Fifteen Mile Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Hardup Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Lake of Bays	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Longline Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Menominee Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Otter Lake (Tock)	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Pell Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Shoe Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Sixteen Mile Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Paint Lake (St. Mary)	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Tooke Lake	Not Increasing	Not Increasing	Not Stressed
Lake of Bays	Wolfkin Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Ada Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Bass Lake (ML)	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Bruce Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Butterfly Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Dyson Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Hamer Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Harp Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Henshaw Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Lake Joseph	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Lake Rosseau	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Lake Rosseau	Little Lake Joseph	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Pickering Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Ricketts Lake	Not Increasing	Not Increasing	Not Stressed
Lake Rosseau	Stewart Lake	Not Increasing	Not Increasing	Not Stressed
Little East River	Bay Lake	0.25	0.09	Vulnerable
Little East River	Bing Lake	0.21	0.43	Not Stressed
Little East River	Clark Lake	Not Increasing	Not Increasing	Not Stressed
Little East River	Emsdale Lake	Not Increasing	Not Increasing	Not Stressed
Little East River	Jessop Lake	Not Increasing	Not Increasing	Not Stressed
Little East River	Lake Waseosa	Not Increasing	Not Increasing	Not Stressed
Little East River	Palette Lake	0.17	0.13	Not Stressed
Little East River	Perch Lake	Not Increasing	Not Increasing	Not Stressed
Little East River	Ripple Lake	Not Increasing	Not Increasing	Not Stressed
Lower Black River	Riley Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Bittern Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Buck Lake (HT)	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Chub Lake (HT)	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Fairy Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Fox Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Golden City Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Lake Vernon	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Mary Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Otter Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Penfold Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Peninsula Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Robinson Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Rose Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Siding Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Tucker Lake	Not Increasing	Not Increasing	Not Stressed
Mary Lake	Walker Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Blackstone Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Burnt Lake (Joselin)	Not Increasing	Not Increasing	Not Stressed
Moon River	Cassidy Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Crane Lake	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Moon River	Flatrock Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Galla Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Go Home Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Haggart Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Healey Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Hesners Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Horseshoe Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Cognashene Bay	Not Increasing	Not Increasing	Not Stressed
Moon River	Little Go-Home Bay	Not Increasing	Not Increasing	Not Stressed
Moon River	North Bay	Not Increasing	Not Increasing	Not Stressed
Moon River	Tadenac Bay	Not Increasing	Not Increasing	Not Stressed
Moon River	Twelve Mile Bay	Not Increasing	Not Increasing	Not Stressed
Moon River	Wah Wah Taysee	Not Increasing	Not Increasing	Not Stressed
Moon River	McKenchie Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Myers Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Second Lake	0.22	0.52	Not Stressed
Moon River	Silver Sand Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Tadenac Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Third Lake	Not Increasing	Not Increasing	Not Stressed
Moon River	Toronto Lake	0.2	0.36	Not Stressed
North Muskoka River	Atkins Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Bonnie Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Clearwater Lake (HT)	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Devine Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Fawn Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Gilleach Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Halfway Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Moot Lake	Not Increasing	Not Increasing	Not Stressed
North Muskoka River	Stoneleigh Lake	Not Increasing	Not Increasing	Not Stressed
Oxtongue River	Brooks Lake	Not Increasing	Not Increasing	Not Stressed
Oxtongue River	Dotty Lake	0.11	0.51	Not Stressed
Oxtongue River	Oxbow Lake	Not Increasing	Not Increasing	Not Stressed
Oxtongue River	Oxtongue Lake	0.15	0.33	Not Stressed
Oxtongue River	South Nelson Lake	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
Oxtongue River	Westward Lake	Not Increasing	Not Increasing	Not Stressed
Rosseau River	Cardwell Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Barrons Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Baxter Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Bearpaw Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Clearwater Lake (GR)	Not Increasing	Not Increasing	Not Stressed
Severn River	Cornall Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Jevins Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Loon Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	McCrae Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	McDonald Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Morrison Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	North Muldrew Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Six Mile Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	South Bay	0.62	0.03	Stressed
Severn River	South Muldrew Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Sparrow Lake	Not Increasing	Not Increasing	Not Stressed
Severn River	Turtle Lake	Not Increasing	Not Increasing	Not Stressed
Skeleton River	High Lake	Not Increasing	Not Increasing	Not Stressed
Skeleton River	Little Long Lake (Rutter)	Not Increasing	Not Increasing	Not Stressed
Skeleton River	Nutt Lake	Not Increasing	Not Increasing	Not Stressed
Skeleton River	Skeleton Lake	Not Increasing	Not Increasing	Not Stressed
Skeleton River	Young Lake	Not Increasing	Not Increasing	Not Stressed
Skeleton River	Young Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Bigwind Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Bird Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Chub Lake (LOB)	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Dickie Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Echo Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Grandview Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Leech Lake (BR)	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	McKay Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	McRey Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Pine Lake (BR)	Not Increasing	Not Increasing	Not Stressed

Quaternary Watershed	Lake Name	R^2 Value (if increasing)	p-value (if increasing)	Category
South Muskoka River	Ridout Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Ril Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Spence Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Spring Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Tackaberry Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Wildcat Lake	Not Increasing	Not Increasing	Not Stressed
South Muskoka River	Wood Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Blue Chalk Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Clear Lake (BR)	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Crosson Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Grindstone Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Gullfeather Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Margaret Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Plastic Lake	0.12	0.22	Not Stressed
Upper Black River	Porcupine Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Raven Lake	Not Increasing	Not Increasing	Not Stressed
Upper Black River	Red Chalk Lake	Not Increasing	Not Increasing	Not Stressed

BR (Bracebridge) GR (Gravenhurst) GB (Georgian Bay) HT (Huntsville)
LOB (Lake of Bays) ML (Muskoka Lakes)

The number of lakes by quaternary watershed that fall into the Not Stressed, Vulnerable and Stressed categories based on the criteria provided above is presented in Table 11.

Table 11. Quaternary watershed grades for the phosphorus indicator.

Quaternary Watershed	Number of Lakes			Grade
	Not Stressed	Vulnerable	Stressed	
Big East River	8	0	0	Not Stressed
Dee River	4	0	0	Not Stressed
Gibson River	4	0	1	Not Stressed
Hollow River	5	0	0	Not Stressed
Kahshe River	9	0	0	Not Stressed
Lake Muskoka	17	0	0	Not Stressed
Lake of Bays	15	0	0	Not Stressed
Lake Rosseau	14	0	0	Not Stressed
Little East River	8	1	0	Not Stressed
Lower Black River	1	0	0	Insufficient Data

Quaternary Watershed	Number of Lakes			Grade
	Not Stressed	Vulnerable	Stressed	
Mary Lake	16	0	0	Not Stressed
Moon River	24	0	0	Not Stressed
North Muskoka River	9	0	0	Not Stressed
Oxtongue River	6	0	0	Not Stressed
Rosseau River	1	0	0	Insufficient Data
Severn River	15	0	1	Not Stressed
Skeleton River	6	0	0	Not Stressed
South Muskoka River	18	0	0	Not Stressed
Upper Black River	10	0	0	Stressed

What do these results mean?

Over ninety-eight percent of the lakes sampled have stable or decreasing phosphorus concentrations with only 0.5% showing a slight increase and 1% showing a statistically significant increase. These results indicate that overall, lakes in Muskoka continue to have excellent water quality.

While this indicator is based only on trends in phosphorus, it is important to note that other factors that impact water quality may be observed on a lake, and that some of these factors are related to phosphorus concentrations. For example, Three Mile Lake in the Township of Muskoka Lakes is noted for its elevated phosphorus levels and the associated water quality issues that may be observed in lakes with elevated levels of phosphorus, such as algal blooms. However, as phosphorus concentrations are currently declining in this lake, it received a grade of not stressed, even though the lake has more phosphorus than it should. The decline in phosphorus is a good news story that reflects the extensive efforts undertaken by the Three Mile Lake Association and watershed residents to address the elevated levels of phosphorus in the lake through good stewardship practices.

A broader consideration of phosphorus concentrations and associated water quality issues is taken by The District Municipality of Muskoka in its proposed Muskoka Official Plan (The District Municipality of Muskoka, 2018), which outlines three criteria, any of which may trigger an investigation on the lake to determine if the issues on the lake are a result of human shoreline development and any associated phosphorus loads, or to other factors such as natural processes or climate change. These criteria are:

a) total Phosphorus (TP) being greater than 20 micrograms/litre;
b) an increasing trend in TP; and/or
c) documented presence of a blue-green algal bloom.

There are currently eight lakes within the District of Muskoka that meet one or more of these criteria: Ada Lake (ML), Brandy Lake (ML), Bruce Lake (ML), Three Mile Lake (ML), Stewart Lake (GB/ML), Barron's Lake (GB), Bass Lake (GR), and Peninsula Lake (HT/LOB). Notwithstanding the grades provided for the phosphorus indicator above, these eight lakes could be considered "vulnerable" when this larger suite of criteria are taken into account.

While phosphorus concentrations, representing trophic status, provide a good general indication of water quality, Muskoka's lakes are changing and are threatened by a variety of stressors in addition to shoreline development (Palmer, Yan, Paterson, & Girard, 2011). The Canada Water Network Research Program carried out in the Muskoka River Watershed from 2012-2015, for example, concluded that the multiple stressors included: increasing concentrations of dissolved organic carbon and chloride, declining concentrations of calcium, invading species populating an increasing number of lakes and the changing climate with resultant changes in precipitation, temperature, runoff and evaporation that affect physical, chemical and biological conditions of lakes (Eimers, 2016). The 2018 Muskoka Watershed Report Card reports on a number of these stressors, including calcium, invasive species, and climate change.

It's your turn!

There are also some simple individual actions that can be undertaken to help reduce the amount of nutrients going into our lakes:

- Eliminate your use of fertilizer, especially in areas near the water;
- Maintain your septic system, including having it pumped out on a regular basis and limiting the amount of water that goes into the system;
- Use phosphate-free cleaners, soap and detergents; and
- Protect the vegetated buffer zone on your shoreline and enhance it if needed. A healthy strip of vegetation along your shoreline will absorb nutrients from your property before they enter the water!

Check out *A FOCA Guide to Citizen Science at the Lake*, a document that provides lake stewards with the tools and information they need to monitor their own lake.

Local Spotlight: Ontario Lake Partner Program

Citizen scientists and lake stewards are key to maintaining and, if possible, enhancing the quality of Muskoka's lakes. You can get involved in monitoring the health of Muskoka's lakes through the Ontario Lake Partner Program, a volunteer-based, water-quality monitoring program established in 2002. This Ministry of the Environment, Conservation and Parks program operates out of the Dorset Environmental Science Centre (DESC) in partnership with the Federation of Ontario Cottagers' Associations. Through this program, volunteers collect lake water samples and return them, postage paid, to DESC, where they are analyzed for total phosphorus and calcium.

Consider joining the Lake Partner Program or volunteering with your local Lake Association to assist in water monitoring efforts! Learn more at http://desc.ca/programs/LPP.

Benthic Macroinvertebrates

What are benthos and why are they important in Muskoka?

Benthic macroinvertebrates – or benthos – are a community of small organisms found in aquatic habitats. While these creatures are small, they are generally large enough to see with the naked eye (macro), have no backbone (invertebrate) and live on the bottom of lakes and rivers (benthic). They include aquatic worms, mites, amphipods and more. Many of the species sampled are in their larval or nymph stage of life, such as dragonflies, mosquitoes and mayflies. Benthic macroinvertebrates generally live in lakes and rivers for 1 to 3 years and are in constant contact with lake sediments. They live attached to rocks, logs, sticks and vegetation, or burrowed into the substrate (Jones, Somers, Craig, & Reynoldson, 2007).

Why do we sample for benthic macroinvertebrates?

Benthos are used as a biological indicator of water quality and habitat conditions. They are important indicators because they spend the majority of their lives in the same body of water, they are easy to sample, and different species have different tolerances to disturbances and pollution. For these reasons, the benthic data collected provides an indication of local water conditions (Jones, Somers, Craig, & Reynoldson, 2007). The consequences of a poorly maintained septic system illustrate this – a fish can swim away from the polluted area, however, since benthos are not as mobile, only pollution tolerant species of benthos will be present after contaminants are leached into the lake. So, when we collect benthic samples, we can tell what the water quality is like by the presence or absence of various benthic species (Jones, Somers, Craig, & Reynoldson, 2007).

Sampling for benthos is important in Muskoka because there are so many separate water bodies present in the District. Lakes will inevitably have different invertebrate communities, and monitoring these is an effective way of characterizing water quality (The District Municipality of Muskoka, 2018). Monitoring the biological communities in Muskoka's lakes is important to ensure the natural integrity and state of the lake is maintained, especially if the shorelines are developed. A healthy lake supports high species richness and abundance. If samples show low diversity and predominantly pollution-tolerant species, the waterbody could be impaired. Biological conditions of the water also reflect both chemical and physical components of the lake. For example, lake acidification is often accompanied by a decline in the total number of species present as well as an increase in the abundance of those species able to tolerate acidity (The District Municipality of Muskoka, 2018).

Benthos also play a key role in the food web. Many fish and dragonflies rely on some benthos as a food source, while other benthos help decompose organic matter that falls into the lake.

How are benthos measured in Muskoka?

Benthic macroinvertebrates in Muskoka are reported as the percentage of pollution-sensitive species found in each sample from a lake over the past five years. These pollution-sensitive species include larval mayflies (*Ephemeroptera*), dragonflies (*Odonata*), and caddisflies (*Trichoptera*), collectively referred to as %EOT.

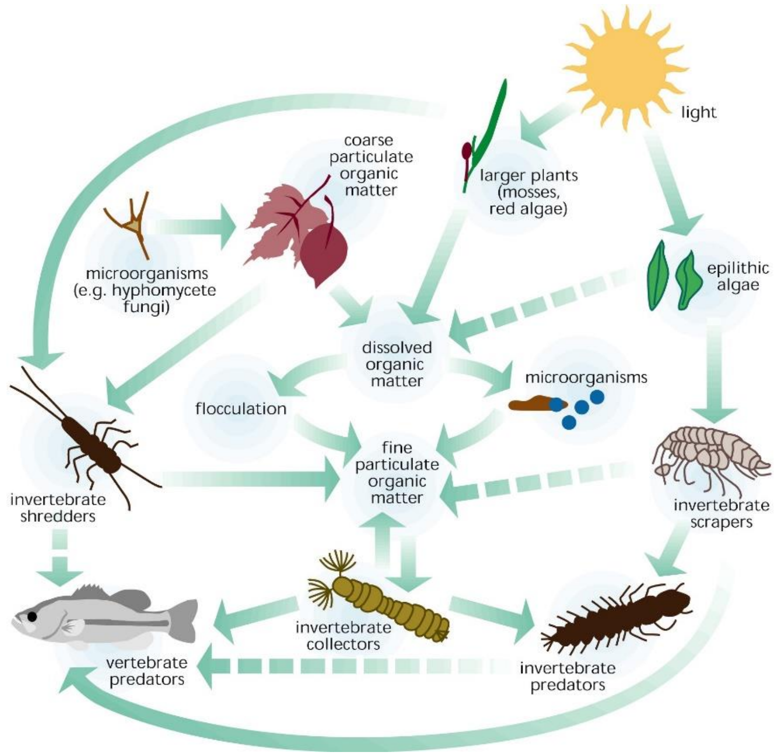


Figure 7. The role of benthic macroinvertebrates in the aquatic food web (Source: USDA)

These EOT species are very sensitive to pollution and habitat alterations. Their abundances should be prominent in healthy ecosystems, but their numbers will typically decline relative to other benthos in response to stress imposed by human activities (The District Municipality of Muskoka, 2018).

Mayfly larvae thrive in cool, oxygen-rich and unpolluted lakes and streams, feeding primarily on algae and detritus. They can be identified by their three-pronged tail and gills that insert in the upper surface of the abdomen. Once mature, mayflies will extend their wings and become terrestrial (Herbert, 2002).

Dragonflies thrive in cool, clean bodies of water and are unable to tolerate poor water quality and habitat disturbances. Dragonfly nymphs can often be found near aquatic vegetation in calm water. They are carnivores that feed on other insects such as mosquitoes and midges. In their nymph stage, they can be identified by their large head and big eyes, along with their large body (Herbert, 2002).

Caddisfly larvae are sensitive to polluted waters and low oxygen levels. They can be found in a variety of aquatic habitats including cool or warm water streams, lakes, marshes and ponds. Caddisfly larvae have a unique mode of protection: they build protective cases of small stones or pieces of wood around their bodies, held together by silk they secrete (Herbert, 2002).

