Muskoka Watershed Report Card 2023

BACKGROUND REPORT

Muskoka Watershed Council

September 2023 | www.muskokawatershed.org

ISBN 978-0-9940191-3-4

This report should be cited as:

Background Report, 2023 Muskoka Watershed Report Card. Muskoka Watershed Council, Muskoka, Canada, 2023. 194 pages.

TABLE OF CONTENTS

MESSAGE FROM THE CHAIR

Producing the Muskoka Watersheds Report Card is arguably one of the most important tasks the Muskoka Watershed Council (MWC) does. While the Report Card itself is a tiny thing it is backed by a substantial body of supporting documents, particularly the Background Report. That report documents the rationale behind each indicator used, the data sources, the approach taken, and the results obtained and includes substantial information not included in the Report Card itself, even in abbreviated form.

Dr. Peter Sale

Why does MWC produce report cards every five years or so? In the belief that we all need to be reminded from time to time about how we are doing in looking after this marvelous environment. Because the Report Card is really a report on how well we are caring for this place, a place whose health is vital for the continued quality of our lives and for the robustness of our economy.

I've found working with the members of MWC and the numerous volunteers who have helped us in this effort one of the most satisfying tasks during my second term as Chair. The commitment, the effort to be accurate and to draw sound, fact-based conclusions, and the belief that our community wants, and is willing to delve deeper into knowledge about the health of our environment were all exemplary. As a result, the quality of this Report Card sets a standard of accuracy and rigor that other groups in other places can aim for, and a high bar for us next time (in 2028).

MWC knows that the health of our watersheds ultimately is in the hands of our citizens, and I thank you for reading this Report Card. The news is not all good, and there is an urgent need to improve the way in which we care for this place we all love. Each one of us can do more than we are currently doing, and MWC is now embarking, with numerous partners, on a path towards a rather different way of managing environment, a more integrated approach that has the capacity to deal with the types of threats now facing this ecosystem. Our goal is to ensure the high quality (health) of our watersheds persists into the future. We want good outcomes for the seventh generation into the future as well as for the next few years.

SUMMARY

The 2023 Muskoka Watershed Report Card is the sixth report card issued by the Muskoka Watershed Council since 2004. In producing it, we have used best available data to assess a range of attributes of the environment. Each attribute is an indicator that measures one aspect of ecosystem health. Taken together, the results of these analyses provide a nuanced picture of the state of our watersheds.

As in previous report cards, we report, for nearly all indicators, that the environment is in good condition. That, however, is not the most important message we derive from this effort.

As in previous report cards, many of the indicators reveal concerning trends towards reduced ecosystem condition. Our healthy watersheds are slowly becoming less healthy. These trends, despite being gradual are concerning because continued gradual decline leads to major change over a decade or so, and current management policies and procedures do not seem able to halt or reverse these trends. The Watershed Council is now working with others to bring advanced, watershed-scale, adaptive environmental management and land-use planning to this region.

After an introduction providing basic information on the Muskoka watersheds and a general outline of how we proceeded, the Background Report contains fourteen chapters, one for each of fourteen topics on watershed health. Six chapters relate specifically to indicators of the quality of our lakes. These are the concentration of calcium in lake water, the concentration of phosphorus in lake waters, the concentration of chloride in lake water, the composition of benthic invertebrates in samples from shallow lake sites, the status of cold-water fish populations, and the frequency of algal blooms. Two chapters provide indicators of forest health: the amount of interior forest and the extent of fragmentation of forested land. Two chapters concern the status of our biodiversity (species at risk and invasive species) and a third concerns climate trends. Two other chapters provide a brief comment on birds and a detailed look at Beech bark disease, a troubling invasive pathogen in our forests. The final chapter

explores the meaning of *watershed health* providing an up-to-date discussion of the nature of ecosystems, especially their persistence and resilience.

Each of these chapters covers the rationale for the particular approach, sources of data, analyses done, results and conclusions. Readers may notice that the analyses have been more circumspect in several cases than in our 2018 Report Card because we now view the available data as too sparse to draw firm conclusions. This is particularly the case for data on species at risk and on invasive species. In both cases the available data are indicative, providing facts on the presence of certain species within these categories, but they are not definitive. There has been insufficient research to know the status of most rare or threatened species, or to know the extent to which invaders are expanding their occurrence across the region or impacting other species. Since biodiversity loss is a worldwide problem of some concern, and given this region's extensive natural environments, it is unfortunate that more is not known because our watersheds might serve as an important refuge for at risk species. This is one place where individual citizens can make a real contribution simply by reporting their sightings of uncommon, endangered, or invasive species to national databases using one of several cellphone apps.

Throughout this Background Report, MWC has attempted to focus where possible on trends in status through time as well as on current state. This effort has revealed concerning trends with respect to calcium, chloride, climate, winter ice cover on lakes, and algal blooms.

Calcium concentration in lake waters has been declining over the last several decades; however, data available to us were too sparse to allow investigating trends over that time period for particular lakes. Nevertheless, 28% of 187 lakes being monitored during the last five years had calcium concentrations below a threshold of 2 mg/L, a level that is problematic for species attempting to build their skeletons.

Data on phosphorus suggest that an encouraging trend towards lower concentrations in lake waters may be slowing: 5% of lakes sampled show significantly higher concentrations than in 2018. Data were inadequate to examine trends in status of forests, although several quaternary watersheds are in a state where management to prevent further fragmentation is warranted.

For the first time, this Report Card examines the frequency of confirmed blooms of blue-green algae. Something that *never* happened in Muskoka lakes is now an infrequent, but regular occurrence with several lakes reporting blooms in any year. The reasons for this trend are obscure but climate is a likely factor.

Chloride data for 274 lakes revealed 71% of lakes have concentrations above 1 mg/L, strongly suggesting they have been made saltier by our use of salt on roads. Of these, 24% have chloride concentrations higher than 10 mg/l, a twenty-fold increase over background and a level that can be lethal for certain zooplankton important in lake food webs (13% exceeded 20 mg/L). Between 2018 and 2022, chloride concentrations had increased by more than 0.5 mg/L in 80 (28%) lakes and decreased by at least 0.5 mg/L in just 13 lakes.

As in 2018, this Report Card provides data on species at risk and on invasive species. MWC now considers the available data inadequate to infer whether there have been changes in status of any of these species. Both chapters update information on which species at risk are known to occur in Muskoka and which invasive species are particularly problematic. As well there is discussion of the relationship of lists of endangered species (species at risk) or lists of invasives to the important question of biodiversity decline. Biodiversity decline is a worldwide problem of considerable concern, and our generally good quality natural environments could be providing important refuges for rare and threatened species. Lack of data prevents evaluations of species status, and the Report Card advocates for interested citizens to take advantage of the several cellphone apps enabling them to record sightings of rare or unusual species. With a richer data set, it would be possible to answer some questions concerning the status of rare native species or infer the full effects on biodiversity of particular invasives.

The chapter on beech bark disease provides a detailed exposition of the complexity of dealing with an invasive pathogen. This disease, caused by an invasive scale insect which harbours a pathogenic fungus, is now spreading through Muskoka, likely because warmer winters are permitting the survival of the scale insect. Beech is an important tree in our forests, providing food for numerous faunae, and a significant part of the canopy. The report outlines the complexity of events that follow the killing of a tree by the pathogen. When forests are being managed for timber, the aftermath results in extensive suckering from remaining roots leading to thickets of stunted beech which crowd out other trees that might replace the canopy. Relatively labour-intensive methods of treatment are at present the only way to manage stands to prevent the suckering and encourage species not impacted by the pathogen.

Climate change is now sufficiently advanced that local weather data reveal significant trends in several measurements of temperature or precipitation. We report on several increasing trends in temperature over the past 140 years, and an increase in total rainfall (while amount of snow remained constant) over 140 years. The greatest warming (about 1^{o}C per 100 years) occurred in autumn and winter while the change in rainfall amounts to a month more of rainy days (>1 mm rain) per year than 100 years ago. There is also limited evidence that storms are becoming more intense: the number of storms yielding more than 51 mm rain during 2000 to 2019 was double that in the 30 years from 1970 to 1999.

MWC's 2018 Report Card reported that the number of days of winter ice cover on lakes had declined since 1975. Here, those data are extended to 2022. Lakes in Muskoka are experiencing about 20 fewer days of ice cover than in the mid-1970s.

The final chapter on ecological integrity, the best definition of what is meant by environmental health, paints a picture of our environment that will be unfamiliar to many people. Our watersheds are living, interconnected, dynamic ecosystems that respond to the various pressures placed upon them by our activities or by events unrelated to us. We cannot prevent them responding, and we usually lack the power to steer their responses. Successful management of these ecosystems requires that we recognize our relative weakness, understand the causes of their responses, and tailor our own actions to best help these ecosystems to retain their resilience. Our *actions* here refer to everything we do, not just to actions we take deliberately as part of environmental management. To be successful in managing natural environments, such as found in the Muskoka watersheds, in this modern, changing world, we will have to recognize the true nature of natural ecosystems and tailor management actions accordingly. The good news is that doing so is possible and can be compatible with a strong economy and a growing population.

In 2023, the Muskoka watersheds are in good health. But they are deteriorating slowly and unless we adjust our management efforts they will degrade in coming decades. With the right approaches, we can be reasonably optimistic about the longer term, but token efforts to alter current practices will not be sufficient. The Muskoka region is a valuable jewel that we must take care of. If we do, it will yield immeasurable benefits to us for decades to come.

INTRODUCTION

SHIFTING BASELINES AND THE MUSKOKA WATERSHEDS

The 2023 Muskoka Watershed Report Card is the 6th report card issued by the Muskoka Watershed Council (MWC) since 2004. With this near-twenty-year record of reporting, it is appropriate that we focus as much or more on trends in the status of our environment as on its current state.

In each of its previous report cards, MWC has concluded that the overall health of our environment is very good, although some concerning trends have been detected. If MWC were to continue its emphasis on current status in 2023 and into the future, the message would continue to be, overall, a comforting one: the health of our environment is generally very good. We are very lucky to live here and fortunate that wise management of environment has prevailed. The downward trends in environmental health that have been reported are all gradual and unless the circumstances deteriorate suddenly, it will be many years before MWC is forced to report that the health of our environment is poor.

The Muskoka community faces the risk of what ecologists call the *shifting baseline syndrome*. Every few years, attempting to report on the overall health of an ecosystem, observers can find the situation little changed from the last time they looked into it despite the fact that it has been slowly degrading year by year. The observers have mentally re-set their baselines, based on the immediate past, forgetting what things were like decades earlier. From this can come complacency.

This shifting of baselines is a natural human process which makes it very difficult to see slow changes, even when setting out explicitly to measure and report any such changes; we continuously modify our unconscious baseline expectations. The shifting baseline syndrome fools professional scientists charged with measuring and monitoring environmental conditions just as much as it fools the public. It is a major reason why so many fisheries around the world, such as Canada's Atlantic Cod fishery, have collapsed despite being carefully managed. Deteriorating trends have been seen and recorded, but the long-term impact of them has not been appreciated until far too late. It is also why parks and conservation areas can seem to be 'in good condition' over many years, only to be found to be seriously degraded by overuse or inappropriate use subsequently. In this Report Card, we strive to guard against letting our baselines shift.

THE GOAL

In producing this Report Card, MWC intends to raise public awareness of the state of our environment, and to identify any undesirable trends in environmental health that need to be corrected if the long-term health of this environment is valued. No part of Muskoka is now in pristine condition, unaffected by the presence of humans: the goal of MWC in producing periodic report cards is to remind people of the environment's current state and whether that state appears to be drifting further away from pristine conditions. This information can be used by individuals and by those charged with protecting/conserving our environment to guide changes in behaviour as well as in policies and regulations that should remedy deleterious trends before the state of the environment becomes irretrievably poor.

Using available local data, MWC's Report Card evaluates ecological conditions, general threats, and drivers of change. It identifies areas of special concern and highlights emerging issues such as climate change. At the same time, the Report Card 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 2023 Muskoka Watershed Report Card is intended for a wide audience: 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 watersheds. As well, it includes several *stories* that illustrate current trends and future risks. The environmental evaluations contained within the Report Card are *made-in-Muskoka* and 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 (DMM), the Dorset Environmental

Science Centre (DESC), the Ontario Lake Partner Program (LPP), and Environment and Climate Change Canada (ECCC).

OBJECTIVE

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

RATIONALE

MWC commends those municipalities within our region that have consistently prioritized providing sound management of the environment in their official documents, including the policies and regulations they have enacted. Their clear recognition of the economic and non-economic value of a healthy environment, and their efforts over many years, are a major reason why our environment is in as good condition as it is.

For example, DMM, the six Area Municipalities within it, and Seguin Township and Township of Algonquin Highlands all make protection of the natural environment paramount in their Official Plans. Within the Strategic Priorities of DMM approved in 2016, the first goal is to;

"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."

MWC 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 for 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 them. 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 evaluates 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 ENVIRONMENT

The Muskoka environment, that wonderful mix of rocks, trees and water, is a living ecological system. It is rich in native plants and animals, possesses great scenic beauty, and sustains the major sectors of an economy built on tourism and outdoor recreation, while also providing important natural resources and sustaining our lives in less material ways. This is an environment whose health is of intrinsic economic and cultural importance to the local community and to Ontario. Most people who live and work in Muskoka understand the close links between our environment and our economy, as well as the many ways in which this vibrant natural environment enriches their own lives. Most people also understand that this environment can only be kept healthy through wise management. This Report Card provides the information needed to enable individuals, community groups, the corporate sector, and government at all levels to plan and to modify their activities in ways that will maintain and even restore the overall health of this environment while enabling our human endeavors to also be sustained.

THE MUSKOKA WATERSHEDS – TIME FOR SOME GEOGRAPHY

So, what are the Muskoka watersheds? A watershed or drainage basin is that area of land on which surface waters drain towards a particular waterway; it is defined by those water flows and the natural variations in elevation that underlie them. Every piece of land lies within a watershed. Watersheds, by their nature, can be nested within still larger watersheds, and geographers speak of nested sets of primary, secondary, tertiary, and quaternary (or even smaller scale) watersheds.

In Canada, the GeoBase Surface Water Program, within Natural Resources Canada, has responsibility for systematizing, naming and numbering, the many watersheds that comprise our landscape. The region we mostly think of as *Muskoka* lies within the Great Lakes-St. Lawrence primary watershed and the Lake Huron secondary watershed. Within that secondary watershed are a number of tertiary watersheds. Tertiary watershed No. 02EB, the Muskoka River Watershed, occupies that region of central Ontario stretching from the headwaters of the North and South branches of the Muskoka River in Algonquin Provincial Park, south and west through Lake Muskoka, continuing as the Moon River and the Musquash River which jointly deliver the water to Georgian Bay. This watershed is the primary focus of this Report Card. Directly south of No. 02EB lies tertiary watershed No. 02EC, the Severn River-Lake Simcoe Watershed.

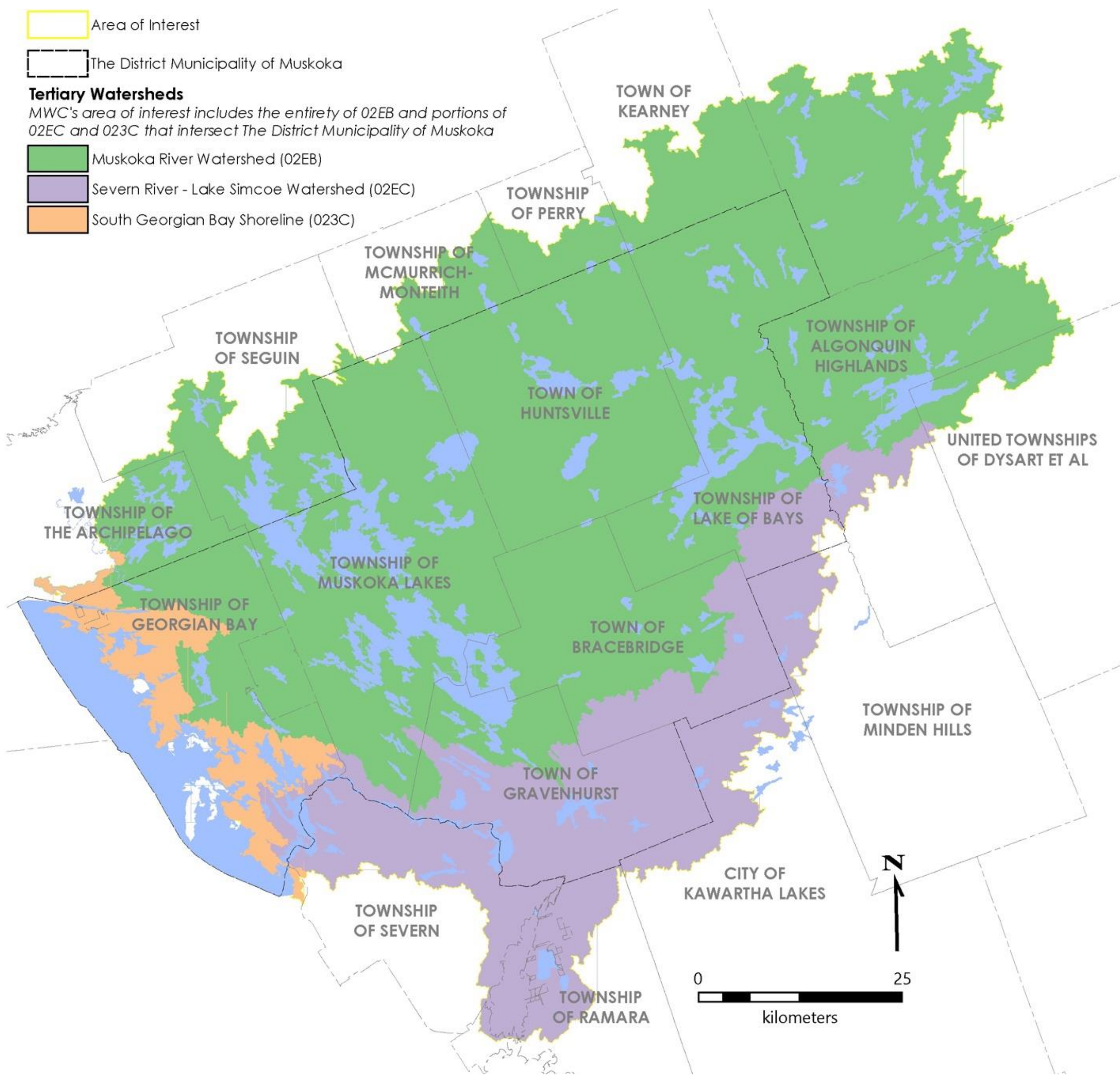

Figure 1. Tertiary watersheds that make up the region referred to in this Report Card as the Muskoka watersheds. The area shaded as a portion of 02EC is the combined area of the five quaternary watersheds within 02EC that lie partially within the District Municipality of Muskoka. Watershed 02EC extends further to the south.

About 70% of the Muskoka River Watershed lies within DMM, but seven other lower-tier and three other upper-tier municipalities include portions of this watershed. Small portions of the Severn River-Lake Simcoe Watershed also fall within DMM.

In addition to watersheds 02EB and 02EC, the western boundary of our area of interest includes three small portions of land draining directly to Georgian Bay. These are part of tertiary watershed No. 023C, South Georgian Bay Shoreline. Still, these small portions of land are also included within DMM. This Report Card covers *all of the Muskoka River Watershed plus those portions of the Severn River-Lake Simcoe Watershed and the South Georgian Bay Shoreline* that lie within DMM.

When this Report Card refers to the *Muskoka watersheds* it is referring to all of No. 02EB (the Muskoka River Watershed), the small portion of No. 023C, South Georgian Bay Shoreline, and those portions of No. 02EC (the Severn River-Lake Simcoe Watershed), that lie within the District of Muskoka. In this, MWC's *area of interest* remains unchanged from previous report cards.

At the level of quaternary watersheds, readers may notice some changes from 2018. Responsibility for designating quaternary watersheds in Ontario lies with the Ministry of Natural Resources and Forestry (MNRF). At the smaller geographic scales of quaternary watersheds, the ability to accurately define boundaries is constrained by the available detailed mapping data, and MNRF undertook to redefine the quaternary watersheds using the most up-to-date, high-resolution lidar data. In doing this revision, MNRF also made some decisions to split large riverine watersheds to create a set of more or less equal-sized pieces of the landscape. The revised watershed boundaries were published in early 2020.