Data analysis

The District Municipality of Muskoka works with local Lake Associations to monitor benthos through the District's Biological Monitoring Program using the protocol developed by the Ontario Benthos Biomonitoring Network (OBBN) (Jones, Somers, Craig, & Reynoldson, 2007). Since 2004, the District of Muskoka has continuously sampled 45 lakes across the watershed. Scientists at the Dorset Environmental Science Centre provided additional benthic data from sampling efforts undertaken since the mid 1970's through the Province's Long-term Ecosystem Science Program. This program focuses on headwater lakes and streams located in south-central Ontario that are representative of tens of thousands of lake catchments on the Canadian Shield. Through this program, benthos are collected from 19 lakes and 14 streams in the Dorset area of the Muskoka Watershed once per year. Data for an additional 82 lakes were provided by Jones et al. (2007), who in 2012 and 2013 conducted a survey in the area with funding from the Canadian Water Network.

The resulting dataset includes 114 lakes and provides information on how biological systems are responding to a variety of natural and human-related stressors, including chemical changes in the water such as increases in phosphorus, nitrogen and chloride, physical changes in the water such as temperature, or landscape changes such as shoreline degradation, runoff, and near shore construction.

The following steps were taken to determine the category for each quaternary watershed based on the benthic indicator:

1. The normal range for %EOT in Muskoka area lakes was determined by randomly selecting one data point from each lake sampled between 2012 and 2017 and characterizing the distribution of values observed among these lakes (Figure 8);
2. The average %EOT was calculated for each lake using data collected between 2012 and 2017. For lakes with more than one site, the average of all the sites was calculated.
3. The average %EOT calculated for each lake was compared to the normal range developed in step 1 to determine whether the lake is typical, atypical or extremely atypical; and
4. The category for each quaternary watershed was determined based on the following:
    - **Typical**: 50% or more of the lakes in the watershed are Typical
    - **Atypical**: 50% or more of the lakes in the watershed are Atypical
    - **Extremely Atypical**: 50% or more of the lakes in the watershed are Very Atypical

It is difficult to assess a waterbody as stressed, vulnerable or not stressed based on the benthic community because a variety of factors, such as land use stressors (i.e. groomed lawn or agricultural practices), habitat attributes (i.e. macrophyte abundance and lake bottom substrate), human activities (i.e. boat traffic), and history of colonization by benthic species, among others, will determine the species present. Instead, benthic communities were used to characterize lakes as typical or less typical for Muskoka. The classification of each lake based on benthic macroinvertebrates is determined using the following categories:

- **Typical:** %EOT is between the 10th and 90th percentile. These lakes resemble the majority of lakes in Muskoka, and therefore are comprised of typical percentages of EOT species.
- **Atypical**: %EOT is between either the 5th and 10th percentile or the 90th and 95th percentile. These lakes are outside of the normal range of the majority of lakes in Muskoka. The percentages of EOT species may be slightly higher or lower compared to the majority of lakes in Muskoka.
- **Extremely Atypical:** %EOT is less than the 5th percentile or greater than the 95th percentile. These lakes do not represent the majority of lakes in Muskoka in terms of the percentages of

EOT species. These lakes may have very high or very low percentages of EOT species compared to the majority of lakes in Muskoka.

As a result, once the mean for each lake is plotted on the reference distribution (Figure 8) the value will either fall in the green (typical), yellow (atypical), or red (extremely atypical) area on the graph.

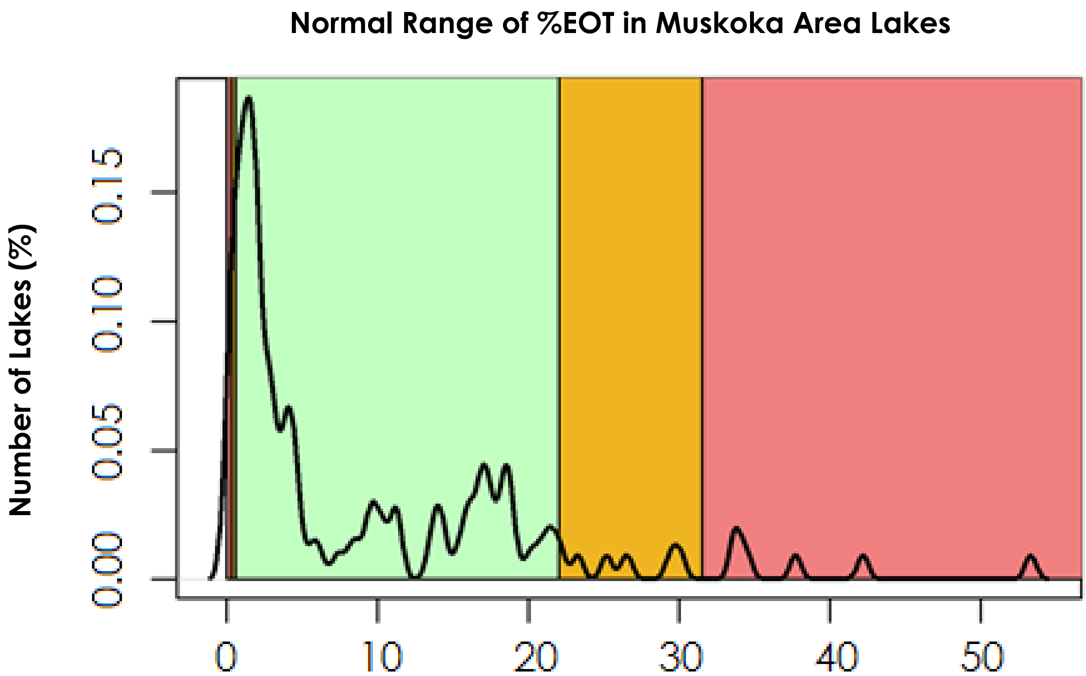


Figure 8. The range of %EOT values of sampled lakes in Muskoka from 2012 to 2017. Typical is highlighted in green, which is between the 10th and 90th percentile (%EOT is between 0.55 and 20.99). Atypical is highlighted in orange, which is between the 5th and 10th percentile (%EOT is between 0.3 and 0.54), and 90th and 95th percentile (%EOT is between 22.1 and 28.01). Extremely atypical is highlighted in red, which is less than the 5th percentile (%EOT is less than 0.29), or greater than the 95th percentile (%EOT is greater than 31.5).

Results

The classification of each lake is presented in Table 12. The overall classification by quaternary watershed is presented in Table 13. Note that there is no data for the Rosseau River and Lower Black River Quaternary Watersheds.

Table 12. Benthic classification by lake.

Quaternary Watershed	Lake Name	Average %EOT	Classification
Big East River	Bella Lake	14.21	Typical
Big East River	Foote Lake	10.96	Typical
Big East River	Green's Lake	1.98	Typical
Big East River	Ishkuday Lake	1.48	Typical
Big East River	Hot Lake	0.00	Extremely Aypical
Big East River	Islet Lake	0.55	Typical
Big East River	Jubilee Lake	3.92	Typical
Big East River	Lupus Lake	1.74	Typical
Big East River	Maggie Lake	0.93	Typical
Big East River	North Rain Lake	4.87	Typical
Big East River	Pincher Lake	23.92	Atypical
Big East River	Rain Lake	1.20	Typical
Big East River	Rebecca Lake	11.08	Typical
Big East River	Sawyer Lake	0.26	Extremely Atypical
Big East River	Solitaire Lake	0.54	Atypical
Big East River	Sunset Lake	0.00	Extremely Atypical
Big East River	Surprise Lake	2.67	Typical
Big East River	West Dolly Lake	1.45	Typical
Big East River	Weed Lake	1.46	Typical
Dee River	Three Mile Lake (ML)	8.65	Typical
Gibson River	Bear Lake	1.89	Typical
Hollow River	Hinterland Lake	0.55	Typical
Hollow River	Kawagama Lake	0.97	Typical
Hollow River	Louie Lake	0.79	Typical
Hollow River	Mackittrick Lake	1.22	Typical
Hollow River	Troutspawn Lake	4.08	Typical
Kahshe River	Bass Lake (GR)	6.87	Typical
Kahshe River	Kahshe Lake	22.10	Atypical
Kahshe River	Sunny Lake	26.88	Atypical
Lake Muskoka	Brandy Lake	12.17	Typical
Lake Muskoka	Gull Lake	15.56	Typical
Lake Muskoka	Hoc Roc River	11.28	Typical
Lake Muskoka	Leonard Lake	26.57	Atypical
Lake Muskoka	Lake Muskoka	0.83	Typical
Lake Muskoka	Pine Lake	17.17	Typical
Lake Muskoka	Thompson Lake	1.82	Typical
Lake Muskoka	Unnamed Lake 1	1.96	Typical

Quaternary Watershed	Lake Name	Average %EOT	Classification
Lake Muskoka	Unnamed Lake 2	1.08	Typical
Lake Muskoka	Unnamed Lake 3	2.76	Typical
Lake of Bays	Lake of Bays	1.09	Typical
Lake of Bays	Longline Lake	2.41	Typical
Lake of Bays	Menominee Lake	16.27	Typical
Lake of Bays	Tooke Lake	0.90	Typical
Lake Rosseau	Ada Lake	13.76	Typical
Lake Rosseau	Armishaw Lake	1.50	Typical
Lake Rosseau	Bruce Lake	10.39	Typical
Lake Rosseau	Brush Lake	2.46	Typical
Lake Rosseau	Hamer Lake	48.88	Extremely Atypical
Lake Rosseau	Henshaw Lake	4.55	Typical
Lake Rosseau	Lake Joseph	0.32	Atypical
Lake Rosseau	Lake Rosseau	0.41	Atypical
Lake Rosseau	Little Lake Joseph	0.98	Typical
Lake Rosseau	Stewart Lake	6.56	Typical
Little East River	Arrowhead Lake	3.70	Typical
Little East River	Bay Lake	5.86	Typical
Little East River	Birch's Lake	3.37	Typical
Little East River	Clear (Emsdale) Lake	0.30	Atypical
Little East River	Fish Lake	1.72	Typical
Little East River	Little Arrow Head Lake	0.00	Extremely Atypical
Little East River	Jessop Lake	1.78	Typical
Little East River	Ripple Lake	1.10	Typical
Little East River	Lake Waseosa	17.74	Typical
Mary Lake	Buck Lake (HT)	10.66	Typical
Mary Lake	Chub Lake (HT)	31.53	Extremely Atypical
Mary Lake	Fairy Lake	5.42	Typical
Mary Lake	Fox Lake	14.12	Typical
Mary Lake	Harp Lake	20.99	Typical
Mary Lake	Mary Lake	2.45	Typical
Mary Lake	Peninsula Lake	11.04	Typical
Mary Lake	Otter Lake	20.17	Typical
Mary Lake	Robinson Lake	9.40	Typical
Mary Lake	Round Lake	2.09	Typical
Mary Lake	Sims Lake	3.57	Typical
Mary Lake	Tongua Lake	0.87	Typical
Mary Lake	Lake Vernon	3.75	Typical
Mary Lake	Walker Lake	46.67	Extremely Atypical

Quaternary Watershed	Lake Name	Average %EOT	Classification
Mary Lake	Weeduck Lake	0.25	Extremely Atypical
Moon River	Healey Lake	1.66	Typical
Moon River	Kapikog Lake	2.97	Typical
Moon River	Sawyer Lake	0.26	Extremely Atypical
North Muskoka River	Fawn Lake	1.10	Typical
North Muskoka River	Gilleach Lake	33.42	Extremely Atypical
North Muskoka River	Moot Lake	1.18	Typical
Oxtongue River	Cradle Lake	28.01	Atypical
Oxtongue River	Hilly Lake	1.49	Typical
Oxtongue River	Loft Lake	3.06	Typical
Oxtongue River	Oxtongue Lake	2.40	Typical
Oxtongue River	Smoke Lake	2.07	Typical
Oxtongue River	Tea Lake	1.70	Typical
Oxtongue River	Upper Oxbow Lake	6.15	Typical
Oxtongue River	Westward Lake	4.13	Typical
Oxtongue River	Westwood Lake	13.34	Typical
Severn River	Barron's Lake	7.22	Typical
Severn River	Loon Lake	6.72	Typical
Severn River	North Muldrew Lake	23.26	Atypical
Severn River	Six Mile Lake	11.34	Typical
Severn River	Boot Lake	4.41	Typical
Severn River	South Muldrew Lake	17.27	Typical
Skeleton River	Skeleton Lake	1.74	Typical
Skeleton River	Young Lake	11.68	Typical
South Muskoka River	Bigwind Lake	23.05	Atypical
South Muskoka River	Dickie Lake	20.87	Typical
South Muskoka River	Grandview Lake	1.58	Typical
South Muskoka River	Heney Lake	17.95	Typical
South Muskoka River	Leech Lake	6.45	Typical
South Muskoka River	Ridout Lake	17.3	Typical
South Muskoka River	Ril Lake	17.99	Typical
Upper Black River	Blue Chalk Lake	19.19	Typical
Upper Black River	Crosson Lake	26.18	Atypical
Upper Black River	Plastic Lake	19.19	Typical
Upper Black River	Red Chalk Lake	24.61	Atypical

BR (Bracebridge) GR (Gravenhurst) GB (Georgian Bay) HT (Huntsville)
LOB (Lake of Bays) ML (Muskoka Lakes)

Table 13. Classification by quaternary watershed for the benthic macroinvertebrate indicator.

Quaternary Watershed	Number of Lakes			Classification
	Typical	Atypical	Extremely Atypical	
Big East River	14	2	3	Typical
Dee River	1	0	0	Insufficient Data
Gibson River	1	0	0	Insufficient Data
Hollow River	5	0	0	Typical
Kahshe River	1	2	0	Atypical
Lake Muskoka	9	1	0	Typical
Lake of Bays	4	0	0	Typical
Lake Rosseau	7	2	1	Typical
Little East River	7	1	1	Typical
Lower Black River	0	0	0	Insufficient Data
Mary Lake	12	0	3	Typical
Moon River	2	0	1	Typical
North Muskoka River	2	0	1	Typical
Oxtongue River	8	1	1	Typical
Rosseau River	0	0	0	Insufficient Data
Severn River	5	1	0	Typical
Skeleton River	2	0	0	Insufficient Data
South Muskoka River	6	1	0	Typical
Upper Black River	2	2	0	Atypical

What do these results mean?

The majority of sampled lakes within the Muskoka Watershed are classified as typical. 14% of sampled lakes are classified as atypical, indicating that the benthic species present and/or populations are slightly out of the ordinary. Only 7% of lakes sampled within the watershed are classified as extremely atypical. Four of the lakes (Hot Lake, Sawyer Lake, Weeduck Lake, and Sunset Lake) were only sampled once, and may not reflect an accurate representation of the lake. Additional sampling should be carried out on these lakes to obtain a better sense of the biological quality of those waterbodies. The other lakes that ranked as extremely atypical (Gilleach Lake, Hamer Lake, Chub Lake, and Walker Lake) had an unusually high count of %EOT. The reasons for these high counts should be explored to gain a better understanding of these lakes, however some possible explanations could be better than normal water or habitat quality, unusual substrate, unusual influence of inflow streams, high food availability, or sampling location.

The majority of quaternary watersheds within the Muskoka Watershed support typical benthic macroinvertebrate communities. The few atypical quaternary watersheds require more study to determine why this is so. Research may be needed to determine causation.

It's your turn!

More data is always needed, especially in quaternary watersheds with few lakes sampled. Get involved in monitoring the benthic macroinvertebrates in your local lake through the District of Muskoka's Biological Monitoring Program!

District staff are available to work with lake associations and other community organizations to collect benthic data by providing expertise and equipment, while the association provides volunteers. Learn more about the Biological Monitoring Program at www.muskokawaterweb.ca/lake-data/muskoka-data/biological-monitoring-data.

Local Spotlight: Peninsula Lake Association

Lake association volunteers on Peninsula Lake have been sampling for benthic macroinvertebrates since the Biological Monitoring Program was established by the District of Muskoka in 2004. Each summer, volunteers assist the District's Biological Monitoring Technician collect and analyze samples from three different sites established around the lake, one site sampled per year. Collectively, the Peninsula Lake Association has enthusiastically collected over 4,700 benthos, gaining an understanding of the biological condition of their lake in the process. Hats off to the Pen Lake volunteers!