As a result, the quaternary watersheds of 2023 are mostly changed from the quaternary watersheds in place when we produced the 2018 Report Card. Only two names remain unchanged, and identification codes have been reassigned. Rest assured that the land has not shifted, only the bureaucracy that provides us with official names and boundaries. So, in 2023, we say goodbye to the Dee River, Mary Lake, and Gibson River quaternary watersheds (among others), while saying hello to the Musquash River, Lake Vernon, and Blackstone Harbour quaternary watersheds (among still others), and the boundaries of all except possibly the Hollow River and Kahshe River quaternary watersheds have been altered. Once more, nothing has changed on the ground, only our official names for particular places. In 2023, there are 19 quaternary watersheds, plus three small portions of tertiary watershed 023C, South Georgian

Bay Shoreline, falling within the region referred to as the Muskoka watersheds. No. 023C has not been mapped at a quaternary level. These are shown in Figure 2 and listed in Tables 1 and 2.

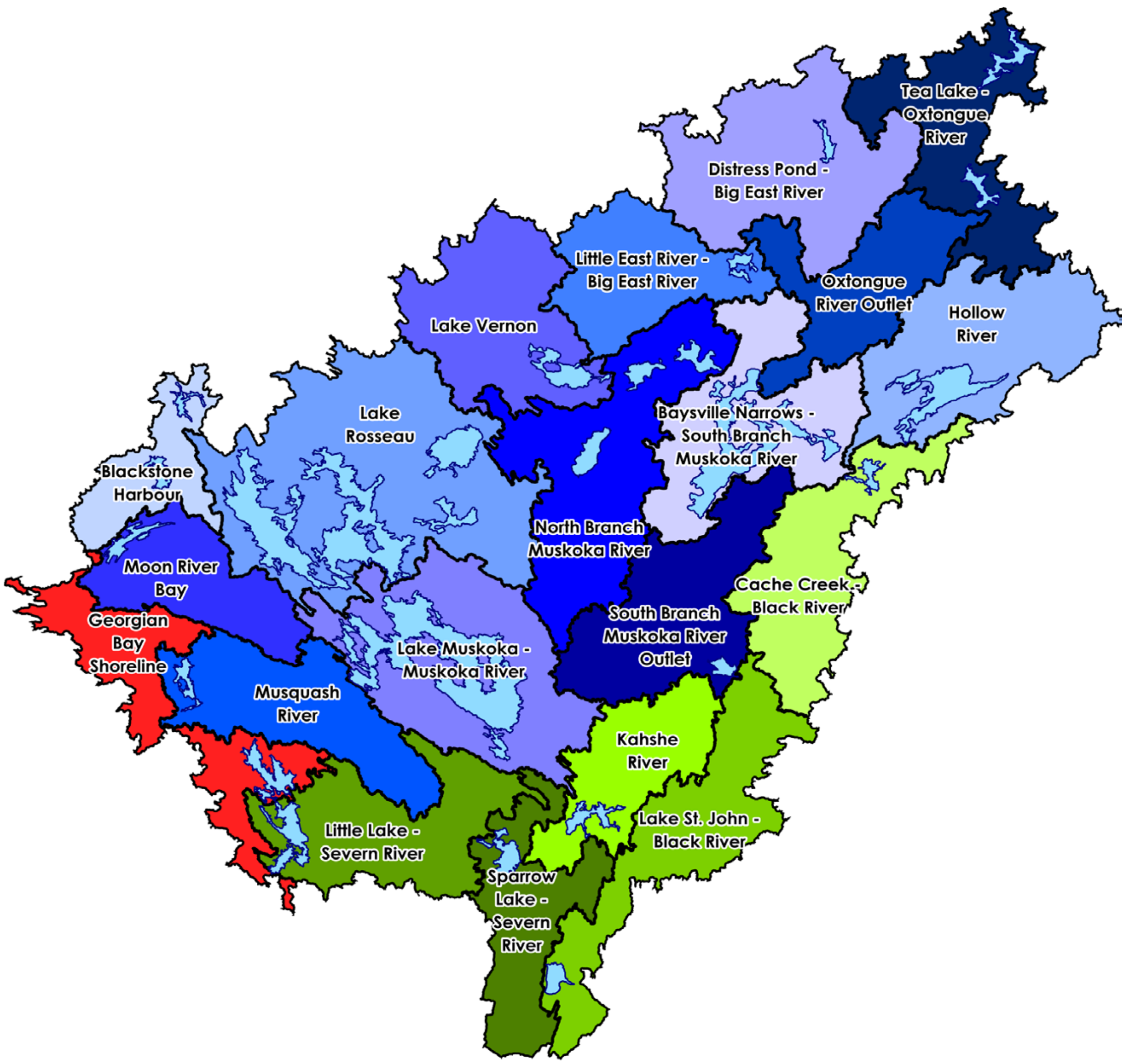

Figure 2. The 19 quaternary watersheds, and the portion of tertiary watershed, South Georgian Bay Shoreline, for which we evaluate data and report on environmental health. Also shown are the major lakes, to enable locating places on this map.

Table 1. Codes, names, and areas* of the quaternary watersheds comprising the Muskoka River Watershed (No. 02EB), and the previous codes and names of watersheds containing each piece of the landscape.

Watershed Code	Watershed Name	Area (Hectares)	Previous Code	Previous Name
02EB-01	Moon River Bay	24,011.19	2EB-02 (part)	Moon River
02EB-02	Blackstone Harbour	17,456.84	2EB-02 (part)	Moon River
02EB-03	Musquash River	31,763.96	2EB-02 (part), 2EB-03	Moon River, Gibson River
02EB-04	Lake Muskoka-Muskoka River	52,488.53	2EB-04, 2EB-14 (part)	Lake Muskoka, North Muskoka River (part)
02EB-05	South Branch Muskoka River Outlet	36,393.19	2EB-09 (part)	South Muskoka River (part)
02EB-06	North Branch Muskoka River	48,281.23	2EB-14 (part)	North Muskoka River (part)
02EB-07	Baysville Narrows-South Branch Muskoka River	39,041.49	2EB-09 (part)	South Muskoka River (part)
02EB-08	Lake Vernon	36,958.74	2EB-13 (part)	Mary Lake (part)
02EB-09	Lake Rosseau	79,570.26	2EB-05, 2EB-06, 2EB-07, 2EB-08	Lake Rosseau, Rosseau River, Skeleton River, Dee River
02EB-10	Little East River-Big East River	27,566.35	2EB-10 (part) 2EB-15 (part) 2EB-16 (part)	Lake of Bays (part) Big East R (part) Little East R (part)
02EB-11	Oxtongue River Outlet	27,023.02	2EB-10 (part) 2EB-11 (part)	Lake of Bays (part) Oxtongue River (part)
02EB-12	Distress Pond-Big East River	46,473.53	2EB-15 (part)	Big East River (part)
02EB-13	Hollow River	40,922.21	2EB-12	Hollow River
02EB-14	Tea Lake-Oxtongue River	34,369.41	2EB-11 (part)	Oxtongue River (part)

** Columns 1-3 (from left) are downloaded from the Ontario Watershed Boundaries list at https://www.arcgis.com/home/item.html?id=0391524acaa64dad9d0eba7efbb6794d#data. Columns 4-5 are based on a comparison with earlier data.*

Table 2. Codes, names, and areas** of quaternary watersheds that together comprise the Severn River-Lake Simcoe Watershed (No. 02EC), and the previous watersheds containing each piece of the landscape. Shaded rows (pale blue) are watersheds that fall outside the MWC area of interest. The final row (pale green) represents three portions of tertiary watershed 023C, South Georgian Bay Shoreline, that drain directly to Georgian Bay. Quaternary watersheds have not been defined for 023C.

Watershed Code	Watershed Name	Area (Hectares)	Previous Code	Previous Name
02EC-01	Little Lake-Severn River	34,516.75	2EC-17 (part)	Severn R (part)
02EC-02	Sparrow Lake-Severn River	26,771.22	2EC-17 (part)	Severn R (part)
02EC-03	Lake Simcoe	8,873.53		
02EC-04	Lake St John-Black River	37,643.36	2EC-14 (part)	Lower Black River (part)
02EC-05	Head River	61,974.57		
02EC-06	Holland River	35,812.75		
02EC-07	Pefferlaw River	42,837.44		
02EC-08	Talbot River-Trent Severn Waterway	35,884.80		
02EC-09	Cache Creek-Black River	33,523.66	2EC-15	Upper Black R
02EC-10	Black River	32,706.81	2EC-14 (part) 2EC-17 (part)	Lower Black R (part) Severn River (pt)
02EC-11	Beaver River	32,672.45		
02EC-12	Anson Creek	25,036.86		
02EC-13	Kahshe River	24,572.25	2EC-16	Kahshe River
02EC-14	Holland River East Branch	22,374.30		
023C	South Georgian Bay Shoreline (part)	22,000 (Approx)	2EB-02 (part) 2EC-17 (part)	Moon R (part) Severn R (part)

*** Columns 1-3 (from left) are downloaded from the Ontario Watershed Boundaries list at https://www.arcgis.com/home/item.html?id=0391524acaa64dad9d0eba7efbb6794d#data. Columns 4-5 are based on a comparison with earlier data. The total area of Watershed 023C is 338,370 ha of which approximately 22,000 ha lie within the District Municipality of Muskoka.*

With few exceptions, and to the extent that mapping data permit, official watershed boundaries are natural, ecological boundaries. It makes sense to report on environmental health using these natural boundaries instead of municipal boundaries. In this Report Card, MWC reports on environmental health at the quaternary watershed scale where possible. The Muskoka watersheds cover a large area and pressures on environment vary from place to place within them. However, many indicators do not lend themselves to being examined at the quaternary watershed scale, the effects of climate change are one obvious example. For other indicators there is insufficient data available for some of the more remote quaternary watersheds. In these cases, the evaluations must be Muskoka-wide, or for some of the quaternary watersheds only.

THE MUSKOKA RIVER WATERSHED, NO. 02EB

The Muskoka River Watershed (02EB) is located in central Ontario 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 general characteristics of the Muskoka River Watershed are provided in Table 3.

Table 3. Watershed characteristics of the Muskoka River Watershed (02EB).

Characteristic	Value
Watershed Area	5,423 km^2
Approximate Permanent Population*	69,000
Approximate Seasonal Population*	96,000
Number of Major Towns	3 (Bracebridge, Gravenhurst, Huntsville)
Number of Villages and Hamlets	11
Number of Quaternary Watersheds	14
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

** Permanent population estimates based on Canadian 2021 census data for municipalities with municipalities that straddle watersheds divided accordingly. Seasonal population estimates based on published estimates by the District Municipality of Muskoka, Seguin Township, and the Township of Algonquin Highlands and set equal to estimated permanent populations for other municipalities; municipalities that straddle watersheds divided accordingly.*

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 5,423 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, Moon and Musquash Rivers. 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 watershed is bounded to the west by 023C, South Georgian Bay Shoreline.

THE SEVERN RIVER-LAKE SIMCOE WATERSHED, NO. 02EC

The Severn River-Lake Simcoe Watershed (02EC) 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. This Report Card concerns only 1,212 km^2 of the northern portions of the watershed.

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 Lakes Simcoe and 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 Severn River-Lake Simcoe Watershed included in the Report Card is sparsely populated (less than 63,000 total 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 because of a vibrant tourism industry and seasonal residents. The characteristics of the Severn River-Lake Simcoe Watershed are outlined in Table 4.

Table 4. Watershed characteristics of the Severn River-Lake Simcoe Watershed (02EC). Values in brackets are for the portion of the watershed covered by this Report Card.

Characteristic	Value
Watershed Area	4,463 km^2 (1,570 km^2)
Approximate Permanent Population	(30,500*)
Approximate Seasonal Population	(32,200*)
Upper-Tier Municipalities	4 (1)**
Lower-Tier Municipalities	9 (5)
Number of Quaternary Watersheds	14 (5)
Number of Lakes	Over 500

** Permanent population estimates based on Canadian 2021 census data for municipalities with numbers for municipalities that straddle watersheds divided accordingly. Seasonal population estimates based on published estimates by the District Municipality of Muskoka, and the Township of Algonquin Highlands and set equal to estimated permanent populations for other municipalities; numbers for municipalities that straddle watersheds divided accordingly.*
*** One single-tier plus three upper-tier municipalities.*

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

WATERSHED USE

The Muskoka watersheds support 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 such as; waterpower generation, farming, timber harvest, and mining of gravel and dimensional stone 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 spring surface water phosphorus was evaluated and reported, usually using the provincial guidelines. Provincial guidelines have changed over time, 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. These changes have been due to advances in the underlying science. Consequently, values reported in the 2023 Report Card are not always easily compared to values of that indicator in an earlier report card.

In some earlier report cards, MWC attempted to average values for indicators to achieve an overall grade for the environment. That practice was abandoned in 2018. In the 2023 Report Card values for specific indicators are reported separately. Each is an indicator of a unique aspect of watershed health.

INDICATORS USED IN THE 2023 MUSKOKA WATERSHED REPORT CARD

Decisions on indicators to use in the 2023 Report Card commenced with a review of the eight indicators used in 2018. Six of them were examined at a quaternary watershed scale. All eight are included in 2023, although the way they are treated has changed in several ways. Species at risk and invasive species are reported on, but data are now considered inadequate to use these as quantitative indicators of the state of our biodiversity. Climate change has been evaluated in three ways, two new this year. Three new indicators, chloride in lakes, frequency of algal blooms, and status of fishery species have been introduced. The final chapter asks, "What is watershed health?" and explores the concept of *ecological integrity,* the term preferred by ecologists evaluating ecosystems. This chapter is an introduction to the dynamic, living nature of watersheds. Altogether, the 2023 Report Card includes six indicators examined at a quaternary watershed scale and five others reported on for the Muskoka watersheds overall as well as the discussions of bird populations, Beech bark disease, and ecological integrity. These 14 topics provide the data that underlie this year's Report Card (Table 5).

Table 5. Topics (mostly specific indicators) used to assess the health of the Muskoka watersheds in 2023. Italics = indicator used in 2018.

Indicator	Aquatic/Terrestrial	Quaternary scale	Comments
Calcium	Aquatic	Yes	Surface water calcium
Phosphorus	Aquatic	Yes	Spring surface water phosphorus
Benthic Macroinvertebrates	Aquatic	Yes	Percentage of sensitive species
Chloride	Aquatic	Yes	Spring surface water chloride
Fish populations	Aquatic	No	Fishing regs being changed because of changing conditions
Algal Blooms	Aquatic	No	The frequency is increasing
Interior Forest	Terrestrial	Yes	Percentage of total forest
Fragmentation	Terrestrial	Yes	Loss of large forest patches
Bird Populations	Terrestrial	No	A potential indicator if data can be assembled
Invasive Species	Both	No	Known invasives in the region
Beech Bark Disease	Terrestrial	No	Case study of the complex remediation required to deal with this invasive pathogen
Species at Risk	Both	No	Are these being well managed?
Climate Change	Both	No	Trends in weather detected, also environmental changes being detected
Ecological Integrity	Both	No	Why important, how to measure

Decisions on indicators to use and how to use them required careful consideration of data availability, recommendations from scientists, and a desire to include a broad range of aspects of environmental health. This Background Report also includes suggestions for improving the data in future years. Indicators were also chosen with the intention of creating a consistent, easily understandable foundation for incorporating new evidence in future reporting.

Indicators of ecological health are most meaningful and effective if interpreted together because all aspects of the environment are linked (Briggs, 1999). In this way, they serve much like the blood work and other diagnostic tests routinely used by medical professionals when assessing health of a patient. Just as there is not a single test for overall human health, there is no test yet available that measures overall environmental health. Our discussion of ecological integrity in Chapter 14 examines this issue.

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 lakes, calcium levels are low enough to stress species like *Daphnia,* an important zooplankton species at the bottom of the food chain. Calcium is evaluated at a quaternary watershed scale.

Total Phosphorus (TP) is a measure of the amount of phosphorus present in a waterbody. Typically, it is measured in surface waters in the spring while lake water has not yet stratified. Because it is an essential nutrient, the amount of phosphorus present is one guide to how productive a lake can be. Higher amounts of TP may increase the likelihood that a waterbody will experience excessive aquatic plant growth and/or a nuisance algal bloom. Phosphorus is evaluated at a quaternary watershed scale.

Benthic Macroinvertebrates (BMIs) are the numerous larval insects and other small animals living on or in the sand or mud at the bottom of lakes or rivers. They 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 sensitive benthic species can provide an indication of water quality. They are evaluated at a quaternary watershed scale.

Chloride (Cl): Our waters are naturally low in dissolved salts (chloride), but our road-management activities introduce salt to the environment and that salt can impact nearby forests and lakes. Chloride concentrations in most lakes in this region are now much higher than in the past. This elevated chloride level may negatively affect some important aquatic species. Chloride concentration in lake waters is a new indicator in 2023 and is evaluated at the quaternary watershed scale.

Fish Populations: Fish play important ecological roles in our lakes and rivers. Sportfish sustain an important recreational fishery and the Ministry of Natural Resources and Forestry is responsible for managing this fishery sustainably so that species will remain present into the future. We do not report on the status of particular fish species for this Report Card. Instead, we report on the revision to fishery regulations that is being carried out across Ontario, and the reasons why a revision has been necessary. This is a story of a changing environment for fish in the Muskoka watersheds that is reducing the capacity of certain species to survive and reproduce, while benefiting other species. Another new indicator for 2023.

Algal Blooms: There is general concern in this region that the occurrence of algal blooms, particularly of the potentially toxic blue-green algae, is increasing in our region. The number of confirmed reports of algal blooms each year is another new indicator in 2023.

Interior Forest habitat is forest habitat at least 100 m from a forest edge. Interior forest is buffered from external disturbances by that 100 m of surrounding forest. Interior forest supports a wide variety of forest-dependent wildlife that do not live closer to forest edges; it's an important habitat for sustaining overall biodiversity. The proportion of interior forest is an indicator of the quality of our forested land and is evaluated at the quaternary watershed scale.

Fragmentation occurs when a new road, hydro corridor or similar disturbance cuts through a forest and divides a large natural area into smaller pieces. 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. Fragmentation is analyzed at the quaternary watershed scale.

Bird Populations: Available data are inadequate to use birds as indicator species this year but if more reporting of species occurs, they can become a valuable terrestrial indicator of biodiversity decline or forest fragmentation in future report cards.

Invasive Species are plants, animals, and micro-organisms that out-compete native species for habitat and resources when they arrive in habitats outside their natural range. Invasive species can significantly reduce the biodiversity of an area. Invasive species have been an indicator in past report cards, but there are problems with data reliability. Also, many invasive species have managed to move quite quickly across our region. We also identify the invasives currently known to be present and how to report invasive species when you find them.

Beech Bark Disease: The story of Beech bark disease is included as an example of the complex habitat-scale impacts, and difficult remediation required to deal with this invasive pathogen.

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. As in 2018, we do not report details of occurrence at a quaternary watershed scale 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 is more broadly discussed including the question of whether enough is being done to sustain their populations.

Climate Change is already here and is having significant impacts on the Muskoka watersheds. The 2018 Report Card presented changes in the duration of winter ice cover on lakes as an indicator of climate change. In 2023 those data are updated, and we add information on trends in air temperature, patterns of precipitation, and the link between storms and floods. All these trends are likely to continue as the planet warms. Implications for environmental health are discussed.

Ecological Integrity is a measure of the capacity of an ecosystem to be resilient when stressed by changing environmental conditions. Ecological integrity is therefore an important measure of the capacity of our environment to withstand changes being caused by increased development and use or by climate change and other factors. There is no simple measure of ecological integrity, and yet ecological integrity comes closest to what we mean when we speak about environmental health. We discuss it, because understanding ecological integrity helps one understand that the ecosystems that comprise our environment are complex, multi-dimensional ecological systems that respond to stressors of different kinds in multiple ways. We must use the precautionary principle when dealing with such complex systems.