Interior Forest

What is interior forest and why is it important in Muskoka?

Interior forest habitat is located deep in the forest, secluded from the impacts of forest edge development and open habitats (Burke, Elliott, Falk, & Piraino, 2011). The interior forest in Muskoka is primarily comprised of shade-tolerant and late-successional species such as sugar maple, American beech, basswood, ironwood, hemlock, and eastern white cedar. A group of mid-tolerant shade tree species such as eastern white pine, red pine, red oak, bur oak, swamp white oak, ash, yellow birch and black cherry are less common, but still important in interior forest in Muskoka (Cappella, 2018).

Many of Muskoka's wildlife species depend on interior forest habitat, however the development of roads, houses and other human-made structures fragment forested land greatly reducing the amount of interior forest. Certainly, interior forest ecosystems can be threatened by permanent changes to the landscape such as development and permanent roads. Smaller impacts may also arise from seasonally used trails (snowmobile trails) (Cappella, 2018). Although fragmented forests can still provide habitat for a vast array of wildlife, they lack patches of interior forest of sufficient size to sustain many interior species. Fragmenting can also interrupt the ecologically important connectivity across forested land.

Ecosystem services of interior forest habitat are similar to those of all forests but these areas are naturally more protected from outside intrusion and are a key foundation for a watershed's natural ability to function. Ecosystem functions include the filtering and absorption of water into the ground; absorption of large amounts of carbon dioxide that would otherwise be released into the atmosphere; and photosynthesis (plants use energy from sunlight and nutrients from the soil and air to yield the organic molecules and oxygen that are essential to the survival of living things). These ecological services and more are essential to wildlife well-being, as well as human health (Muskoka Watershed Council, 2014).

Forests are structurally diverse habitats, encompassing a wide array of microhabitats that together support a great diversity of species. These forests provide food, water and shelter for these species, allowing for breeding opportunities away from predators (Environment Canada, 2013). Most, if not all, terrestrial species in Muskoka benefit from forested habitat. Many Muskoka terrestrial species cannot survive without forested habitats (Environment Canada, 2013).

Birds are commonly used as an indicator of forest health as they integrate biological, physical and chemical conditions required to support healthy population (Burke, Elliott, Falk, & Piraino, 2011). Birds are a particularly effective barometer of forest size and shape, since many of our native species need large expanses of interior forest habitat. Many forest-nesting birds shun edges because of the increased risk of predation or nest parasitism, as well as inhospitable temperature and moisture conditions or insufficient food. Forest edges are also more susceptible to human disturbance (Burke, Elliott, Falk, & Piraino, 2011).

Studies in the Severn Sound area, southwest of the Muskoka River Watershed, indicate that on a scale of a single Breeding Bird Atlas square, or 10,000 hectares, there is a strong increase in the number of forest bird species as total forest cover increases. Forest-interior bird species exhibited the greatest increase (Environment Canada, 2004).

Species diversity typically increases with forest cover, although the size and composition of forests determine what species live there. In the Severn Sound study of birds, forest interior bird species continued to increase in number until there was at least 35% total forest cover. The proportion of interior forest cover was also found to have significant effects on the number of bird species when combined with total forest cover (Environment Canada, 2004).

Research shows that the amount of forested cover in a watershed is correlated to the long-term persistence of species, particularly forest birds (Burke, Elliott, Falk, & Piraino, 2011). As development expands into a forested area, species may start to disappear, and the remaining ones either become rare or sometimes fail to reproduce, while others may adapt to the new conditions. The species that are able to adapt are those that do not require specialized habitats such as interior forest or are more tolerant to human-induced disturbances. These species are able to persist and may even thrive in an urban setting.

The amount of forested area in a watershed determines its ability to support large mammals such as moose and wolves. One reason why moose are absent from southern Ontario is because the land is cleared. Now, moose are predominantly found in central and northern Ontario (Ministry of Natural Resources, 1988). Moose use different part of the forest throughout the seasons. For instance, in the summer months, moose move to marshes and swamps to feed on aquatic plants, and in the winter, they use hemlock and cedar forest for shelter from both predators and high snow. Some smaller mammals, such as the Northern Flying Squirrel, also require relatively high amounts of forest cover. These examples show that in general, there is a relationship between the extent of forest cover and wildlife species present (Environment Canada, 2013).

Forest types in Muskoka

Located on the Canadian Shield, Muskoka is characterized by till soil with exposed bedrock. The thin, naturally nutrient-poor soils and surrounding environment naturally dictate the vegetation communities that thrive here and, in turn, limit which trees may grow. Muskoka's forests are situated within the Great Lakes-St. Lawrence Forest Region, an area of transition between the Boreal Forest Region to the north and the Deciduous Forest Region in the south, resulting in a diverse forest across the watershed.

The high elevations of Algonquin Parks have soils mostly derived from ice-deposited till and support hardwood forests. White Pine and Red Pine stand tall on the landscape and are dominant forest types where Muskoka meets Georgian Bay. Pine and Oak forests dominate along Muskoka's most western townships. The centre and eastern parts of Muskoka is covered with forests of deciduous, broad-leaved trees, mostly sugar maple and American beech. In the low areas between hills and the thin ribbons along lake shores, the tree cover consists of conifers such as white spruce, balsam fir, eastern white cedar, and hemlock.

The Ministry of Natural Resources and Forestry and Westwind Forest Stewardship Inc. have developed a Forest Management Plan for the French-Severn Forest, in which Muskoka lies. This plan seeks to address and manage the social, economic, and environmental values of sustainable forest management.

Threats to Muskoka's forests

Ontario's forests are increasingly threatened by alien and invasive forest plant species, and Muskoka is no different. According to the Ministry of Natural Resources and Forestry (2018), invasive forest plant species can:

- Decrease diversity of native flora;
- Hamper tree growth and regeneration;
- Change forest ecosystem and community dynamics; and
- Negatively affect the forest industry, recreation and aesthetic values.

Garlic mustard is an example of an invasive plant that is a threat to Muskoka's forest. This plant has the potential to quickly invade a relatively undisturbed forest, displacing native wildflowers such as trilliums and trout lily. It also interferes with the growth of fungi present in soil that brings nutrients to the roots of the plants, hindering other native plants (Ontario's Invading Species Awareness Program, 2018). Check out the Invasive Species Reports Indicator for more information about invasive species in Muskoka.

Invasive insects and diseases also have the capability of destroying an entire forested ecosystem. Many countries, including Canada, have trade restrictions to reduce the opportunities for introducing new invasive species to other regions. For instance, beech bark disease is threatening one of the most common and ecologically important trees in Muskoka's local forests. Beech bark disease has been in Canada for close to 100 years but was only identified in the Muskoka region in 2010. Butternut trees, another important interior forest species, are affected by a mitosporic fungus which has also reached Muskoka. Some 90% of trees have been killed by this aggressive infection in Canada and butternut trees are now classified as endangered as a result (Natural Resources Canada, 2018).

Forest fires are also a concern in Muskoka, especially when summer conditions are hot and dry. However, forest fires are relatively rare in this area and are almost always limited to the understory (Cappella, 2018). Forest fires are a natural process needed for regeneration, and while fire suppression in Muskoka protects lives and property, it does not allow for natural disturbance processes to take place. Through forest management, a diverse and resilient forest can be promoted in the face of a changing climate (Cappella, 2018).

How is interior forest measured in Muskoka?

Interior forest in Muskoka was analyzed using Geographic Information System Mapping Technology. Using a land use layer from the Ontario Ministry of Natural Resources and Forestry (2018), the forested areas of Muskoka were identified and a 100-meter buffer was applied to the periphery to account for the forest edge effect. The remaining area is interior forest and the size was calculated in hectares per quaternary watershed. Currently, the total interior forest cover across the watershed is 46%, with an average of 51% per quaternary watershed.

According to Environment Canada (2004), interior forest ecosystems are at significant risk if interior forest cover in a watershed falls below 15%. Therefore, the interior forest indicator was graded using the following criteria:

- **Not Stressed**: More than 50% of the quaternary watershed is interior forest.
  Greater than 50% interior forest at the watershed scale will ensure that interior forest bird species and sensitive mammals have adequate habitat and that there is minimum

conflict with humans. These areas are less likely to be impacted by invasive species. This is a local benchmark based on existing interior forest with input from local ecologists.

- **Vulnerable**: Between 20% and 50% of the quaternary watershed is interior forest.
  When 20% to 50% of the watershed is interior forest, there is moderate habitat available for most interior species. However, invasive species may pose a greater risk. This is a local benchmark based on existing interior forest coverage with input from local ecologists.

- **Stressed**: Less than 20% of the quaternary watershed is interior forest.
  Where there is less than 20% interior forest at the watershed scale, forest interior bird species and sensitive mammals will have reduced and possibly inadequate habitat and there will be more conflict with humans. This is a local benchmark based on existing interior forest with inputs from local ecologists.

Results

Table 14 summarizes the amount of interior forest habitat in each quaternary watershed. Interior forest cover varies greatly across Muskoka, from approximately 17% in the Severn River Watershed to over 60% in the Rosseau River Watershed.

Table 14. Amount of interior forest habitat in by quaternary watershed.

Quaternary Watershed	Watershed Area* (ha)	Interior Forest Area (ha)	Interior Forest (%)	Grade
Big East River	64819.97	37,305.18	57.55%	Not Stressed
Dee River	13662.51	6,470.14	47.36%	Vulnerable
Gibson River	18597.67	8,420.74	45.28%	Vulnerable
Hollow River	36656.90	21,107.52	57.58%	Not Stressed
Kahshe River	23259.13	9,302.40	39.99%	Vulnerable
Lake Muskoka	32297.00	12,009.88	37.19%	Vulnerable
Lake of Bays	30101.31	17,295.08	57.46%	Not Stressed
Lake Rosseau	27724.14	11,788.52	42.52%	Vulnerable
Little East River	9623.50	4,745.45	49.31%	Vulnerable
Lower Black River	50918.88	18,287.27	35.91%	Vulnerable
Mary Lake	61102.19	32,825.79	53.72%	Not Stressed
Moon River	71697.17	29,778.39	41.53%	Vulnerable
North Muskoka River	24849.94	11,505.23	46.30%	Vulnerable
Oxtongue River	60852.21	32,897.22	54.06%	Not Stressed
Rosseau River	12991.38	7,861.34	60.51%	Not Stressed
Severn River	66177.78	11,412.16	17.24%	Stressed
Skeleton River	6750.90	3,662.02	54.24%	Not Stressed

Quaternary Watershed	Watershed Area* (ha)	Interior Forest Area (ha)	Interior Forest (%)	Grade
South Muskoka River	35096.50	19,180.00	54.65%	Not Stressed
Upper Black River	39075.23	23,201.14	59.38%	Not Stressed
Overall	**686,254.00**	**319,055.44**	**46.49%**	

*Includes all land and water except for the 17 largest lakes in Muskoka, which represent a significant break in the natural landscape. This approach builds on past reporting methodologies and is endorsed by local ecologists. It is also consistent with the methodology for the fragmentation indicator.

What do these results mean?

The Severn River Watershed is the only watershed graded as stressed. While this watershed still has over 17% of interior forest, it also has many lakes and a large area of exposed bedrock, both of which are great habitat for a variety of species, but do not support interior forest. Therefore, while this quaternary watershed may not have as much interior forest as other watersheds, it still has a significant amount of continuous natural habitat which provides many ecological, social, and economic benefits.

Most quaternary watersheds are graded as either vulnerable or not stressed. These watersheds should continue to be sustainably managed in order to maintain these important forests.

It's your turn!

Visitors from all over the world come to Muskoka to see its scenic forested landscape. However, as new infrastructure is built to accommodate residents and visitors alike, forest health may be threatened.

If you live on a large property, organizations such as the Ontario Woodlot Association (www.ontariowoodlot.com) have developed many resources to assist landowners who wish to explore management options for their forests. For instance, sizable properties may enrol in the Managed Forest Tax Incentive Plan or the Conservation Land Tax Incentive Plan through the Ministry of Natural Resources and Forestry. More resources include:

- A Landowner's Guide to Selling Standing Timber booklet (www.ontariowoodlot.com/publications/owa-publications/landowner-guides/a-landowner-s-guide-to-selling-standing-timber)
- A Landowner's Guide to Careful Logging booklet (www.ontariowoodlot.com/publications/owa-publications/landowner-guides/a-landowner-s-guide-to-careful-logging)
- The Landowners' Guide to Controlling Invasive Woodland Plants booklet (www.muskokawaterweb.ca/the-landowner-s-guide-to-controlling-invasive-woodland-plants)

Local Spotlight: Westwind Forestry Stewardship Inc.: Sustainable Forest Management in Muskoka

Forestry in Ontario must follow the direction of the Crown Forest Sustainability Act. A requirement of the Crown Forest Sustainability Act is that forest management activities will create a future forest landscape with a composition and structure similar to those created by natural processes and emulating the effect of natural disturbances on forests such as wind, fire, insect and disease.

In Parry Sound-Muskoka, sustainable forest management is primarily regulated by the 2019-2029 French-Severn Forest Management Plan (FMP). This plan also recognizes the importance of opportunities for participation in the FMP process by First Nation and Métis communities and individuals. As part of this plan, Westwind Forest Stewardship Inc. conducts computer modeling of the forest over a 150-year time frame using aerial imagery of the forest. A baseline scenario is established by removing harvesting and forest firefighting variables and allowing forest ecosystems to grow without human influence. This baseline scenario is called the Simulated Range of Natural Variation (SRNV). The 2019-2029 FMP has landscape level management objectives that dictate harvest amount and pattern consistent with retaining and sustaining a forest representative of the SRVN (including a number of forest interior ecosystems). The management program relies on a set of indicators derived from the SRNV for the French-Severn Forest which are assessed at 10, 20 and 100 years and form part of the long-term management direction.

The long-term management direction includes four key landscape level objectives which have targets for mature and old (which includes old growth) forest, young (early successional) forest, deer and moose emphasis areas. Sustainable forest management through the planning, harvest, regeneration and tending of crown forests makes it possible to move towards targets associated with these landscape level indicators.

There are also a number of objectives that protect a variety of social, cultural and environmental values. Values are protected at a variety of spatial scales to provide habitat for a very broad range of wildlife, to support interactions among wildlife species, and to facilitate ecosystem processes. Species specific protections and management activities are also considered where required (such as for Blanding's turtles and red-shouldered hawks). Increasing the amount of yellow birch and black cherry on the landscape and maintaining red oak as well is another objective, and is achieved by targeted silvicultural activities. Retaining these tree species requires forests to be harvested using the shelterwood silviculture system in order to reduce competition from sugar maple and beech and let enough light reach the forest floor. Increasing the number of these mid-tolerant shade tree species increases biodiversity and helps wildlife by providing food, as the supply of beechnuts is reduced due to beech trees dying from the invasive beech bark disease. Sustainable forest management promotes healthy forests and increases resilience in the face of a changing climate.

Invasive Species Reports in Muskoka

What are invasive species and why are they important in Muskoka?

Invasive species are plants, animals and micro-organisms that out-compete native species for habitat and resources when introduced outside of their own natural distribution. Their introduction and spread threatens local ecosystems, the economy and our own health (Ontario's Invading Species Awareness Program, 2018).

These species typically exhibit five main characteristics:

1. Able to rapidly reproduce;
2. Able to thrive in disturbed areas;
3. Able to out-compete native species for food and habitat;
4. Have few natural predators; and
5. Are highly adaptable.

For these reasons, invasive species are extremely difficult to eradicate once established and their ecological effects are often irreversible as they can alter entire habitats and/or food webs, decrease biodiversity, and threaten species at risk. Next to habitat loss caused by development, invasive species are the leading cause of decreased biodiversity and contribute to native species endangerment (Simberloff & Schmitz, 1997).

Establishment of invasive species can result in significant costs to property owners and/or local governments attempting to control their detrimental impacts. For example, in Canada, annual invasive species management is estimated to cost as much as $20 billion to the forest sector, $7 billion for aquatic invasive species management in the Great Lakes and $2.2 billion for invasive plants management in the agricultural sector (Environment Canada, 2010). Invasive species also pose human health impacts such as increased risk of West Nile and Lyme disease.

Further, invasive species pose a particular threat to the Muskoka region because of the popularity of outdoor recreation making use of its natural environment. Increased tourist traffic and recreational activities such as boating, ATVing and hiking act as potential pathways heightening the risk of introduction or spread of invasive species. In addition, since aquatic invasive species are frequently spread initially by international shipping, parts of Muskoka in proximity to Georgian Bay and Severn River are at a higher risk for aquatic invasive species than some inland lakes.