BENCHMARKING

For some indicators, with quantitative data at the quaternary watershed scale, indices of health are calculated at that finer scale by setting benchmark values of the indicator representing *not stressed, vulnerable,* and *stressed* states. We report details of how the benchmarks are determined.

The benchmarks are based on the best available science and keyed to typical Muskoka environmental quality. In other words, the division into *not stressed, vulnerable,* and *stressed* is appropriate to the generally high-quality environment found in Muskoka. Muskoka's benchmarks are typically higher than those used in southern Ontario where, on average, environments are more degraded.

The remaining indicators either provide assessments of health at the tertiary watershed scale or provide no quantitative assessment because of data inadequacy. Whether at quaternary or tertiary watershed scale, we have looked in this Report Card for evidence of trends in health over time. Where degradation is apparent, it is important to consider management actions to restore watershed health: acting sooner can be much more effective than acting once a crisis point is reached.

CHAPTER 1 – CALCIUM CONCENTRATIONS IN MUSKOKA'S LAKES

Author: Dr. Neil Hutchison
Reviewed by: Dr. Norman Yan

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). Calcium carbonate in lakes plays an important role in buffering against acid rain. Calcium is also an essential nutrient for every living plant and animal species. Aquatic life, including freshwater mussels, crayfish, and the water flea *Daphnia,* consist of 5-30% calcium and so require a lot of calcium in their water (District Municipality of Muskoka, 2018). This is problematic when calcium levels are low to start with and then decrease.

ACID RAIN AND CALCIUM

Lakes in Muskoka are especially vulnerable to the effects of acid rain because most of them are located on the Canadian 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). Between 1960 and 1980, 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. But, 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). This is not as big of a concern in the Severn River-Lake

Simcoe Watershed as its lakes are off the shield and on limestone, which is made of calcium or magnesium carbonate.

Efforts to reduce acid deposition, such as the revision of the United States' Clean Air Act and similar regulations in Canada, reduced the acidity of precipitation by 90%. While this stopped further calcium decline, past and current land use practices also removed calcium from the environment, leaving both forests and lakes increasingly calcium deficient in Muskoka. These historical practices included; the unsustainable use of forest resources such that export of forest products (and the calcium contained in them) from the watershed, forest fire suppression, and land clearing for colonization and agriculture, all reduced the supply of available calcium. As a result, calcium continues to decline, despite the successes in abatement of acid rain, because the pool of calcium in the forest soils has not been replenished.

ECOLOGICAL IMPACTS OF LOW CALCIUM

Scientists are only just beginning to understand the impacts of low calcium on aquatic biota. Current research shows that freshwater zooplankton such as *Daphnia* are particularly sensitive to low calcium. *Daphnia* are tiny invertebrates that require calcium in the water to build their carapaces. There are billions of them in a typical Muskoka lake and they are important animals. As keystone herbivores in lake food webs, they help keep lakes clear by eating the algae that might otherwise accumulate to unpleasant levels (Yan & Jeziorski, 2011). They are very important prey, providing food to many fish, particularly the youngest and smallest life stages.

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). Declining calcium levels have also led to the increased abundance of a jelly-clad water flea called *Holopedium*, 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). *Holopedium* are now found in most lakes in Muskoka. On the other hand, the low calcium concentrations across the Muskoka watershed have limited the spread and colonization of invasive zebra mussels, as they require higher calcium levels to survive than what are found in our waters.

Research using Muskoka waters shows that *Daphnia* populations in laboratories become vulnerable and their reproductive output decreases when average calcium concentrations are below the threshold of 2.0 milligrams per litre (mg/L) (Ashforth & Yan, 2008). In waters with less than 1.5 mg/L of calcium, most native species of *Daphnia* can no longer live and reproduce.

These results were used to classify the status of Muskoka's lakes for the Report Card. The following criteria were chosen for categorizing lakes based on the average calcium concentrations measured from 2018 to 2022:

- 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.

HOW IS CALCIUM MEASURED IN MUSKOKA?

The calcium indicator is based on data collected through the District Municipality of Muskoka's (DMM) Lake System Health Water Quality Monitoring Program, with supporting research from the Dorset Environmental Science Centre (DESC). DMM has monitored over 190 lakes across the District for over 40 years, assessing many water quality parameters. Calcium was added to the parameter list in 2004. Scientists at DESC provided additional data collected through the long-term ecosystem science program, which provides detailed results for headwater lakes and streams located in southcentral Ontario that are representative of tens of thousands of lake catchments on the Canadian shield.

RESULTS

The Report Card assessed 197 lakes for the calcium indicator using DMM data. The average calcium concentration for each lake was calculated using data collected from 2018 to 2022 (2017 data were included if only 1 or 2 measurements were present for the 2018-2022 period). The number of samples analysed for each lake are provided in Table 6.

Table 6. Number of samples analysed for each lake.

Sample Size	Number of Lakes
1	81
2	71
3	40
4	4

Across the Muskoka Watershed, 55 of the 197 (28%) lakes sampled for this Report Card (Figure 3) were classified as *vulnerable*, as they have an average calcium concentration below the threshold of 2.0 mg/L calcium. 24 (12%) of these lakes are below 1.5 mg/L, the threshold at which sensitive species become stressed. The remaining 142 (72%) lakes were considered *not stressed*.

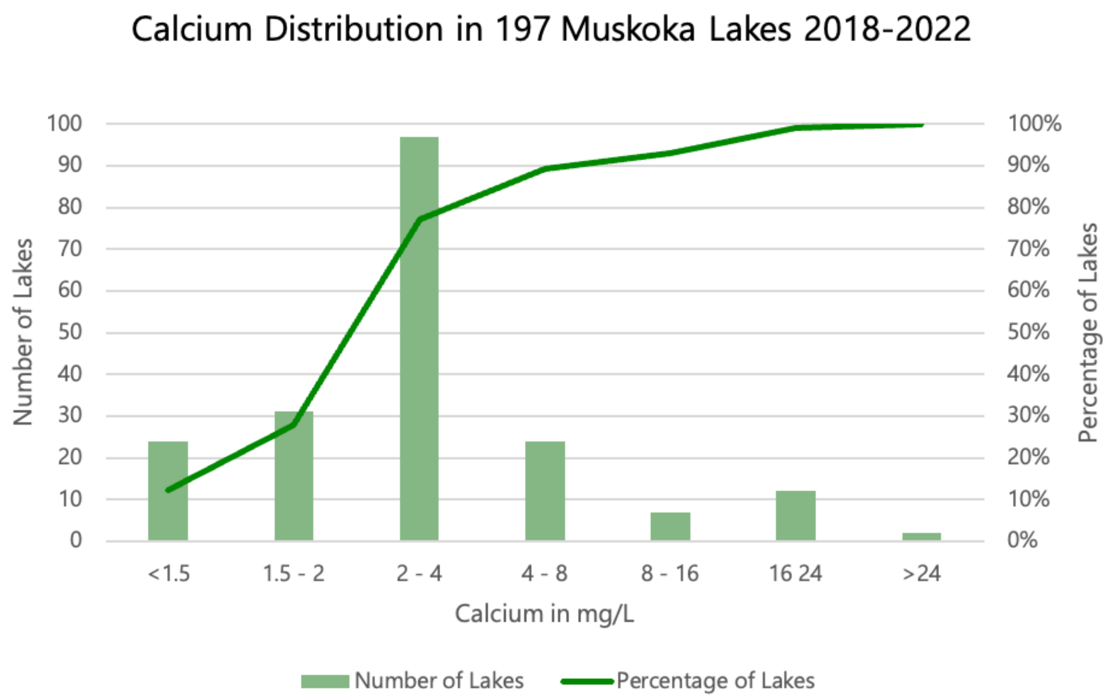

Figure 3. Mean calcium concentration in 197 Muskoka Lakes, 2018-2022.

Table 7. Number of lakes classified in each category of calcium level.

Classification	Code	Number of Lakes
Not Sensitive	NS	142
Vulnerable	V	31
Sensitive	S	24

Table 8. Average calcium concentration and category for lakes sampled from 2018 to 2022.

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Ada Lake	6.6	1	NS
Atkins Lake	4.2	2	NS
Barron's Lake	8.3	4	NS
Bass Lake (GR)	2.7	3	NS
Bass Lake (ML)	2.4	3	NS
Bastedo Lake	2.9	2	NS
Baxter Lake	23.6	2	NS
Bearpaw Lake	2.9	2	NS
Bella Lake	2.5	1	NS
Ben Lake	2.3	1	NS
Bigwind Lake	1.7	2	V
Bing Lake	1.6	2	V
Bird Lake	2.2	1	NS
Black Lake	2.6	2	NS
Bonnie Lake	2.6	2	NS
Brandy Lake	3.7	4	NS
Brooks Lake	3.1	2	NS
Bruce Lake	3.9	3	NS
Buck Lake (HT)	1.6	1	V
Buck Lake (LOB)	2.1	1	NS
Butterfly Lake	4.6	2	NS
Camel Lake	2.0	2	V
Camp Lake	1.3	2	S
Cardwell Lake	1.3	2	S
Cassidy Lake	3.7	2	NS
Chub Lake (HT)	2.3	1	NS
Chub Lake (LOB)	1.3	1	S
Clark Lake	1.4	1	S
Clear Lake (BB)	2.9	2	NS
Clear Lake (ML)	4.2	1	NS
Clearwater Lake (GR)	2.7	1	NS

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Clearwater Lake (HT)	2.9	2	NS
Cognashene Bay	17.3	2	NS
Cooper Lake	1.5	1	V
Cornall Lake	4.5	2	NS
Cox Bay	3.9	1	NS
Crosson Lake	1.1	1	S
Dark Lake	3.5	2	NS
Deer Lake	1.5	1	V
Devine Lake	1.5	2	V
Dickie Lake	2.5	2	NS
Doeskin Lake	2.9	1	NS
Dotty Lake	1.6	2	V
Echo Lake	2.5	2	NS
Fairy Lake-Main	2.5	1	NS
Fairy Lake-North Muskoka River Bay	2.6	1	NS
Fawn Lake	1.8	3	V
Fifteen Mile Lake	1.8	1	V
Flatrock Lake	3.3	3	NS
Foote Lake	1.8	1	V
Fox Lake	1.5	1	S
Galla Lake	2.2	2	NS
Gartersnake Lake	1.3	1	S
Gibson Lake-North	2.6	3	NS
Gibson Lake-South	2.3	3	NS
Gilleach Lake	1.3	2	S
Go Home Bay	13.5	2	NS
Go Home Lake	3.4	2	NS
Golden City Lake	0.8	1	S
Grandview Lake	4.5	1	NS
Grindstone Lake	2.2	3	NS
Gull Lake	5.5	3	NS
Gullwing Lake	2.5	2	NS

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Haggart Lake	3.1	1	NS
Halfway Lake	2.7	2	NS
Hamer Bay	3.9	1	NS
Hardup Lake	1.9	2	V
Healey Lake	1.8	1	V
Heney Lake	1.3	2	S
Henshaw Lake	6.7	1	NS
Hesner's Lake	3.3	1	NS
High Lake	2.6	2	NS
Jessop Lake	1.5	1	V
Jevins Lake	6.8	2	NS
Joseph River	3.7	1	NS
Kahshe Lake-Main	2.3	3	NS
Kahshe Lake-Grant's Bay	2.2	3	NS
LaFarce Lake	3.8	1	NS
Lake Huron-North Bay	12.9	1	NS
Lake Joseph-Main	3.9	1	NS
Lake Joseph-North	4.2	1	NS
Lake Joseph-South	3.9	1	NS
Lake Muskoka-Bala Bay	3.2	2	NS
Lake Muskoka-Boyd Bay	3.0	1	NS
Lake Muskoka-Dudley Bay	3.2	1	NS
Lake Muskoka-Main	3.0	1	NS
Lake Muskoka-Muskoka Bay	6.3	1	NS
Lake Muskoka-Whiteside Bay	3.3	1	NS
Lake Rosseau-Brackenrig Bay	3.7	3	NS
Lake Rosseau-East Portage Bay	3.7	3	NS
Lake Rosseau-Main	3.6	3	NS
Lake Rosseau-North	3.3	3	NS
Lake Rosseau-Skeleton Bay	3.6	3	NS
Lake Rosseau-Wallace Bay	3.7	1	NS
Lake Vernon-Hunter's Bay	2.1	1	NS

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Lake Vernon-Main	2.0	1	V
Lake Vernon-North Bay	1.9	1	V
Lake Waseosa	2.3	1	NS
Leech Lake	2.9	1	NS
Leonard Lake	2.3	4	NS
Little	19.2	2	NS
Little Go-Home Bay	24	2	NS
Little Lake Joseph	3.6	1	NS
Little Long Lake	2.0	2	V
LOB-Dwight Bay	1.8	3	V
LOB-Haystack Bay	2.3	3	NS
LOB-Rat Bay	1.9	3	V
LOB-South Muskoka River Bay	2.2	3	NS
LOB-South Portage Bay	2.0	3	NS
LOB-Ten Mile Bay	2.2	3	NS
LOB-Trading Bay	2.0	3	NS
Long Lake	5.2	1	NS
Longline Lake	3.0	2	NS
Longs Lake	3.3	1	NS
Loon Lake	7.3	3	NS
Mainhood Lake	1.9	2	V
Margaret Lake	1.4	2	S
Mary Jane Lake	1.0	1	S
Mary Lake	2.6	3	NS
McCrae Lake	18.8	2	NS
McDonald Lake	20.3	2	NS
McKay Lake	2.2	1	NS
McRey Lake	1.9	1	V
Medora Lake	1.4	2	S
Menominee Lake	2.2	3	NS
Mirror Lake	3.9	2	NS
Moot Lake	1.0	1	S

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Morrison Lake	3.6	2	NS
Myers Lake	2.6	2	NS
Neilson Lake	0.8	1	S
Nine Mile Lake	1.7	2	V
North Muldrew Lake	3.6	2	NS
Nutt Lake	13.7	2	NS
Otter Lake	2.6	1	NS
Oudaze Lake	2.4	3	NS
Oxbow Lake	1.7	2	V
Paint Lake	2.9	3	NS
Palette Lake	4.1	1	NS
Pell Lake	1.7	2	V
Penfold Lake	5.1	1	NS
Peninsula Lake-East	4.1	2	NS
Peninsula Lake-West	4.1	2	NS
Perch Lake	3.8	2	NS
Pine Lake (BB)	2.6	3	NS
Pine Lake (GR)	2.0	1	V
Porcupine Lake	1.8	1	V
Prospect Lake	2.1	2	NS
Rebecca Lake	2.3	1	NS
Ricketts Lake	7.1	1	NS
Ril Lake	2.3	2	NS
Riley Lake	2.3	2	NS
Rose Lake	1.0	2	S
Ryde Lake	2.8	1	NS
Shoe Lake	2.1	2	NS
Siding Lake	1.9	2	V
Silver Lake (GR)	2.9	3	NS
Silver Lake (ML)	6.2	3	NS
Silver Sand Lake	2.3	2	NS
Six Mile Lake-Cedar Nook Bay	14.2	3	NS

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Six Mile Lake-Main	24.4	3	NS
Six Mile Lake-Provincial Park Bay	21.1	3	NS
Sixteen Mile Lake	1.9	2	V
Skeleton Lake	3.8	2	NS
Solitaire Lake	2.1	3	NS
South Bay	16.2	1	NS
South Muldrew Lake	3.8	2	NS
South Nelson Lake	1.2	1	S
Sparrow Lake	34.5	1	NS
Spence Lake-North	1.3	1	S
Spence Lake-South	2.2	1	NS
Spring Lake	2.6	1	NS
Stewart Lake	9.6	4	NS
Stoneleigh Lake	1.3	1	S
Sunny Lake	2.5	2	NS
Tackaberry Lake	1.0	1	S
Tadenac Bay	14.2	1	NS
Tadenac Lake	1.8	1	V
Tasso Lake	1.5	3	S
Thinn Lake	3.6	2	NS
Three Mile Lake (GR)	1.8	2	V
Three Mile Lake-Hammel's Bay	5.2	3	NS
Three Mile Lake-Main	4.3	3	NS
Tooke Lake	4.4	1	NS
Toronto Lake	1.4	1	S
Tucker Lake	1.2	1	S
Turtle Lake	6.4	3	NS
Twelve Mile Bay-East	17.6	2	NS
Twelve Mile Bay-West	21.1	2	NS
Wah Wah Taysee	20.7	2	NS
Walker Lake	3.0	1	NS
Webster Lake	5.6	2	NS

Lake Name	Average Calcium (mg/L)	No of Samples	Sensitivity Classification
Weismuller Lake	3.8	1	NS
Wildcat Lake	1.3	1	S
Wolfkin Lake	3.5	1	NS
Wood Lake	2.5	3	NS
Young Lake	1.9	1	V

BB (Bracebridge) *HT (Huntsville)* *ML (Muskoka Lakes)*

GR (Gravenhurst) *LOB (Lake of Bays)*

TRENDS IN CALCIUM

Previous watershed report cards documented changes in calcium levels on the basis of research conducted in Muskoka-area lakes. Yao et al. (2011) examined 29 years of calcium data from three lakes in Muskoka and found that calcium decline had worsened as recent climate warming has led to decreased water flow, resulting in less calcium being exported from the land to lakes (Yao et al., 2011). Reid (2015) reported that mean calcium concentrations in 104 lakes across the watershed had decreased by 30% since the 1980's. Climate change is likely to further contribute to calcium decline (Yao et al., 2011). DMM lake sampling program has been collecting data on calcium since 2004 and more than 5 samples have been taken in that period for 80% of the lakes. As sampling continues, future report cards may be able to report on any changes in calcium over time in Muskoka's lakes as lakes recover from acid rain or calcium continues to decline.

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 by encouraging Muskokans to use wood ash to return calcium to forest soils where it originated. Applying wood ash to forests or soil is being used in areas around the world, however, wood ash in Ontario is not regularly used as a soil amendment 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 fotmw.org.

CHAPTER 2 – PHOSPHORUS CONCENTRATIONS IN LAKES

Author: Rebecca Willison

Water quality is one of the fundamental components of a healthy watershed. As people live, work, and play around lakes, they may impact and change lake ecosystems. One change that may be 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 Environmental Sciences Ltd., 2016). Algal blooms can detract from the recreational use of water and, in some cases, can result in deoxygenation of deep waters leading to mortality of species such as lake trout.

Phosphorus has many pathways of entry to a waterbody, both from natural processes and human activities. Natural processes include the weathering of rocks, erosion of soil, decay of organic material, and deposition from the atmosphere through pollen and dust (Ontario Ministry of 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 (Ontario Ministry of Environment, Conservation and Parks, 2010).

Excessive phosphorus loading can degrade water quality and disrupt the balance in aquatic ecosystems (Ontario Ministry of Environment, Conservation and Parks, 2010). 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 Environmental Sciences Ltd., 2016). Climate change may also affect phosphorus levels. 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 Environmental Sciences Ltd., 2016).

TROPHIC STATUS IN AREA LAKES

In any watershed, there is natural variation in phosphorus concentrations among lakes because of differences in lake size, the amount of wetland in the lake catchment area, and characteristics of water flow through the lake. Lakes are generally classified into one of three categories based on their nutrient status. Lakes with less than 10 micrograms per litre (µg/L) or parts per billion 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 recreational activities and cottage development. 73% of lakes included in the Report Card sampled between 2001-2022 are oligotrophic.

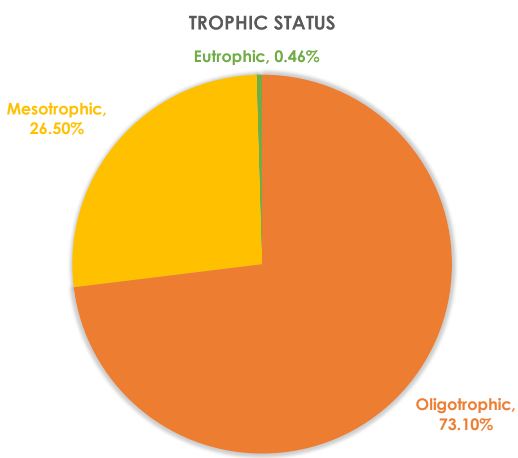

Figure 4. Distribution of sampled lakes by trophic status (2001-2022).