Every quaternary watershed in Muskoka contains at least some invasive species. Table 15 includes information on invasive species in Muskoka, how and when they got here, and their ecological impacts.

Table 15. Invasive species in Muskoka and their impacts (Source: EDDMapS, Invading Species Awareness Program).

Species Name	How It Got Here	Year Sighted in Muskoka*	Ecological Impacts
Spiny Waterflea	Ballast water of ships from Eurasia	1968	Since their main diet is other zooplankton and they are avoided as food by fish, they reduce food supplies for small fish and young sport fish such as bass, walleye and yellow perch.
Rusty Crayfish	Introduced from other areas by anglers dumping bait	1975	They compete with native crayfish for food and resources and reduce spawning and nursery habitat for native fish.
Round Goby	Ballast water of ships from Europe	1999	They reduce populations of sport fish by eating their eggs and young, and competing for food sources. They are also linked to outbreaks of botulism type E
Rainbow Smelt	Intentional stocking in Michigan	1968	They compete with native fish for food and eat the young of other species. They cause a reduction in native fish species such as yellow perch, walleye, whitefish and lake trout.
Purple Loosestrife	Intentionally introduced as an ornamental garden species	2004	It reduces biodiversity, degrades habitat for native birds and insects, clogs irrigation canals, and degrades farmland.
Phragmites	Unknown but native in Eurasia	2001	It decreases native plant biodiversity, provides poor habitat and food supply for wildlife, and increases fire hazards.
Japanese Knotweed	Intentionally introduced as an ornamental species and planted for erosion control	2004	It degrades wildlife habitat, reduces plant biodiversity, and its aggressive root system can break through concrete.
Giant Hogweed	Brought from southwest Asia as a garden ornamental	2009	It shades out native plants and can cause severe phytodermatitis.
Eurasian Water Milfoil	Aquarium trade or ballast water of ships	1969	It reduces biodiversity, reduces oxygen levels in water, and its thick mats can hinder recreational activities such as swimming, boating and fishing.

*Year first sighted includes year first reported. The species could have been introduced prior to the year first reported.

How are invasive species measured Muskoka?

The Ontario Federation of Anglers and Hunters, in partnership with the Ministry of Natural Resources and Forestry (MNRF), created the Invasive Species Hotline in 1992 for the public to report sightings of invasive species. In 2005, EDDMapS (Early Detection and Distribution Mapping System) was established as a web-based mapping system for documenting the spread of invasive species by citizen scientists while in the field.

The MNRF has identified 24 invasive species of concern in Ontario, seven of which are found in Muskoka. Although this number may appear to be low, significant impacts have already been observed, such as Japanese Knotweed establishing on urban streets, and Phragmites colonizing our wetlands. Public awareness and education are important factors in limiting their impacts on the Muskoka landscape and waterways.

Invasive species in Muskoka are reported for each quaternary watershed as a numerical score out of 100 based on the invasiveness ranking system, where the higher the score, the more harmful the species may be (Jordan, Moore, & Weldy, 2012). This system considers four parameters which are explained in Table 16.

Table 16. Invasiveness Ranking System summary for vegetative invasive species (Jordan, Moore, & Weldy, 2012).

<table>
<tr><th>Parameter</th><th>Impacts</th><th>Highest Possible Score</th></tr>
<tr><td rowspan="3">Ecological Impact</td><td>The impact on the ecosystem and its productivity changes such as erosion and sedimentation, change in nutrient and mineral availability, sunlight availability, salinity and pH</td><td rowspan="3">40</td></tr>
<tr><td>The impact on community structures (alteration to canopy cover, creation or elimination of a layer, ultimately reducing biodiversity)</td></tr>
<tr><td>The impact on other species and their productivity</td></tr>
<tr><td rowspan="5">Biological Characteristics and Dispersal Ability</td><td>The rate of reproduction</td><td rowspan="5">25</td></tr>
<tr><td>The potential for long distance dispersal</td></tr>
<tr><td>The potential to be spread by human activities</td></tr>
<tr><td>The characteristics that increase competitive advantage</td></tr>
<tr><td>Germination rates, regeneration rates and growth vigour</td></tr>
<tr><td rowspan="3">Ecological Amplitude and Distribution</td><td>Habitat suitability for the invasive species</td><td rowspan="3">25</td></tr>
<tr><td>Considers how quickly the species establish in a disturbed habitat</td></tr>
<tr><td>Considers the current introduced distribution in Muskoka and surrounding area</td></tr>
<tr><td rowspan="3">Difficulty to Control or Eradicate</td><td>Viability of seeds and regeneration</td><td rowspan="3">10</td></tr>
<tr><td>Vegetative regeneration</td></tr>
<tr><td>Level of effort required to manage or eradicate</td></tr>
</table>

The invasiveness ranking score is then multiplied by the number of EDDMapS reports of that species in each quaternary watershed (abundance) to give an overall score. The grade for each quaternary watershed was determined based on the follow criteria:

- **Not Stressed**: Total score is less than 5000
- **Vulnerable**: Total score is between 5000 and 10,000
- **Stressed**: Total score is greater than 10,000

Quaternary watershed grades for the invasive species indicator are summarized in Table 17. This indicator is based on datasets of reported sightings obtained from EDDMapS and The District Municipality of Muskoka. As such, it is limited to reported sightings only and may under estimate the abundance of invasive species in a watershed. Less populated watersheds appear to have less sightings, which may mean that there are less invasive species present, or it may mean that there are less people able to observe and report the invasive species that are there. However, it is reasonable to assume that these less populated areas do in fact have less invasive species because there is less of a chance of introduction through human activities, one of the main pathways of introduction. In order to strengthen the data, MWC encourages Muskokans to report all invasive species encountered to EddMapS.

Results

Table 17 provides the invasive species reported in each quaternary watershed and the variables used to calculate the overall score, as well as the grade for each quaternary watershed for the invasive species indicator.

Table 17. Quaternary watershed grades for the invasive species indicator.

Quaternary Watershed	Species Reported	Invasive Ranking Score (IRS)	# of Reports	IRS x # of Reports	Overall Score	Grade
Severn River	Phragmites	92	162	14,904	18,367	Stressed
	Purple Loosestrife	81	9	729		
	Eurasian Water Milfoil	96	10	960		
	Giant Hogweed	73	2	146		
	Japanese Knotweed	96	1	96		
	Round Goby	70	16	1,120		
	Rusty Crayfish	80	2	160		
	Spiny Waterflea	84	30	252		
Lower Black River	Phragmites	92	1	92	428	Not Stressed
	Spiny Waterflea	84	4	336		
Kahshe River	Phragmites	92	3	276	540	Not Stressed
	Japanese Knotweed	96	1	96		
	Spiny Waterflea	84	2	168		
Upper Black River	Phragmites	92	2	184	2,961	Not Stressed
	Giant Hogweed	73	1	73		
	Rusty Crayfish	80	17	1,360		

Quaternary Watershed	Species Reported	Invasive Ranking Score (IRS)	# of Reports	IRS x # of Reports	Overall Score	Grade
	Spiny Waterflea	84	16	1,344		
South Muskoka River	Phragmites	92	19	1,748	2,993	Not Stressed
	Purple Loosestrife	81	1	81		
	Japanese Knotweed	96	1	96		
	Rusty Crayfish	80	6	480		
	Spiny Waterflea	84	7	588		
North Muskoka River	Phragmites	92	22	2,024	4,053	Not Stressed
	Purple Loosestrife	81	2	162		
	Giant Hogweed	73	3	219		
	Japanese Knotweed	96	12	1,152		
	Rusty Crayfish	80	2	160		
	Spiny Waterflea	84	4	336		
Lake Muskoka	Phragmites	92	30	2,760	5,369	Vulnerable
	Purple Loosestrife	81	2	162		
	Giant Hogweed	73	11	803		
	Japanese Knotweed	96	8	768		
	Rainbow Smelt	72	4	288		
	Spiny Waterflea	84	7	588		
Gibson River	Phragmites	92	10	920	1,884	Not Stressed
	Giant Hogweed	73	4	292		
	Spiny Waterflea	84	8	672		
Moon River	Phragmites	92	42	3,864	8,414	Vulnerable
	Purple Loosestrife	81	2	162		
	Eurasian Water Milfoil	96	1	96		
	Giant Hogweed	73	4	292		
	Japanese Knotweed	96	1	96		
	Round Goby	70	4	280		
	Rainbow Smelt	72	5	360		
	Rusty Crayfish	80	3	240		
	Spiny Waterflea	84	36	3024		
Lake Rosseau	Phragmites	92	20	1,840	5,173	Vulnerable
	Giant Hogweed	73	1	73		
	Japanese Knotweed	96	22	2,112		
	Rainbow Smelt	72	2	144		
	Rusty Crayfish	80	1	80		
	Spiny Waterflea	84	11	924		

Quaternary Watershed	Species Reported	Invasive Ranking Score (IRS)	# of Reports	IRS x # of Reports	Overall Score	Grade
Dee River	Phragmites	92	2	184	740	Not Stressed
	Giant Hogweed	73	4	292		
	Japanese Knotweed	96	1	96		
	Spiny Waterflea	84	2	168		
Skeleton River	Phragmites	92	1	92	844	Not Stressed
	Rusty Crayfish	80	1	80		
	Spiny Waterflea	84	8	672		
Rosseau River	No Reports	0	0	0	0	Not Stressed
Mary Lake	Phragmites	92	2	184	5,539	Vulnerable
	Giant Hogweed	73	7	511		
	Japanese Knotweed	96	3	288		
	Rainbow Smelt	72	4	288		
	Rusty Crayfish	80	4	320		
	Spiny Waterflea	84	47	3,948		
Little East River	Rainbow Smelt	72	1	72	320	Not Stressed
	Rusty Crayfish	80	1	80		
	Spiny Waterflea	84	2	168		
Big East River	Japanese Knotweed	96	1	96	1,576	Not Stressed
	Rainbow Smelt	72	2	144		
	Rusty Crayfish	80	2	160		
	Spiny Waterflea	84	14	1,176		
Oxtongue River	Japanese Knotweed	96	3	288	864	Not Stressed
	Rusty Crayfish	80	3	240		
	Spiny Waterflea	84	4	336		
Hollow River	Rusty Crayfish	80	2	160	1,084	Not Stressed
	Spiny Waterflea	84	11	924		
Lake of Bays	Phragmites	92	8	736	2,486	Not Stressed
	Purple Loosestrife	81	2	162		
	Giant Hogweed	73	3	219		
	Japanese Knotweed	96	4	384		
	Rainbow Smelt	72	2	144		
	Garlic Mustard	85	1	85		
	Spiny Waterflea	84	9	756		

What do these results mean?

The Severn River Watershed is the only watershed graded as stressed for the invasive species indicator. This may be a result of it having a higher residential population than other parts of the Muskoka Watershed, which increases the chance of introducing and spreading invasive species, or it may be because a higher population means more people reporting. More reports across the entire watershed are needed to determine the cause. This watershed, as well as the Moon River Watershed, have direct access to international shipping corridors, where there is also a higher risk of invasive species introduction.

Watersheds graded as vulnerable, such as the Lake Muskoka and Lake Rosseau Watersheds, are hot-spot tourist destinations, and are therefore at a greater risk of introduction or spread of invasive species. Human influences on the introduction and spread of invasive species are particularly apparent when zooming into Highway 118 in the South Muskoka River Watershed, as you can see invasive phragmites all along the roadside.

It's your turn!

There are many ways you can help prevent the introduction and spread of invasive species in Muskoka.

When boating or fishing:

- Clean, drain and dry your boat each time you leave a lake
- Never move live fish from one waterbody to another
- Never dump your extra bait in the water

When hiking or camping:

- Stay on the trail and keep your pet on a leash
- Check your hiking gear at the end of your outing for plants and mud that might be carrying invasive plant seeds
- Buy and burn local firewood

When hunting:

- Inspect equipment and remove aquatic plants, animals and mud that are attached to decoy lines or anchors
- Switch to elliptical, bulb shaped, or strap anchors on decoys, which avoid collecting submersed and floating aquatic plants

When gardening:

- Dispose of invasive plants in the garbage. Do not put them in the compost.
- Buy and plant native plant species from reputable garden suppliers

Learn to identify invasive species that are a threat to Ontario and report your sightings to EDDMapS Ontario (www.eddmaps.org), or contact the Invading Species Hotline at 1-800-563-7711.

Local Spotlight: Georgian Bay Forever Phragbusters and Muskoka Watershed Council's Invasive Species Summer Student

Georgian Bay is home to some of Canada's most pristine coastal wetlands. Many creatures and organisms depend on these wetlands for life-sustaining activities like food and foraging, nurseries, spawning, shade and shelter. Invasive phragmites is a significant threat in Ontario and is especially concerning for Georgian Bay's coastal wetlands. In 2015, Georgian Bay Forever recognized this issue and proactively worked on controlling invasive phragmites by helping over 16 communities remove this invasive species. In 2016, Georgian Bay Forever doubled their efforts, eradicating twice the amount of invasive phragmites. In total, Georgian Bay Forever has helped local communities remove over 35,000 kilograms of invasive phragmites from Georgian Bay shorelines.

MWC hosts an invasive species student each summer since 2017 in partnership with the Ontario Federation of Anglers and Hunters' Invading Species Awareness Program to help raise the awareness of invasive species across Muskoka. This student attends a variety of events across the watershed to help educate the public about which species to look out for and what to do if they find them.

Species at Risk in Muskoka

What are species at risk and why are they important in Muskoka?

Species at risk are plants and animals that are threatened with extinction, extirpation, or endangerment in a region. These particular species are at risk because of the natural and human-induced threats that they face, including:

- Habitat loss e.g. wetlands filled in, privately owned forests cut down, grasslands ploughed and fenced
- Habitat fragmentation e.g. roads constructed through natural areas, development in sensitive habitat
- Competition from introduced and/or invasive species
- Traffic mortality
- Illegal harvesting (poaching) and/or overhunting
- Pollution and chemicals
- Disease
- Predation

Once a species is classified as at risk, it is added to the Ontario's List of Species at Risk in one of four categories, as defined in Table 18.

Table 18. Species at Risk Classifications.

Classification	Definition
Special Concern	Lives in the wild in Ontario, is not endangered or threatened, but may become threatened or endangered due to a combination of biological characteristics and identified threats.
Threatened	Lives in the wild in Ontario, is not endangered, but is likely to become endangered if steps are not taken to address factors threatening it.
Endangered	Lives in the wild in Ontario and is facing imminent extinction or extirpation.
Extirpated	A native species that no longer exists in the wild in Ontario but exists elsewhere.

Species at Risk in Muskoka

Being location at the southern edge of the Canadian Shield, Muskoka is the northern limit for many southern species, and the southern limit for many northern species. This has resulted in biologically diverse terrestrial and aquatic ecosystems which provide the resilience necessary to withstand environmental changes and continue to provide the environmental goods and services on which we and other species depend. Unfortunately, there are also 46 species at risk in the watershed (District Municipality of Muskoka, 2018; Georgian Bay Biosphere Reserve). These are tallied in Table 19. As habitats are lost to development and invasive species are introduced, native species will experience additional stress.

Table 19. Species at Risk in Muskoka.

Type	Common Name	Habitat	Status
Amphibian	Western Chorus Frog	Marshes or wooded wetlands for close proximity to both terrestrial and aquatic habitats	Threatened
Bird	Bald Eagle	Large areas of forest cover near lakes or rivers	Special Concern
Bird	Bank Swallow	Low areas along rivers or streams with cliff ledges	Threatened
Bird	Barn Swallow	Open barns, under bridges, in culverts	Threatened
Bird	Black Tern	Shallow cattail marshes and lake edges	Special Concern
Bird	Bobolink	Tall grass prairie, open meadows	Threatened
Bird	Canada Warbler	Damp, mossy forests with dense understory	Special Concern
Bird	Cerulean Warbler	Mature deciduous forests	Threatened
Bird	Chimney Swift	Mature forests, nesting in hollow trees or cave walls. Found in manmade structures in urban settlements (chimneys, air vents, outhouses)	Threatened
Bird	Common Nighthawk	Open areas with low ground vegetation including forest openings, grasslands and bogs	Special Concern
Bird	Eastern Meadowlark	Tall grasses and hayfields	Threatened
Bird	Eastern Wood-pewee	Forest edges	Special Concern
Bird	Golden-winged Warbler	Shrubby fields, woodland edges, abandoned farm fields, wooded swamps	Special Concern
Bird	Henslow's Sparrow	Abandoned farm fields, pastures, wet meadows	Endangered
Bird	Least Bittern	Wetland habitats with cattails and open pools and channels	Threatened
Bird	Olive-sided Flycatcher	Coniferous forests at forest edge and openings such as meadows and ponds	Special Concern
Bird	Peregrine Falcon	Tall, steep cliff ledges close to large bodies of water	Special Concern
Bird	Red-headed Woodpecker	Open deciduous forest with dead trees	Special Concern
Bird	Whip-poor-will	Deciduous or mixed open forests with little or no underbrush	Threatened
Fish	Grass Pickerel	Wetlands, ponds, slow moving streams, shallow bays of larger lakes with warm, shallow water and plants	Special Concern
Fish	Lake Sturgeon	Large rivers and lakes less than 30 feet deep	Special Concern
Fish	Northern Brook Lamprey	Clear, coolwater streams with soft substrates including silt and sand	Special Concern

Type	Common Name	Habitat	Status
Insect	Monarch Butterfly	Meadows and open areas where milkweed and wildflowers grow	Special Concern
Insect	West Virginia White	Moist, deciduous woodlands with a supply of toothwort	Special Concern
Insect	Rusty-patched Bumble Bee	Mixed farmlands, urban settings, savannah, open woods and sand dunes	Endangered
Mammal	Eastern Small-footed Bat	Under rocks, rock outcrops, buildings, under bridges, caves, mines, or hollow trees	Endangered
Mammal	Eastern Wolf	Deciduous or mixed forests near a water source	Special Concern
Mammal	Little Brown Myotis	Trees, abandoned buildings and barns, and cold and humid caves	Endangered
Mammal	Northern Myotis	Under loose bark and in cavities of boreal forest trees, and in caves or abandoned mines	Endangered
Mammal	Tri-coloured Bat	Old forests or barns, and in caves	Endangered
Reptile	Blanding's Turtle	Large wetlands and shallow lakes with abundant vegetation	Threatened
Reptile	Common Five-lined Skink	Underneath rocks on open bedrock	Special Concern
Reptile	Eastern Foxsnake	Prairies, savannahs, rock barrens, wetlands, shoreline edge, forest edge	Endangered
Reptile	Eastern Hog-nosed Snake	Sandy shorelines, swamps, pine or oak woodlands	Threatened
Reptile	Eastern Musk Turtle	Slow moving water with muddy bottoms and abundant vegetation	Threatened
Reptile	Eastern Milksnake	Old fields, pine forest, open deciduous woodland, rock barrens, sand dune	Special Concern
Reptile	Eastern Ribbonsnake	Close to water	Special Concern
Reptile	Massasuga Rattlesnake	Tall grass prairie, bogs, marshes, shorelines, forests, alvars	Threatened
Reptile	Northern Map Turtle	Rivers and lakeshores with emergent rocks and fallen trees	Special Concern
Reptile	Snapping Turtle	Shallow water with soft mud and leaf litter	Special Concern
Reptile	Spotted Turtle	Ponds, marshes, bogs with an abundant supply of aquatic vegetation	Endangered
Plant	Branched Bartonia	Sphagnum bog or fen wetlands dominated by sedges or low shrubs	Threatened
Plant	Broad Beech Fern	Rich soils in deciduous forests dominated by maple and beech trees	Special Concern
Plant	Butternut	Open sunny areas near forest edges with moist, well-drained soil	Endangered
Plant	Engelmann's Quillwort	Shallow waters of lakes, rivers and wetlands	Endangered
Plant	Forked Three-awned Grass	Open, bare ground or sparsely covered grassy areas	Endangered

Species evolution is based on species extinction; species have been going extinct for millions of years. There have been five mass extinctions during which substantial proportions of all species present on the planet went extinct. The most severe of these was at the end of the Permian (approximately 85% of species lost); the most recent was at the end of the Cretaceous (approximately 70% of species lost, including the remaining dinosaurs except the birds). Extinctions have always occurred at slower rates between these mass extinction events. The causes of extinction vary depending on the species. Today, many scientists are concerned that we are entering another mass extinction event, this time caused mostly by human-caused loss and fragmentation of habitat, pollution, and over-harvest by us.

The development of a single subdivision may have minimal impact on a species, but a dozen developments within the species range could significantly impact key habitat and result in a new addition to the species at risk list. Currently, most of the 350 species at risk (not including those of Special Concern) in Ontario are located in the province's southern regions of the province, where the majority of the population and, in turn, urban development exists.

While many people may be aware of the decline of well-known species such as Ontario's turtles, the Peregrine falcon, and the Monarch butterfly, little is known about the loss of important species such as the Eastern Wolf, Lake Sturgeon and Bobolink. Declining populations of all species, particularly those at risk, may impact humans in numerous ways. Humans rely on healthy ecosystems for our quality of life, for cleaning our air and water and, particularly in areas such as Muskoka, for supporting our resource-based economy. High biodiversity is the basis of ecosystem resilience and the foundation of the human economy. For example, the loss of the native bees and pollinators impacts agricultural productivity. The loss of fish species impacts lake dynamics and therefore sport fishing and potentially cottage country tourism. The loss of plants will reduce forest and grassland productivity, and therefore a food source for wildlife will be lost. The recovery of these species can be aided by habitat protection. If a species is listed as being at risk, appropriate habitat for that species is protected by government mandate. However, with the forecasted effects of climate change, some species at risk may be subjected to additional challenges.

It's your turn!

Becoming aware and involved is the best way to help species at risk. It is important to collect as much data as possible, including species at risk sightings in order to better understand how and where populations exist, and where they may be declining. There are many citizen science initiatives that serve to strengthen the existing data. Some include:

- The **Natural Heritage Information Centre** (www.ontario.ca/page/natural-heritage-information-centre) provides helpful information that can aid in recovery efforts and restoration and gathers reports of species at risk sightings.
- **NatureWatch** (www.naturewatch.ca) aims to engage Canadians in collecting scientific information on nature to understand the changing environment. Programs include FrogWatch, PlantWatch, IceWatch, WormWatch and MilkweedWatch.
- Ontario Nature runs the **Ontario Reptile and Amphibian Atlas** Program (www.ontarionature.org/protect/species/herpetofaunal_atlas.php), in which citizen scientists can help track reptiles and amphibians.

- **iNaturalist** (www.inaturalist.org) is an online social network of people sharing biodiversity information to help each other learn more about nature. Record your own observations, get help with identification from experts, and collaborate with others who are also connecting with nature.

Local Spotlight: Developing detailed estimates of detection probability in Eastern Massasauga Rattlesnakes

Sean Hudson, a masters student at Trent University studying environmental and life sciences, won the 2018 Muskoka Summit on the Environment Research Award for his project, which is a continuation of a collaborative project between Trent University and Blazing Star Environmental researching detection probability of at-risk snake species. Snakes are typically elusive and cryptic in the field, making it difficult to assess species population abundance. The objective of Sean's research is to provide detailed estimates of detection probability in the Eastern Massasauga Rattlesnake, and to describe its variation across regions, habitats, survey methods, and environmental conditions.

This study aims to calculate and compare species-specific detectability and site-occupancy; model the effects of environmental, ecological and methodological factors of these parameters; and estimate true detectability of Massasaugas in a detectability experiment.

Information gained from this research will contribute to improving monitoring programs and environmental impact assessments, as well as our ability to track responses to conserve efforts in this hard to detect species.

Fragmentation

Natural areas and fragmentation in Muskoka

In Muskoka, the human population isn't growing as quickly as it is in southern Ontario and with this comes relatively less development pressure. Instead, the tourism industry has grown, making Muskoka one of the premier vacation destinations in Ontario. The naturalness of the watershed is a key driver of the tourism-based economy (MacDougall, 2014). People from all over the world come to Muskoka to enjoy the scenic views and take part in water-based recreational activities. To ensure that these qualities can be maintained, it is important to minimize the fragmentation of landscape (i.e., the breaking apart of large undeveloped areas into smaller and smaller pieces) by maintaining large natural areas in Muskoka. This is a key consideration when planning for development.

In most of Ontario, conservation focus is primarily geared toward maintaining or expanding forest cover (Muskoka Watershed Council, 2014). However, the Muskoka landscape includes substantial forest cover, and it is important to look beyond the simple total of forested land to ensure effective ecosystem conservation. The pattern of the landscape, the way in which patches of different types of environment are arranged across an area, play a major role in determining the effectiveness of that landscape in sustaining a diverse ecological system capable in turn of supporting large mammals, sequestering carbon, supplying oxygen, and providing both solitude and prime recreational resources.

As development proceeds, it tends to change the pattern of the landscape, initially by fragmenting large, contiguous patches of forest or other habitat type into numerous, smaller, separated patches. Such fragmentation, over time, can have major impacts on biodiversity as species which require large, contiguous areas of habitat, or deep, interior forest habitat, disappear. With enough fragmentation, the connectivity of the landscape is compromised, disrupting important ecological processes. Fragmentation can arise through as simple an action as the blazing of an ATV trail or logging road through an area of intact forest, or through such major actions as the establishment of a new 400-series highway, or a new residential subdivision.

A conservative approach has been taken in identifying the current extent of fragmentation of Muskoka's large natural areas.

Why are natural areas important to Muskoka?

Despite the high percentage of natural cover in the Muskoka watershed, development is resulting in a more fragmented landscape. How much disturbance (or development) is too much before habitat is compromised is a very important - but difficult - question to answer (Beacon Environmental, 2012). However, it is appropriate to seek to quantify the level of fragmentation now, as a baseline for comparison with fragmentation in the future.

In order to maintain natural cover as development occurs, growth should be directed to existing urban areas when possible to concentrate environmental effects and reduce the potential for widespread impacts. In contrast, Muskoka's development along shorelines is typically low density, resulting in the potential for widespread impacts across the landscape. The largest lakes in Muskoka have significant levels of shoreline development, including roads, which increases the pressure on many species that rely on access to specific habitats to survive. For this reason, a sustainable and effective framework is important to support the maintenance of healthy natural ecosystems. This may be accomplished through municipal land use policy, private land stewardship initiatives, and land acquisition by local land trusts.

With development comes the need for additional supporting infrastructure (i.e., roads). In Muskoka this is best illustrated by the construction of new roads and the widening of existing roads (i.e., Highways 11, 117 and 118), the clearing of trees for the installation of hydro lines, and the installation of underground utilities. These types of development are major factors in fragmenting habitat.

The recreational activities enjoyed by many seasonal residents may also degrade or fragment the landscape. For instance, while hiking, boating, fishing, cross-country skiing, or snowmobiling may not have any widespread negative ecological effects individually, together these activities may result in habitat alteration, or simply in increasing the extent to which humans intrude on previously remote habitat. They also allow for garbage to be left behind and provide mechanisms for the spread of invasive species.

The benefits of protecting large natural areas

The protection and conservation of large natural areas from fragmentation is imperative to ensure that ecological processes, structure, and functionality are maintained (Riverstone Envrionmental Solutions, 2011). The benefits of maintaining large natural areas are numerous as these areas are typically associated with high biodiversity, multiple habitat types (e.g., forests, wetlands, rock barrens, etc.), and ecosystem stability, resilience, and resistance (Riverstone Envrionmental Solutions, 2011).

Biodiversity is an essential part of our environment that helps local ecosystems to maintain productive soils, clean water, and fresh air. Biodiversity also confers ecosystem resilience, which can help our environment recover from future shocks and changes. Habitat loss because of development is the leading cause of biodiversity loss, second only to the establishment of invasive species.

Contiguous habitat refers to patches of similar habitat that are connected to each other (i.e., the opposite of fragmentation). These connected habitats allow species with large ranges to survive and allow opportunity for species to perform critical parts of their life cycle including reproduction and maintaining healthy populations (Tran, 2007); Riverstone Environmental Solutions, 2011). However, roads and urbanization have considerable effects on wildlife because they often disrupt the connectivity of natural systems, fragmenting these areas into smaller and more isolated areas.

"Ecosystem stability" means that if a disturbance to a natural area were to occur, not all species within that ecosystem would be affected in the same way. In other words, stability is the capacity of an ecosystem to not have its long-term state materially altered despite outside pressures to do so.

"Ecosystem resistance", on the other hand, is the ability of an ecosystem to 'absorb' or recover from negative impacts, or the capacity of an ecosystem to not change its state despite outside pressures to do so. The ability of an ecosystem to resist disturbances and quickly recover from impacts is directly linked to its biodiversity (Riverstone Envrionmental Solutions, 2011).

"Ecosystem resilience" is the capacity of an ecosystem to tolerate outside disturbance without being permanently changed by them. In essence, resilience and resistance are both aspects of stability.

The benefits and services that large natural areas provide are often compromised by habitat loss, which is known to occur as a result of development. Development often occurs in increments, which can be more problematic than large scale changes because the loss of habitat can be difficult to detect, making it challenging to identify the impacts before they happen (Riverstone Envrionmental Solutions, 2011). By measuring fragmentation it is possible to quantify this habitat loss.

The influence of fragmentation on large natural areas and wildlife

Although an aerial view of Muskoka shows a mosaic of mostly green (forests) and blue (water), a grey colour scheme from urbanization is becoming more prominent in some quaternary watersheds. All development, small or large, can contribute to habitat loss, decreased biodiversity, and a fragmented landscape. Although development fulfills human needs and social well-being and generates economic growth, maintaining and conserving the ecological integrity of Muskoka should remain a priority in order to sustain the tourism-based economy closely tied to the natural features in the landscape. Minimizing fragmentation is an important way of conserving ecological integrity.

Roads, which cover only a small portion of the landscape, can have profound negative effects on wildlife populations and water quality. For instance, in the U.S., roads cover only 1% of the total land area, but they have ecological impacts on nearly 20% of the total land area due to wildlife road kill, traffic noise, spread and establishment of invasive species, creation of a vulnerable edge effect, and wetland drainage (Forman, 2000). In addition, during the winter months, most Muskoka roads are maintained with a combination of salt and sand, which typically washes into surrounding water bodies resulting in higher nutrient and sediment concentrations. Many roads, hydro lines, and railway tracks cut through the middle of forest communities, fragmenting these natural areas. The physical presence and operation of hydro lines creates noise and electromagnetic fields that have an impact on wildlife (Tran, 2007). The application of herbicides to maintain the lines can also have significant impacts.

Although humans often use trails to reconnect ourselves with nature, hiking, biking, cross-country skiing, and snowmobiling, these activities all have the potential to impact animal and plant communities. For instance, pedestrian traffic in the middle of a forest can lead to the establishment of invasive species. Birds that are close to a trail seem to consume less food when trails are used regularly, and forage more often and closer to the trail when pedestrian traffic is lighter (Tran, 2007); Blumstein, Fernandez-Juricic, Zollner, & Garity, 2005). Research has also shown that large mammals such as wolves, undergo physiological stress during periods of high snowmobile traffic (Tran, 2007); Creel, et al., 2002).

Large, relatively undisturbed areas are important for a healthy watershed and should remain in their natural state in order to continue to supply goods and services for the esthetic, social, cultural and economic needs of our communities. All types of development result in a fragmented landscape, threatening the state of large natural areas.

How is fragmentation measured in Muskoka?

Analysis of the fragmentation indicator was completed at a quaternary watershed level using GIS and layers obtained from the Province of Ontario and District of Muskoka. The extent of natural area was determined for each quaternary watershed by subtracting altered landscapes (including roads, buildings, railways, utility lines, trails, hydro corridors, urban communities, quarries, and agricultural land) and the 17 largest lakes from the overall watershed area. A 100-metre buffer was applied around each feature to account for edge habitat between development features and the natural area habitat. The 17 largest lakes were removed from the calculation because they are so large that their presence acts as a boundary to other habitats.

The natural areas in the resulting layer were then categorized based on patch size, with larger patches better able to support environmental services. The five categories used were:

1) Patches less than 200 hectares in size
2) Patches 200 to 499 hectares in size
3) Patches 500 to 4,999 hectares in size
4) Patches 5,000 to 9,999 hectares in size,
5) Patches 10,000 hectares in size or greater

Patches less than 200 hectares in size were discarded as they are too small to provide major biodiversity benefits.