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. Almost 27% of lakes included in the Report Card sampled between 2001-2022 are mesotrophic. Lakes with greater than 20 µg/L of total phosphorus are called *eutrophic* lakes. These lakes are enriched with phosphorus and are highly productive. They may also show signs of persistent and nuisance algal blooms. Less than 1% of lakes included in the Report Card sampled between 2001-2022 are eutrophic. Figure 4 shows the classifications of trophic status or productivity of lakes in the Muskoka area. Lakes in the Muskoka area, like others on the Canadian shield, are naturally low in 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 (DESC) over a 40-year period has shown an overall decline in total phosphorus concentrations in both developed and undeveloped lakes in Muskoka. 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, agriculture, and logging.

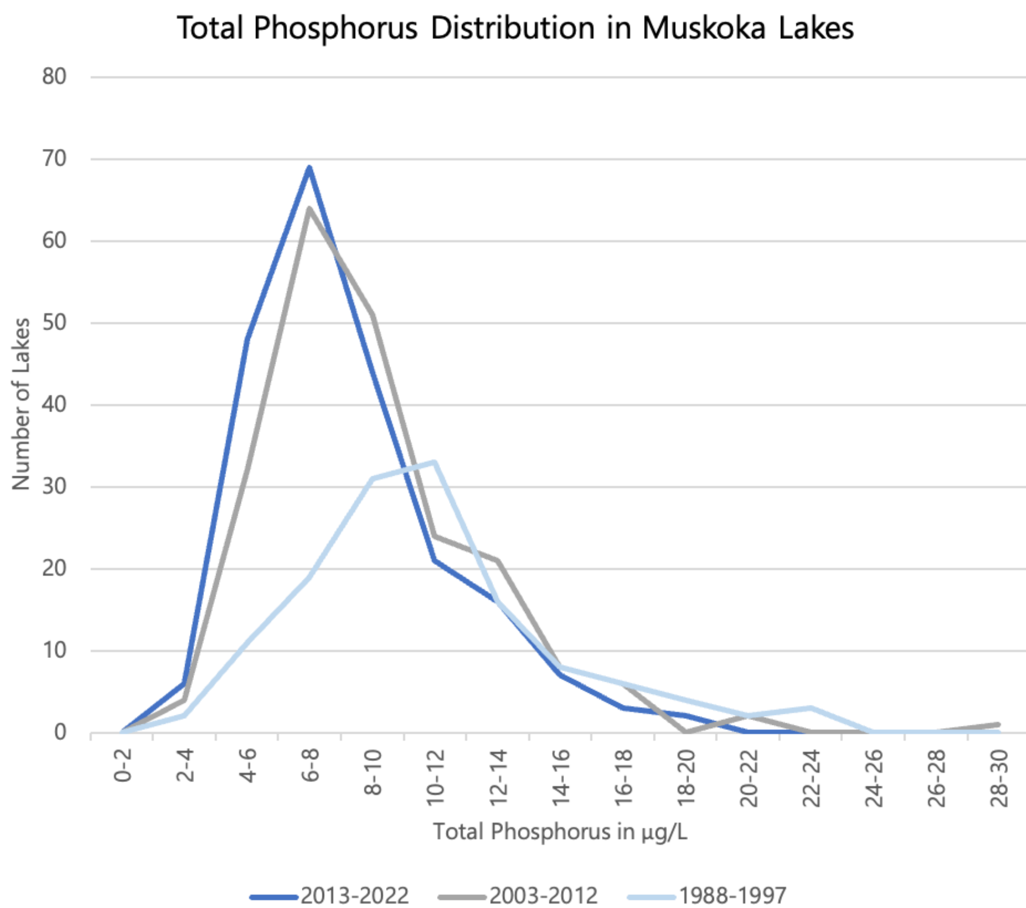

Figure 5. Distribution of sampled lakes in Muskoka's watersheds based on 10-year average phosphorus concentrations for three time periods: 2013 to 2022 (n= 216), 2003 to 2012 (n= 213) and 1988 to 1997 (n= 135).

This trend of decreasing phosphorus concentrations is also seen in the District Municipality of Muskoka's (DMM) and the Lake Partner Program's (LPP) datasets. Figure 5 shows the average spring turnover phosphorus concentrations for a range of lakes in Muskoka's watersheds for three time periods (1988-1997, 2003-2012, and 2013-2022). Lower phosphorus concentrations are seen in the more recent time periods.

HOW IS PHOSPHORUS MEASURED IN MUSKOKA?

Datasets were obtained from DMM Lake System Health Water Quality Monitoring Program and the Ontario Ministry of the Environment, Conservation and Parks (MECP) LPP and analyzed for the phosphorus indicator in the Report Card.

DMM has monitored over 160 lakes across the District for almost 40 years, assessing many water quality parameters including phosphorus. LPP 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 DMM dataset was used for lakes within the District and the LPP dataset was used for lakes within the watershed but outside of the District. In total, 218 lakes were assessed for the phosphorus indicator.

The 2023 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 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 2022 was plotted on a line graph.
2. A trend line was added to the graph, and
    a. If the trend line was decreasing (i.e., negative slope of the regression), the lake is deemed *not stressed* as total phosphorus concentrations are not increasing
    b. If the trend line was horizontal (i.e., no slope), the lake is deemed *not stressed* as total phosphorus concentrations are not increasing
    c. If the trend line was increasing (i.e., positive slope of the regression), 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 trend line of the regression does not describe the data well. If the r^2 value was greater than 0.1, the p-value (probability) of the trend line was calculated to determine if the slope was significantly different than zero, and subsequently categorized 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 and the slope of the regression was positive and > 0.1.
- Stressed: The p-value of the regression is equal to or less than 0.05 and the slope of the regression was positive and > 0.1.

Quaternary watershed 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 for the quaternary watersheds can be seen in Table 10.

ABOUT R^2 VALUES, TREND LINES (LINEAR REGRESSION), AND P-VALUES

A trend line (regression line) is a line in a graph that is fitted through data points that best 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 Dotty Lake in the Oxtongue River Outlet Watershed are increasing at an r^2 value of 0.54 (Figure 6). The trend line is going through or close to most of the data points. However, for Mainhood Lake in the Lake Rosseau 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 represents the probability that the trend line is significantly different from zero.

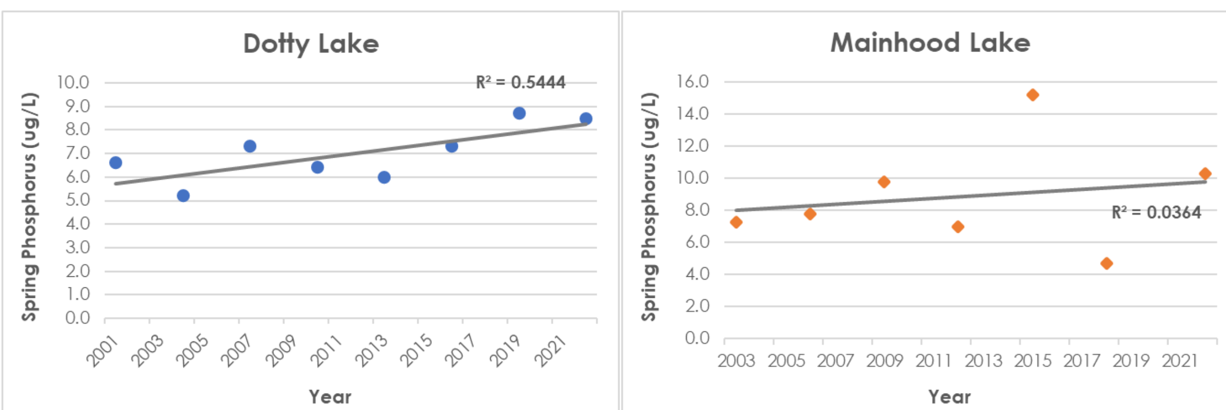

Figure 6. Examples of r^2 values and trend lines.

Table 9. Trends in phosphorus concentrations in lakes sampled between 2001 and 2022 and the category assessed for the Report Card.