For each quaternary watershed, the amount of natural area in each of the remaining four categories were calculated and formed the basis of the grading. It is important to note that natural area classes may span more than one quaternary watershed. Therefore, it's possible to have a patch within a class in a given watershed that appears to have less than the required area. For example, in the Gibson River Watershed, there are only 9,018 hectares of land in the 10,000 and above hectare class size (Figure 9). This would indicate that only a portion of the larger natural area is in the Gibson River Watershed and the remaining portion would be in an adjacent watershed.

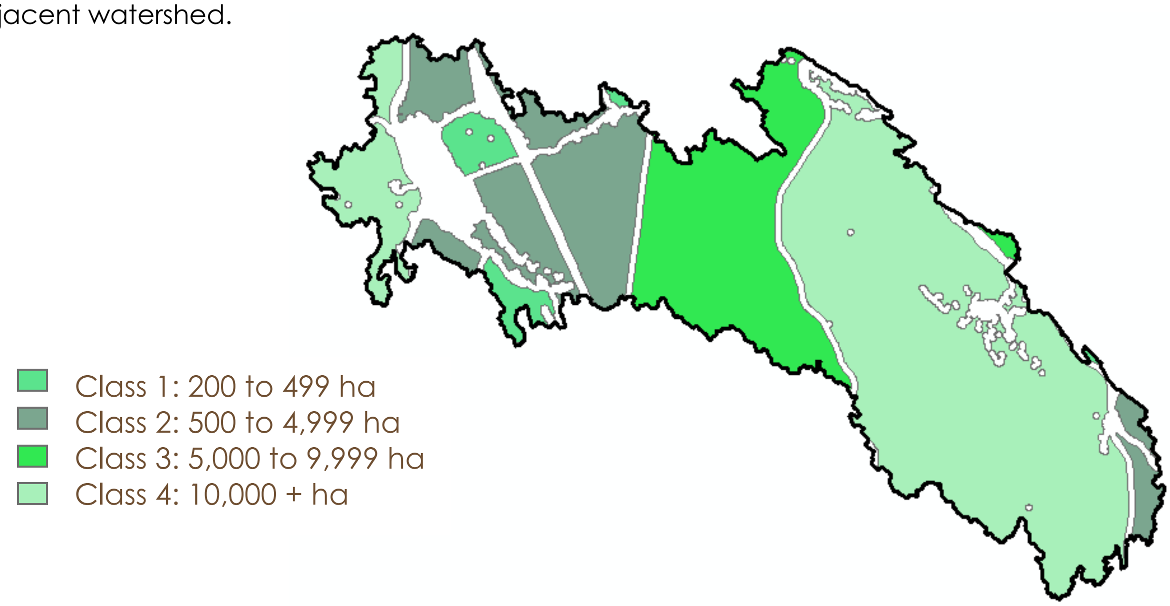


Figure 9. Amount of natural area by patch size in the Gibson River Watershed.

Overall quaternary watershed grades were assigned based on the guidelines provided by *How Much Disturbance is Too Much?* prepared by Beacon Environmental (2012). This report outlines habitat conservation guidance for the Southern Canadian Shield. Watersheds were graded as follows (McIntyre & Hobbs, 1999):

- **Not stressed**: at least 90% of the watershed is covered in natural areas greater than 200 hectares in size.
  These watersheds are characterised by intact landscapes with little to no habitat destruction. Connectivity of the remaining habitat is high and the degree of modification of the remaining habitat is low.

- **Vulnerable**: 60% to 90% of the watershed is covered in natural areas greater than 200 hectares in size.
  These watersheds have a landscape that is variegated with a moderate degree of habitat destruction. Connectivity of the remaining habitat is generally high; however, connectivity may be reduced for species that are sensitive to habitat modification. The degree of modification of the remaining habitat is low to moderate.

- **Stressed**: 10-60% of the watershed is covered in natural areas greater than 200 hectares in size.
  These watersheds have a highly fragmented landscape and may have experienced a high degree of habitat destruction. Connectivity of the remaining habitat is generally low and the degree of modification of the remaining habitat is moderate to high.

Results

Table 20 provides the class size and area for each quaternary watershed, as well as the total percentage of natural area and its resultant grade.

Table 20. Size of natural area by class and quaternary watershed grades for the fragmentation indicator.

Quaternary Watershed and Area (ha)*	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Total Natural Area (%)	Grade
Big East River 64,819.97	200-499	2,251.60	3.47%	8	78.9%	Vulnerable
	500-4,999	14,008.48	21.61%	19		
	5,000-9,999	7,404.10	11.42%	2		
	10,000+	27,537.09	42.48%	2		
Dee River 13,662.51	200-499	952.38	6.97%	4	69.5%	Vulnerable
	500-4,999	6,920.05	50.65%	9		
	5,000-9,999	0.00	0.00%	0		
	10,000+	1,631.84	11.94%	1		
Gibson River 18,597.67	200-499	551.62	2.97%	4	85.2%	Vulnerable
	500-4,999	2,957.46	15.90%	7		
	5,000-9,999	3,353.10	18.03%	2		
	10,000+	8,997.54	48.38%	2		

Quaternary Watershed and Area (ha)*	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Total Natural Area (%)	Grade
Hollow River 36,656.9	200-499	958.03	2.61%	3	83.3%	Vulnerable
	500-4,999	3,171.34	8.65%	3		
	5,000-9,999	238.04	0.65%	1		
	10,000+	26,169.68	71.39%	2		
Kahshe Lake 23,259.13	200-499	1,157.35	4.98%	10	73.7%	Vulnerable
	500-4,999	8,974.70	38.59%	6		
	5,000-9,999	0.00	0.00%	0		
	10,000+	7,023.55	30.20%	2		
Lake Muskoka 32,297	200-499	2,499.39	7.74%	12	57%	Stressed
	500-4,999	11,523.37	35.68%	18		
	5,000-9,999	4,318.47	13.37%	1		
	10,000+	97.32	0.30%	1		
Lake of Bays 30,101.31	200-499	666.78	2.22%	4	73.4%	Vulnerable
	500-4,999	10,270.82	34.12%	8		
	5,000-9,999	8,808.96	29.26%	4		
	10,000+	2,370.19	7.87%	4		
Lake Rosseau 27,724.14	200-499	1,561.40	5.63%	7	59.2%	Stressed
	500-4,999	13,665.64	49.29%	13		
	5,000-9,999	0.00	0.00%	0		
	10,000+	1,194.98	4.31%			
Little East River 9,623.5	200-499	776.37	8.07%		67.1%	Vulnerable
	500-4,999	1,969.91	20.47%			
	5,000-9,999	0.00	0.00%			
	10,000+	3,711.99	38.57%	1		
Lower Black River 50,918.88	200-499	148.82	0.29%	2	88.6%	Vulnerable
	500-4,999	10,273.17	20.18%	9		
	5,000-9,999	4,639.81	9.11%	2		
	10,000+	30,086.42	59.09%	1		
Mary Lake 61,102.19	200-499	2,636.82	4.32%	10	73.7%	Vulnerable
	500-4,999	24,122.04	39.48%	15		
	5,000-9,999	2,008.38	3.29%	2		
	10,000+	16,270.52	26.63%	3		
Moon River 71,697.17	200-499	3,933.38	5.49%	16	78.1%	Vulnerable
	500-4,999	18,602.13	25.95%	15		
	5,000-9,999	17,332.34	24.17%	3		
	10,000+	16,131.83	22.50%	1		
North Muskoka	200-499	2,428.77	9.77%	8	61.9%	Vulnerable

Quaternary Watershed and Area (ha)*	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Total Natural Area (%)	Grade
River 24,849.94	500-4,999	4,712.75	18.96%	11		
	5,000-9,999	0.00	0.00%	0		
	10,000+	8,252.57	33.21%	2		
Oxtongue River 60,852.21	200-499	4,010.06	6.59%	16	76.9%	Vulnerable
	500-4,999	28,219.11	46.37%	24		
	5,000-9,999	4,066.36	6.68%	3		
	10,000+	10,539.51	17.32%	2		
Rosseau River 12,991.38	200-499	386.60	2.98%	1	91.8%	Not Stressed
	500-4,999	1,271.43	9.79%	2		
	5,000-9,999	0.00	0.00%	0		
	10,000+	10,272.24	79.07%	2		
Severn River 66,177.78	200-499	5,586.32	8.44%	23	61.5%	Vulnerable
	500-4,999	26,433.93	39.94%	22		
	5,000-9,999	3,199.72	4.84%	2		
	10,000+	5,484.91	8.29%	2		
Skeleton River 6,750.9	200-499	0.07	0.00%	1	72.2%	Vulnerable
	500-4,999	738.52	10.94%	2		
	5,000-9,999	0.00	0.00%	0		
	10,000+	4,136.36	61.27%	2		
South Muskoka River 35,096.5	200-499	1,197.34	3.41%	8	75.5%	Vulnerable
	500-4,999	6,342.20	18.07%	10		
	5,000-9,999	846.91	2.41%	1		
	10,000+	1,8124.58	51.64%	3		
Upper Black River 39,075.23	200-499	148.62	0.38%	1	86.2%	Vulnerable
	500-4,999	3,788.24	9.69%	3		
	5,000-9,999	12,811.83	32.79%	2		
	10,000+	16,942.27	43.36%	3		
Total		**513,820.42**			**81.9%**	

*Includes all land and water except for the 17 largest lakes in Muskoka. These lakes represent a significant break in the natural landscape. This approach builds on past reporting methodologies, is endorsed by local ecologists, and is consistent with the Interior forest indicator.

What do these results mean?

Currently, the natural cover across the entire Muskoka Watershed (i.e., lakes, wetlands, forests, rock barrens, and other natural ecological communities) is 81.9%.

Although most of the quaternary watersheds are graded as vulnerable, the guidelines presented in *How Much Disturbance Is Too Much?* provide a conservative approach to ensure that development thresholds are not exceeded.

Lake Rosseau and Lake Muskoka are the only quaternary watersheds to be graded as stressed. Both of these quaternary watersheds were among the first areas within the larger Muskoka River Watershed to be developed. Historical development patterns have resulted in relatively higher densities of development, especially along the shorelines, and, in turn, more fragmented landscapes with road infrastructure and other service corridors. Seasonal residential buildings and the corresponding amenities associated with this type of development dominate the landscape.

In contrast, the Rosseau River Watershed is the only watershed to be graded as not stressed. This watershed has a total natural area of 91.8%, most of which is in patch sizes greater than 10,000 hectares in size. This represents very limited fragmentation as the development pattern has resulted in large undisturbed areas that support many of the large mammals native to Muskoka, such as bear and moose.

It's your turn!

Be a land steward!

- If you have a woodlot, carry out good stewardship practices using resources available from the Ontario Woodlot Association and enroll in the Managed Forest Tax Incentive Plan (MFTIP).
- Protect your shoreline. Find more information at www.muskokawatershed.org/wp-content/uploads/2012/08/VegetationBrochure-20121.pdf.
- Invest in low impact development strategies such as grass swales and open ditches, or using rain barrels. Learn more at www.muskokawatershed.org/wp-content/uploads/2011/12/LIDBrochure11.pdf.
- Support your municipality's green infrastructure initiatives such as decreasing energy consumption and greenhouse gas emissions.
- Get more great stewardship ideas in Muskoka Watershed Council's *Living in Cottage Country: What You Need To Know* handbook.

Local Spotlight: Lake of Bays Heritage Foundation

The Lake of Bays Heritage Foundation is a community based non-profit organization committed to protecting the natural, built and cultural heritage of Lake of Bays. It was founded by seasonal and permanent residents in 1985, is a registered charity and a certified member of the Ontario Land Trust Alliance.

The Foundation's main focus is long-term preservation of heritage for future generations by encouraging protection of heritage through education, voluntary stewardship, conservation easements, land donations and land acquisitions. The Foundation has had many successes, some of which include:

- Acquiring over 50% of the Lower Oxtongue River for permanent protection, including 6.5 kilometers of shoreline;
- Preserving one mile of shoreline and 19 hectares of forest at Port Cunnington; and
- Partnering with the Ontario Heritage Trust to be the steward of the 40 hectare Pyke property near Brown's Brae.

The Foundation has many other projects underway, including ones related to invasive species awareness, protection of wetlands, and the preservation of dark skies. Check out their website at http://lakeofbaysheritage.ca to see how you can get involved today!

Climate Change

What is climate change and why is it important in Muskoka?

In Muskoka, local ecological, social and economic systems are impacted by changing climatic conditions caused by the global warming trend being driven by modern society's excessive emissions of greenhouse gases. Although climate change science is advancing, the Earth's climate is extremely complex which makes projections of the future climate challenging, especially on a local scale. However, as local data are collected, it is evident that climate change is a reality in Muskoka, and our understanding of its current and future effects are improving with time. This indicator focuses on physical changes the Muskoka Watershed has undergone due to climate change, measured by lake surface water temperatures in the summer and ice coverage on lakes in the winter (Sale, et al., 2016).

The Muskoka Watershed Council has reported on climate change several times. In 2007, climate was featured in the Muskoka Watershed Report Card. In 2010, the Muskoka Watershed Council released a paper, "*Climate Change and Adaption in Muskoka*", to provide information on how the changing climate will affect Muskoka's natural and socio-economic communities. A more comprehensive report, "*Planning for Climate Change in Muskoka*", was released in 2016 and examined the likely impacts climate change will have on Muskoka's natural systems by mid-century.

This section of the Report Card will report on climate-related trends that have been observed across the watershed and what they mean for our weather, lakes, forests and our health.

How is climate change measured in Muskoka?

The impacts of climate change can be demonstrated through several measurements. Some of these are the changing patterns of precipitation, increase in air and water temperatures, and water level changes. While climate change is a planet-scale process, examination of local-scale measurements can clarify our understanding of local climate change and the resulting local consequences for the Muskoka Watershed. Two useful measurements are duration of ice coverage on lakes during the winter months, and surface water temperatures of lakes in the summer months. Data for these measurements are easily accessible for use and include historical records spanning as far back as the early 1980's, providing us with a local long-term trend. Further, ice coverage and summer surface water temperature measurements are widely recognized and recommended by the science community, including the U.S. National Oceanic and Atmospheric Administration (NOAA). Further, *The State of Ontario's Biodiversity 2010 Highlights Report* by the Ontario Biodiversity Council states that "changes in ice cover on northern hemisphere lakes are a strong signal of global climate change. Changes in freeze-up and break-up times can affect the food supply for aquatic life, alter fish spawning, and cause birds to change their migration patterns. Less ice means more water may evaporate and turn into snow which will fall across the area".

2018's *State of the Bay* presented by the Georgian Bay Biosphere Reserve reports on climate change in a similar manner, primarily at the Lake Huron scale.

Data sources

Surface water temperature data have been collected by The District Municipality of Muskoka for many area lakes since 1980. Ice coverage data have been collected by the Dorset Environmental Science Centre since 1975.

Results

Ice cover

The ice coverage data show that the number of ice covered days for various lakes in the Muskoka Watershed is on the decline (Figure 10).

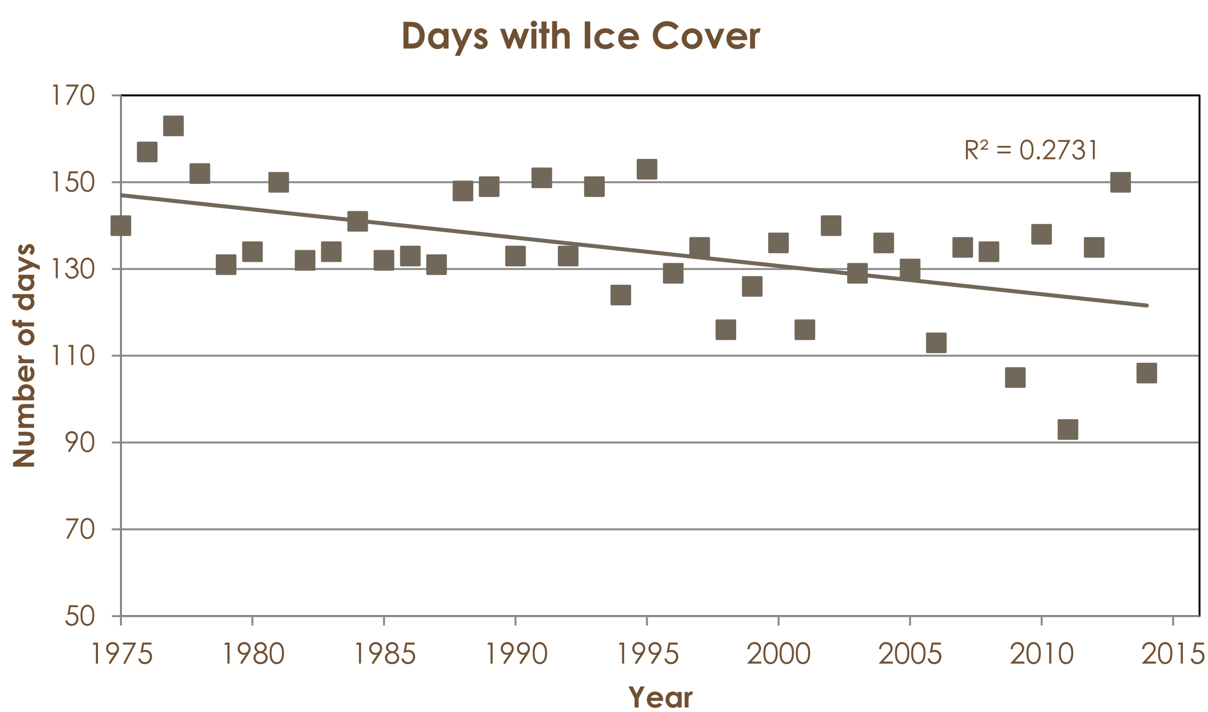


Figure 10. The number of days with ice cover on lakes from 1975 to 2015. In 1975, there was an average of 140 days with ice on the lakes. By 2015, an average of 121 days of ice cover was observed.

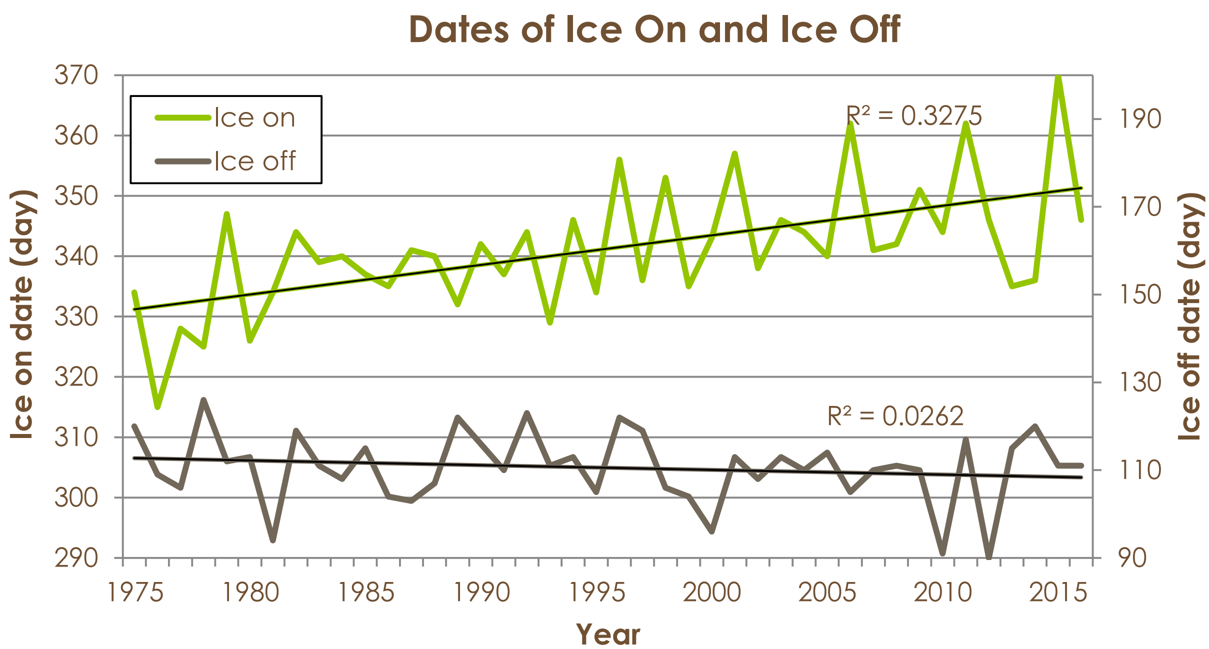


Figure 11. Dates of ice on and ice off at various lakes in Muskoka from 1975 to 2017. The date of first ice freeze up (ice on) is plotted (green line, left-hand axis) as the Julian day for each year. The date the lake opened in spring (ice off) is plotted (black line, right-hand axis) also as the Julian day for each year. (Julian day is the day number where 1 January = day 1 and 31 December = day 365.) The trend towards a later freeze up in the fall is statistically significant, while the slight advance in ice off date is not significant.

The linear trend line in Figure 10 indicates a long term declining trend in the number of days with ice on the lakes. Over the past three decades, the climate in Muskoka has become noticeably warmer, and the duration of the open-water season has correspondingly increased. That increase in duration has occurred primarily because ice cover is now forming over 3 weeks later in the fall season than it did in 1975. The data points in Figure 10 and the data lines in Figure 11appear to display more variability in increases and decreases within the last 10 years. This corresponds to fluctuating seasonal variability of temperatures, also a likely indication of climate change.

Although ice thickness is not measured on Muskoka's lakes in the winter, it is expected that changes in the time available between freeze-up and break-up are likely to result in thinner ice today because of the shorter duration of ice cover. No specific data for Muskoka exist, however the Ministry of Natural Resources and Forestry has projected that lakes throughout Fishery Management Zone 15 (which includes Muskoka) will lose 6-9 cm of ice thickness by the end of 2040, and 9-12 cm by 2100 (Minns, Shuter, & Fung, 2014). To summarize, ice break up and freeze up dates are responding to a warming climate, increasing the duration of the summer open water period for Muskoka's lakes, and ice thickness is expected to decrease as the duration of ice coverage declines (Minns, Shuter, & Fung, 2014).

Surface water temperature

Changes in surface water temperature (°C) were observed using data collected on 164 lakes by the District of Muskoka from 1982 to 2016. Readings were taken during August at 0.5 metres below the surface. If readings were taken more than once on a lake during August, the data was averaged. The data show that summer surface water temperatures in Muskoka's lakes has increased 0.5 °C on average over the past 35 years (Figure 12).

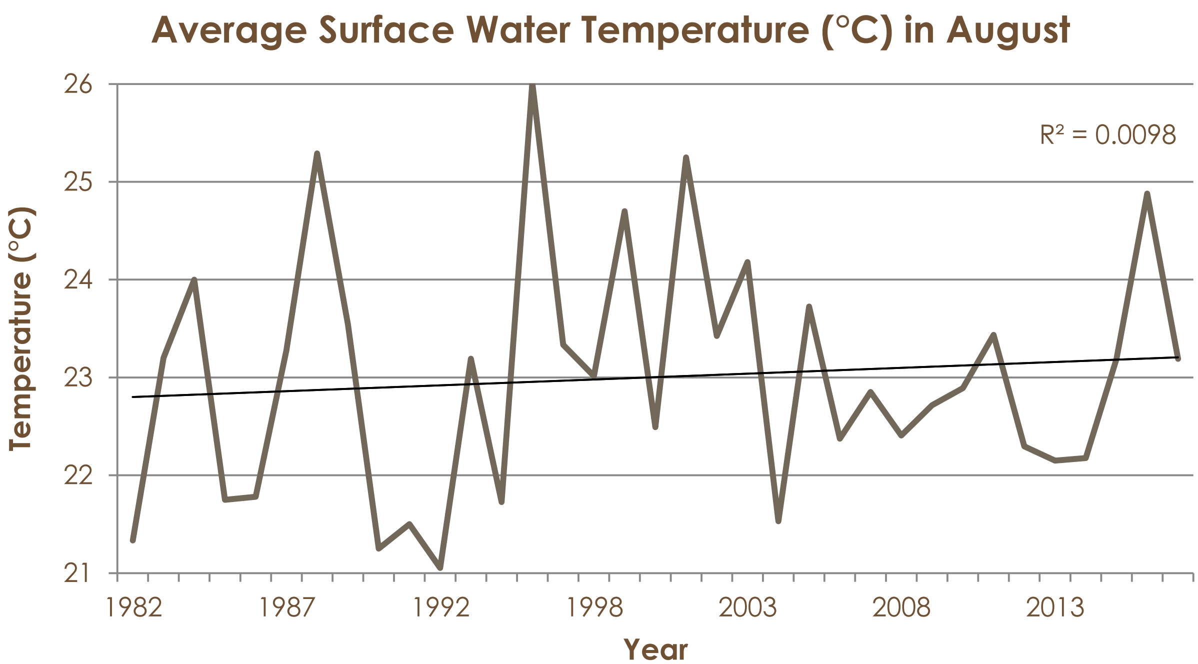


Figure 12. Average summer surface water temperature (at 0.5 meters depth) in various lakes in Muskoka. The trend line indicates that surface water temperature is increasing.

While the trend line is not yet statistically significant, this rate of warming is similar to the trend seen in Georgian Bay Biosphere's 2018 *State of the Bay* report, in which summer surface water temperatures in Lake Huron have increased 0.7 ±0.3 °C per decade between1980 and 2014 (Georgian Bay Biosphere Reserve, 2013). The warming trends observed in Muskoka are not as pronounced. This is most likely due to the characteristics of Muskoka's lakes – small, inland, and largely shaded, whereas Lake Huron is larger and wide open for sunlight penetration.

These data on ice cover and surface temperature demonstrate an important feature of most climate-related data – there is very considerable year-to-year variation coupled with a clear, long term trend. For example, ice formed on the lakes a month later in 2015 than in 2016; however ice retreated off the lakes within the same 2 days between the years. Further, 2016 was the warmest the lakes have been since 2001, following a hot and dry summer, however the years between that range were 2 °C cooler.

What does a changing climate mean for Muskoka?

Both the increase of surface water temperature and the declining ice coverage days indicate that climate change has arrived on our front door step. Changes in our climate will not just lead to changes in the weather. While it is not yet possible to precisely define future climates, the growing expertise in climate science makes it possible to set out plausible and likely climatic conditions for the future, which will have a wide range of impacts on our environment and our lives, including on our weather, our lakes, our forests, and our health.

How will climate change affect our weather?

While there will still be warm years and cold ones, wet ones and dry ones, the typical year by mid-century is likely to be 3-4 °C warmer each month than the present, and about 10% wetter. As well, precipitation will likely shift toward the winter and spring season, so that summer and fall will be dryer than the present. The increased precipitation during the winter months, and the expectation that much of this will come as rain rather than snow, may greatly alter the typical annual pattern we currently experience – accumulating snowpack, spring thaw, and a summer with sustained but reduced flow through our waterways. Instead, most of the winter precipitation may flow downstream during frequent thaws during that season. The reduced availability of water during summer and fall, and the warmer climate expected, will mean that our lakes during the winter will be ice free longer, midwinter thaws will flood our shorelines, our forests will experience drought leading to increased risk in fire, and extreme wind and storms can damage habitats, infrastructure and crops (Sale, et al., 2016).

How will climate change affect our lakes?

The warming climate will influence the physical, biological and chemical characteristics of surface waters, which in turn will influence the rest of the water column. Climate determines the quantity of water in the system through the rate of precipitation, as well as the rate of evaporation and transpiration given an increase in air temperature. Since the climate is changing, we can expect there to be changes in the functioning of Muskoka's lake ecosystems, as well (Sale, et al., 2016).

The warming climate will cause noticeable changes in the thermal regimes of some Muskoka lakes, making their surface waters warmer in the summer than at present, which will directly affect aquatic biota. The extent of this warming may prove lethal to some planktonic species, such as *Daphnia*. This may lead to reordering of zooplankton communities, which in turn may change the capacity of those lakes to support fish species. Moreover, the warming climate may increase stress on cold-water fish species such as Lake trout, and some lakes many be unable to continue to support them all together. Small lakes will be most affected, since they have a greater potential of becoming anoxic under the warming climate. Changes in water temperature may also affect spawning timing for some fish species, as well as the productivity of the lower food web, and increased presence of invasive species and algal blooms (Georgian Bay Biosphere Reserve, 2013).

How our lakes warm during the season, and whether they develop stable thermal stratification through summer and fall, have important consequences for concentrations of dissolved oxygen and nutrients such as phosphorus both in the warmer surface waters and the cooler deep waters (Sale, et al., 2016).

The change in seasonal patterns and amount of precipitation, combined with the increase in evapotranspiration, are expected to change the amount of water transported through the system to Georgian Bay. Seasonality of flow will likely be more pronounced, resulting in much more winter and spring and more periods of summer or fall drought. In milder than usual years, winter flow may cause nuisance flooding. In colder than average years, winter precipitation may result in substantial snowpack and significantly larger spring floods than at present. Maintaining flow in rivers and streams during late summer and fall, and keeping water in wetlands may become more difficult, and changes could have real impacts on certain animal species, especially fish. For instance, changes in water levels and flow may impact spawning and egg incubation in waterbodies (Georgian Bay Biosphere Reserve, 2013). Moreover, seasonal drying of wetlands is anticipated and will have important consequences for species composition and their ecological functions in the hydrological systems (Chu, 2015).

How will climate change affect our forests?

Climate change affects Muskoka's terrestrial environments as well as its aquatic ones. Just as in the aquatic environments, changes in annual patterns of temperature and precipitation are both important factors.

Climate change alters the frequency and severity of natural disturbances such as drought, fire, windfall, insect outbreak and disease, while also pushing the forest into a climatic regime that will favour growth to a different degree for each tree species. Trees adapted to the present day climate in Muskoka are expected to be under increasing climate stress. Growth rates will be reduced, reproductive success lowered, and susceptibility to disease and insect pests will be heightened. Tree species do shift their ranges when climate changes, but their ability to move depends entirely on the dispersive capabilities of their seeds.

During the early Holocene, as the Pleistocene ice sheet melted back, tree species moved at rates varying between 0.1 to 2 kilometers per year as the North American climate warmed, but Figure 13 suggests the rate of movement needed to keep up to climate is on the order of 6 kilometers per year, as projected by the Ontario Forest Research Institute and Ministry of Natural Resources and Forestry (Sale, et al., 2016).

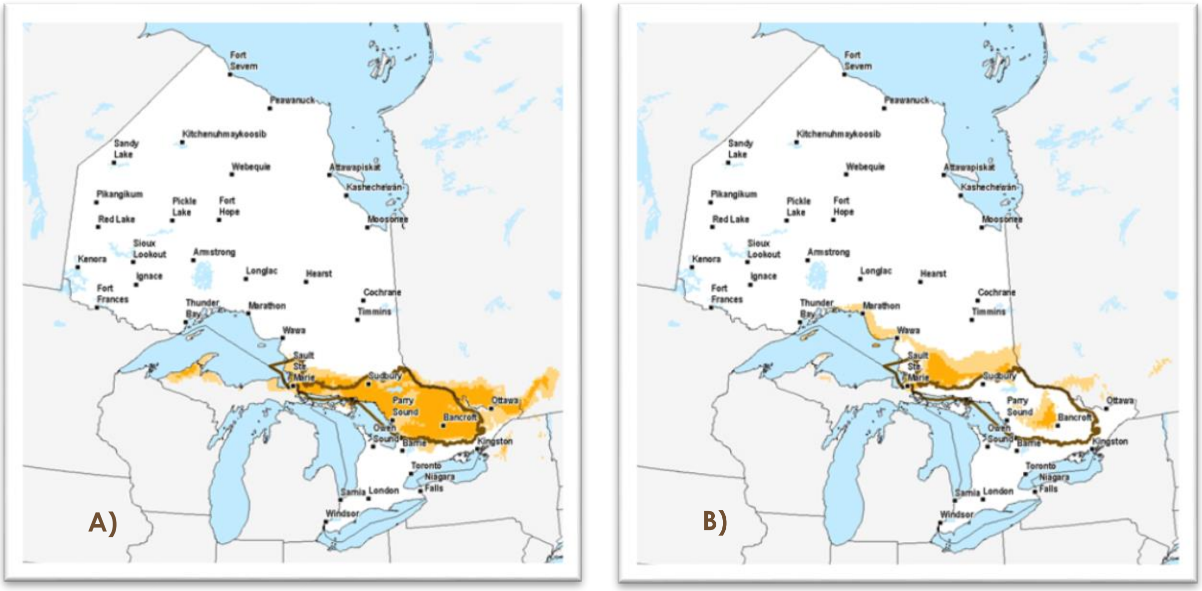


Figure 13. Shifting growth zones of Ontario. Maps of Ontario showing Ecoregion 5E and depicting all areas within Ontario that possess the climate typical for 5E during 1971-2000. Map A) shows that the characteristic 5E climate is largely restricted to that ecoregion except in areas to the east along the Ottawa and St. Lawrence Rivers at present. Map B) shows the situation expected by mid-century. This map shows the climate typical of 5E at present will be almost entirely absent from that region by 2040, but is present in a number of regions to the north. Forests adapted to the present climate in Ecoregion 5E will be stressed by a changed climate by mid-century. Images courtesy of Ontario Forest Research Institute, Ministry of Natural Resources and Forestry.

Some tree species may be able to adapt to the changing climate, but it looks as though our forests are going to be 'sorting out' their responses to the changing climate for many decades to come. The consequences of climate change for Muskoka's forests will be a progressive thinning out of forests, with fewer trees of currently dominant species, and insufficient numbers of newly arrived southern species to take their places (Sale, et al., 2016).

Though it may seem logical that if our climate will be reflective of a more southern forest that we should start planting trees from southern Ontario or north central U.S., Westwind Stewardship Inc. notes that while such trees might be appropriate for the expected conditions in Parry Sound/Muskoka in the year 2115, they still are not appropriate now. Major changes in forest management direction based on expected future conditions would result in failures because those trees would not be well suited for the conditions they will experience in the earlier parts of their life (Davidson, 2015).

Further, the milder winters will be favourable for invasive species and forest pests that would have otherwise been killed off by harsh winter conditions. Forests will also undergo drought during the summer and fall months, creating dry and unproductive soils. These changes may trump the anticipation of longer and warmer growing seasons that were once seen as an advantage of climate change in North America. The value of our forests, under these circumstances, will be reduced in terms of wood production, 'leaf viewing' tourism, and in the provision of ecosystem services such as carbon sequestration, water management and local climate amelioration (Sale, et al., 2016).

The wildlife that call these forests home will also be at risk of losing habitat, especially those that are less adaptable. These changes will force many species to migrate to a new location, change their breeding seasons, and seek new food sources (Ministry of Natural Resources and Forestry, 2016; Georgian Bay Biosphere Reserve, 2013).

How will climate change affect our lives?

Milder winters, a longer growing season, and warmer, drier summers might seem ideal for people who value Muskoka primarily for the outdoor recreational possibilities offered in the warmer months. However, these projected changes are substantial relative to any time in human history, and they will bring some negative impacts.

The more variable weather anticipated in the future will challenge winter road transport, and increase the risk of fire, flood and drought (and, in turn, the cost of property insurance). Summer and fall drought will impact the tourism value of iconic streams and rivers and will also raise issues for homeowners dependent on wells for domestic water supply.

Climate change is also likely to have some significant impacts on public health due to the new opportunities for insect- or tick-borne pathogens that, until now, have been unable to tolerate our climate. Among these are Lyme disease, West Nile virus, and malaria. The risk of West Nile virus is particularly heightened because spring floods give rise to suitable breeding grounds for mosquitoes. More direct effects of warmer weather on human health will come as heat stress and heat-related death, and from deteriorating air quality and smog, which will enhance respiratory diseases such as allergies and asthma. The incidence of respiratory allergies and asthma has already been increasing in Ontario (Sale, et al., 2016).

The projected shift in seasonal pattern of precipitation toward the winter months and the expected increase in frequency of severe weather events will have major impacts on winter road maintenance and stormwater management. With an expected average increase of 17% more precipitation falling during the winter months, we must plan for a significant increase in cost of winter road maintenance. What is now classified as the 100-year flood event is likely to become far more frequent, and we will have to expand our water management capacity to cope. Drought seen in our warmer summers may reduce the tourism and recreational amenity of the landscape, affecting economic activity, property values, and livelihoods. Warmer summers also call for turning on the air conditioner. Since most buildings are now air conditioned, the warmer climate will increase operating costs and electricity demands, although new construction will be able to avoid this by adopting more appropriate passive solar and other green design elements.

It's your turn!

Help mitigate climate change on a local scale by improving your own understanding of the Muskoka environment and how it will respond to a changing climate, and talk to others about this issue. You can also actively participate in local monitoring programs, seek to reduce your carbon footprint, and support local policies that include climate change adaption strategies.

Local monitoring programs

Far more is known about Muskoka's lakes than most other Canadian regions given the area's extensive and long-standing lake monitoring programs; however, there is still much that is not known about our shared waters. Building datasets through local monitoring initiatives and broadening them where possible will strengthen our understanding of how climate change is affecting Muskoka's environment and our communities. Become an active citizen scientist by participating in initiatives including the District of Muskoka's Biological Monitoring Program, Ontario's Lake Partner Program, NatureWatch, and other programs supported by your Lake Association or community. Your participation will enhance ongoing monitoring efforts and, in turn, provide a local foundation from which we can collectively anticipate, and perhaps mitigate, changes to our watershed due to our changing climate.

Reduce your carbon footprint

Canadians rank per-capita as one of the largest energy consumers in the world. Consuming excessive energy results in the waste of non-renewable resources and unnecessary emissions of greenhouse gases into the atmosphere. Although the population of Muskoka may be relatively small, everyone still can play a key part in reducing our collective greenhouse gas emissions. Be energy efficient by buying energy efficient vehicles, hang your laundry outside when possible instead of using a dryer, install a programmable thermostat, and change your light bulbs to LEDs.

Our food preferences can also impact our climate. Choose organic and locally grown foods, or better yet, grow some of your own food when possible. Meat and dairy production are responsible for18% of greenhouse gas emissions (Sale, et al., 2016), so try a plant-based diet. Further, accumulating garbage in landfills produce methane, a potent greenhouse gas, which can easily be reduced by composting and recycling as much as possible.

Advocate for change

Lastly, become an advocate for change. Write to your area politicians at all levels of government and demand action to address climate change issues.

Climate change initiated by human activities can be slowed with effort.

Local Spotlight: Simcoe Muskoka District Health Unit

The effects of climate change are not limited to the environment. The Simcoe Muskoka District Health Unit is bringing awareness to the public of how climate change can influence human health at a local level. For instance, their recent *Climate Change Vulnerability Assessment* (Levison, Whelan, & Butler, 2017) reported that climate change will increase your risk of:

- Respiratory illness (exposure to ground level ozone, particulate matter, air pollution caused by traffic);
- Heat related illness;
- Foodborne and waterborne illness including food and water security;
- Injuries due to extreme weather events (flooding, tornadoes, forest fires, winter storms, drought);
- Vector-borne disease (mosquito and tick-borne illness); and
- UV-related skin cancers.

While everyone feels the effects of climate change, factors such as age, gender, health status, and access to resources will make some people more vulnerable to the impacts of climate change than others. Therefore, it's important to not only plan for climate change through a mitigation or adaption strategy for the sake of the environment, but to also protect yourself. Be sure to review their assessment report at www.simcoemuskokahealth.org/docs/default-source/topic-environment/smdhu-vulnerability-assessment-2017-(final-for-posting-on-internet).pdf?sfvrsn=0 to learn more about potential climate-sensitive health outcomes, who is vulnerable to these outcomes, and action plans to mitigate the impacts felt by all as a result of climate change.

Cumulative Impacts

Anthropogenic stressors such as urban development, agricultural practices, industrial activities, and a changing climate are growing concerns in the Muskoka Watershed because these stressors can alter physical, chemical and biological conditions of ecosystems (MacDougall, 2014). Although the Muskoka Watershed Report Card identifies individual stressors impeding on watershed health, assessing individual indicators together allows you to dive into a deeper understanding of how all aspects of the environment are inherently connected.

According to the Canadian Environmental Assessment Agency (Hegmann, 1999):

> *"Cumulative effects are changes to the environment that are caused by an action in combination with other past, present and future human actions."*

The District Municipality of Muskoka's proposed Official Plan (The District Municipality of Muskoka, 2018) recognizes cumulative effects as being critical for the District of Muskoka's environmental health and resiliency and notes that:

> *"Multiple environmental stressors can impact development (i.e. climate change, invasive species, habitat fragmentation, etc.) and are often dynamic and varying. Conversely, seemingly small, cumulative impacts of development can have significant negative consequences for ecosystems and environmental resilience over time. Measuring and assessing cumulative impacts of development on Muskoka`s watersheds, environment, and overall quality of life is challenging."*

In 2016, the Canadian Water Network delivered a Muskoka-based study which established an understanding of cumulative effects within the watershed (Eimers, 2016). The study considered various parameters of aquatic environmental health or stressors in Muskoka. The conclusions of this study describe how stressors are linked, and how these may directly or indirectly impact freshwater services. A summary of the study is seen in Figure 14.

Forest fragmentation is an example of how a single environmental stressor may, together with other stressors over time, culminate in more significant impacts. Although individual patches of forests may still be present after development or infrastructure (i.e., a road network) is constructed, catastrophic impacts can occur long before the final remaining forest patches are diminished or removed entirely. While a forest may still be considered a forest if patches of trees remain, we may have also unknowingly lost critical resources on which our ecosystem depends. This is because the ecological impacts can accumulate to a greater degree than the small incremental patch removals.

As the forest is fragmented, more light and wind can creep in from the edges, and interior forest habitat converts to edge habitat (McGarigal, Romme, Crist, & Roworth, 2001). Subsequently, populations that require interior forest habitat may dwindle, allowing opportunities for invasive species to establish, and for adaptive species to thrive. Ecological diversity, resilience and resistance can be reduced and the ecosystem can no longer withstand the implications of climate change as vigorously as it once did. In addition, rain from heavy precipitation events once easily absorbed by the forest floor may now cause flooding or erosion from the cleared areas which now have impermeable surfaces (such as fields, roads or parking lots), or run directly into a lake, picking up sediments and nutrients along the way. Eventually, the ecological functions and services from the former forest are diminished, perhaps even lost, even though some patches of trees are standing.

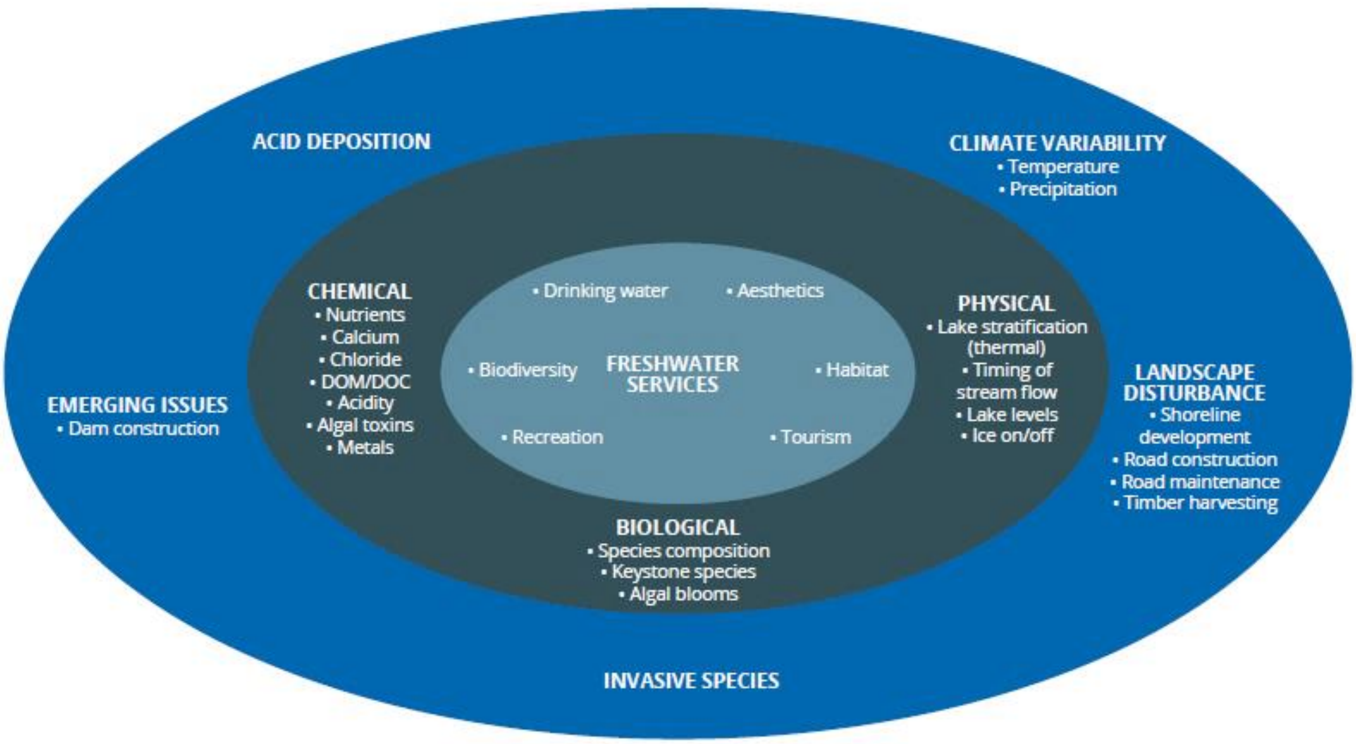


Figure 14. Human activities and stressors operating at regional and local scales over time cumulatively affect ecological processes and freshwater services in the Muskoka River Watershed (Eimers, 2016).

Commonly, efforts to address cumulative impacts appear to be focused on decision support tools, including data collection and monitoring. Certainly, through the identification of data gaps through the preparation of this Report Card, there is much work to be done on that front in Muskoka and across Ontario. However, data collection and, in turn, calculating cumulative effects and the resulting impacts is only the start; the challenge will persist, recognizing that we are about to exceed some threshold in ecosystem change, and taking decisive action to prevent it.

Community-based reports such as this one may be a tool for which to drive forward discussions and considerations about cumulative effects. Certainly, reporting on various conditions across a community can create foundations by which to consider collective issues, rather than focussing solely on specific and sometimes narrow indicators. For example, as part of Muskoka Community Foundation's ongoing efforts to create awareness and understanding of the issues impacting Muskoka, the Foundation issues a Muskoka Vital Signs© Report, which now includes environmental factors in community well-being. Vital Signs© is a national program led by community foundations across the country. It is an initiative registered to and coordinated by Community Foundations of Canada that leverages local knowledge to measure the vitality of communities and support action towards improving the collective quality of life. The Muskoka Community Foundation will be releasing the Muskoka Vital Signs© Report in October 2018. That Report, together with this MWC Report Card and other local evaluations and assessments including the Georgian Bay Biosphere Reserve's 2018 State of the Bay Report in 2018, can do much to advance the consideration of cumulative impacts in Muskoka.

Conclusion

Muskoka, with its memorable natural landscapes and its distinctive environment, is in good ecological health. Our phosphorus levels are stabilizing, our benthic communities are 'typical' and thriving, and we are fortunate to have significant, large, continuous natural areas and interior forest habitats for all biota including species at risk.

However, we cannot be complacent. Muskoka is also facing significant environmental issues. Declining nutrients like calcium, particularly in the northeastern watersheds, are reducing the growth rate of our forests and altering the composition of our aquatic fauna. Invasive species are establishing themselves and spreading across the watershed. Thirty years of local water temperature and ice cover data show a warming trend that matches global climate change predictions and raises questions about coming environmental, social and economic impacts and, in turn, about how we as individuals and as a community can appropriately respond.

In addition, despite vigorous monitoring and data collection efforts across the watershed, data gaps exist and, in certain areas, are insufficient for clear conclusions to be drawn. Data collection must be expanded. Only by monitoring and reporting can we understand human impacts and environmental sensitivities affecting the watershed, and only by informing ourselves about environmental sensitivities can we create and cultivate conditions to manage them.

Against this environmental backdrop, an extraordinary number of local organizations and individuals are working to ensure Muskoka's environmental future is a healthy and viable one. Many local initiatives are underway to address the issues we collectively face, and the efforts of many are bringing made-In-Muskoka approaches to cultivating watershed health. This must be continued, and the work we do to conserve, protect, and enhance Muskoka must be ongoing and ever expanding, particularly to recognize the interrelationship between environmental management and healthy community and economy. Together, we must be vigilant in our stewardship efforts to ensure a healthy Muskoka for all, for today and for the generations to follow.

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