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Ada Lake	16.3			Not Stressed
Armishaw Lake	7.2	0.84	0.08	Vulnerable
Atkins Lake	7.6			Not Stressed
Axle Lake	6.2			Not Stressed
Barron's Lake	20			Not Stressed
Bass Lake (GR)	18.6	0.17	0.24	Not Stressed
Bass Lake (ML)	8.4			Not Stressed
Bastedo Lake	7.4			Not Stressed
Baxter Lake	10.3			Not Stressed
Bay Lake	6			Not Stressed
Bear Lake	7.4			Not Stressed
Bearpaw Lake	13.8			Not Stressed
Bella Lake	7.2			Not Stressed
Ben Lake	8.7			Not Stressed
Bigwind Lake	6	0.04		Not Stressed
Bing Lake	5.5	0.12	0.44	Not Stressed
Bird Lake	10.6			Not Stressed
Bittern Lake	7.2			Not Stressed
Black Lake (ML)	15			Not Stressed
Blackstone Lake	7.5			Not Stressed
Bonnie Lake	5.6			Not Stressed
Brandy Lake	18			Not Stressed
Brennan Lake	10.3			Not Stressed
Brooks Lake	8.2			Not Stressed
Bruce Lake	11.5			Not Stressed
Brush Lake	5.2	0.01		Not Stressed
Buck Lake (HT)	11.8			Not Stressed
Buck Lake (LOB)	6.7			Not Stressed
Burnt Lake	6	0.01		Not Stressed
Burr Lake	7.2	0.04		Not Stressed
Butterfly Lake	11.8			Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Camel Lake	8.6	0.01		Not Stressed
Camp Lake	4	0.04		Not Stressed
Cardwell Lake	8.7	0.03		Not Stressed
Cassidy Lake	9.3			Not Stressed
Chub Lake (HT)	8.9			Not Stressed
Chub Lake (LOB)	9.4			Not Stressed
Clark Lake	12.2			Not Stressed
Clear Lake (BB)	5.5			Not Stressed
Clear Lake (ML)	6.1			Not Stressed
Clearwater Lake (GR)	4.8			Not Stressed
Clearwater Lake (HT)	6.6			Not Stressed
Clinto Lake	5.2	0.27	0.37	Not Stressed
Cognashene Bay	5.7			Not Stressed
Cooper Lake	9.2	0.01		Not Stressed
Cornall Lake	9.5			Not Stressed
Crane Lake	4.8	0.05		Not Stressed
Crosson Lake	9			Not Stressed
Dark Lake	8.2			Not Stressed
Deer Lake	5.9	0.13	0.42	Not Stressed
Devine Lake	12			Not Stressed
Dickie Lake	7.9			Not Stressed
Doeskin Lake	15			Not Stressed
Dotty Lake	7	0.55	0.04	Stressed
Draper Lake	7.6	0.01		Not Stressed
Dyson Lake	5			Not Stressed
Echo Lake (LOB)	7.5			Not Stressed
Emsdale Lake	5.9	0.34	0.02	Stressed
Fair Lake	7.4	0.42	0.23	Not Stressed
Fairy Lake	8.8			Not Stressed
Fawn Lake	15.2			Not Stressed
Fifteen Mile Lake	5.4			Not Stressed
First Lake	8.1	0.43	0.11	Not Stressed
Flatrock Lake	7.7			Not Stressed
Flaxman Lake	4.5	0.11	0.67	Not Stressed
Fletcher Lake	6.3	0.05		Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Foote Lake	9.5	0.09		Not Stressed
Forget Lake	5.9	0.21	0.3	Not Stressed
Fox Lake	12.1			Not Stressed
Galla Lake	7.2			Not Stressed
Gartersnake Lake	13.3			Not Stressed
Gerow Lake	9.5			Not Stressed
Gibson Lake	10.7			Not Stressed
Gilleach Lake	9.6			Not Stressed
Gloucester Pool	9.8			Not Stressed
Go Home Bay	6.5			Not Stressed
Go Home Lake	6.7			Not Stressed
Golden City Lake	13.7			Not Stressed
Grandview Lake	5.5			Not Stressed
Grindstone Lake	10.3			Not Stressed
Gull Lake	6.4			Not Stressed
Gullfeather Lake	11.2	0.01		Not Stressed
Gullwing Lake	11.5			Not Stressed
Haggart Lake	10.2			Not Stressed
Halfway Lake	12.7			Not Stressed
Hardup Lake	7.4			Not Stressed
Harp Lake	7.5	0.1		Not Stressed
Healey Lake	7.7	0.12	0.44	Not Stressed
Healey Lake	8.4			Not Stressed
Heney Lake	6.6			Not Stressed
Henshaw Lake	5.2			Not Stressed
Hesner's Lake	7.3			Not Stressed
High Lake	4.6			Not Stressed
Horseshoe Lake	7.2			Not Stressed
Jessop Lake	12.2			Not Stressed
Jevins Lake	13.7			Not Stressed
Kahshe Lake	11.8			Not Stressed
Kapikog Lake	6.1			Not Stressed
Kawagama Lake	4	0.23	0.03	Stressed
Lake Joseph	4.3			Not Stressed
Lake Muskoka	6.1			Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Lake of Bays	5.3			Not Stressed
Lake Rosseau	6.7			Not Stressed
Lake Vernon	9.4			Not Stressed
Lake Waseosa	9.1			Not Stressed
Leech Lake (BB)	7.9			Not Stressed
Leonard Lake	5.9	0		Not Stressed
Little Go-Home Bay	10.3			Not Stressed
Little Lake	10.4	0.01		Not Stressed
Little Lake Joseph	5.6			Not Stressed
Little Long Lake	6.2			Not Stressed
Livingstone Lake	5.1			Not Stressed
Long Lake	6.1			Not Stressed
Long's Lake	9.1			Not Stressed
Longline Lake	6.9			Not Stressed
Loon Lake	7.6			Not Stressed
Lower Fletcher Lake	6.3			Not Stressed
Mainhood Lake	8.9	0.03		Not Stressed
Mansell Lake	10.1	0.42	0.04	Stressed
Mary Lake	9			Not Stressed
McCrae Lake	9.6	0		Not Stressed
McDonald Lake	9.8			Not Stressed
McFadden Lake	8	0.81	0.29	Not Stressed
McKay Lake	10.4	0.01		Not Stressed
McKechnie Lake	5.4	0.06		Not Stressed
McRey Lake	12.4			Not Stressed
McTaggart Lake	10.5			Not Stressed
Medora Lake	7.5			Not Stressed
Menominee Lake	8.8			Not Stressed
Mirage Lake	14.8			Not Stressed
Mirror Lake	6.3			Not Stressed
Mirror Lake	7.6	0.04		Not Stressed
Moon River	6.8			Not Stressed
Moot Lake	13.1			Not Stressed
Morrison Lake	8.7	0.04		Not Stressed
Myers Lake	9.3			Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Neilson Lake	14.3			Not Stressed
Nine Mile Lake	9.7	0		Not Stressed
North Bay	12.3			Not Stressed
North Muldrew Lake	9.3			Not Stressed
Nutt Lake	7.2			Not Stressed
Otter Lake	5	0		Not Stressed
Otter Lake (HT)	8.8	0		Not Stressed
Oudaze Lake	10.4			Not Stressed
Oxbow Lake	6.3			Not Stressed
Oxtongue Lake	7.2	0.01		Not Stressed
Paint Lake	8			Not Stressed
Palette Lake	12.2	0.09		Not Stressed
Pell Lake	11.6			Not Stressed
Pender Lake	5.6	0.88	0.02	Stressed
Penfold Lake	14.9			Not Stressed
Peninsula Lake	9.5			Not Stressed
Perch Lake	11.2			Not Stressed
Pickering Lake	13.4	0.04		Not Stressed
Pigeon Lake	7.5			Not Stressed
Pine Lake (BB)	7.7	0.23	0.19	Not Stressed
Pine Lake (GR)	8.2			Not Stressed
Porcupine Lake	6.6			Not Stressed
Portage Lake	6.2	0.38	0.1	Not Stressed
Prospect Lake	8.2			Not Stressed
Raven Lake	6.1			Not Stressed
Rebecca Lake	5.4			Not Stressed
Ricketts Lake	9.6			Not Stressed
Ril Lake	8.2			Not Stressed
Riley Lake	14.8			Not Stressed
Ripple Lake	10.3	0.85	0	Stressed
Roberts Lake	8.1			Not Stressed
Rose Lake	13.3			Not Stressed
Ryde Lake	17.2			Not Stressed
Second Lake	10.8	0.45	0.15	Not Stressed
Shoe Lake	5.8	0.1		Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Siding Lake	13.2			Not Stressed
Silver Lake (GR)	10.6			Not Stressed
Silver Lake (ML)	8.3			Not Stressed
Silver Sand Lake	8.3			Not Stressed
Six Mile Lake	8.4			Not Stressed
Sixteen Mile Lake	7			Not Stressed
Skeleton Lake	3.7	0		Not Stressed
Solitaire Lake	5.2			Not Stressed
South Bay	14.1	0.33	0.08	Vulnerable
South Muldrew Lake	7.8			Not Stressed
South Nelson Lake	8.2			Not Stressed
Sparrow Lake	11.5			Not Stressed
Spence Lake	8.6			Not Stressed
Spring Lake	6.3			Not Stressed
Stewart Lake	6.5			Not Stressed
Stoneleigh Lake	12.1			Not Stressed
Sucker Lake	5.4	0.1		Not Stressed
Sunny Lake	6.2			Not Stressed
Tackaberry Lake	5.5			Not Stressed
Tadenac Bay	6.2			Not Stressed
Tadenac Lake	7.2	0.06		Not Stressed
Tasso Lake	5			Not Stressed
Thinn Lake	10			Not Stressed
Third Lake	9.9			Not Stressed
Three Mile Lake (GR)	10.5			Not Stressed
Three Mile Lake (ML)	15.6			Not Stressed
Tiffin Lake	6.9	0.09		Not Stressed
Toad Lake	7.4	0.1		Not Stressed
Tooke Lake	4.9			Not Stressed
Toronto Lake	8.3			Not Stressed
Troutspawn Lake	7.5			Not Stressed
Tucker Lake	5.2			Not Stressed
Tucker Lake	8.9	0.29	0.07	Vulnerable
Turtle Lake	7.7			Not Stressed
Twelve Mile Bay	7.4			Not Stressed

Lake Name	Avg TP 2001-2022 (µg/L)	r^2 value*	p-value**	Category
Virtue Lake	9.7	0.35	0.09	Vulnerable
Wah Wah Taysee	3.4			Not Stressed
Walker Lake	5.3			Not Stressed
Webster Lake	16.7	0.81	0.01	Stressed
Weismuller Lake	14.2			Not Stressed
Wildcat Lake	7.2	0.02		Not Stressed
Windfall Lake	7.9	0.81	0.1	Not Stressed
Wolf Lake	5.9	0		Not Stressed
Wolfkin Lake	7.1	0		Not Stressed
Wood Lake	7.1			Not Stressed
Yarrow Lake	9.2	0.14	0.54	Not Stressed
Young Lake	7.3			Not Stressed

** r^2 value only calculated if trendline is increasing.*

*** p-value only calculated if r^2 value is high.*

BB (Bracebridge) GR (Gravenhurst) LOB (Lake of Bays)

GB (Georgian Bay) HT (Huntsville) ML (Muskoka Lakes)

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 https://www.ontario.ca/page/water-sampling-and-testing-inland-lakes.

Table 10. Quaternary watershed grades for the phosphorus indicator showing the number of lakes by quaternary watershed that fall into the not stressed, vulnerable, and stressed categories.

Quaternary Watershed	Number of Lakes			Grade
	Not Stressed	Vulnerable	Stressed	
Georgian Bay Shoreline	12	1	0	Not Stressed
Moon River Bay	8	0	0	Not Stressed
Blackstone Harbour	13	1	1	Not Stressed
Musquash River	7	0	1	Not Stressed
Lake Muskoka-Muskoka River	17	0	0	Not Stressed
South Branch Muskoka River Outlet	19	0	0	Not Stressed
North Branch Muskoka River	19	0	0	Not Stressed
Baysville Narrows-South Branch Muskoka River	17	0	0	Not Stressed
Lake Vernon	5	0	0	Not Stressed
Lake Rosseau	33	2	0	Not Stressed
Little East River-Big East River	12	0	3	Not Stressed
Oxtongue River Outlet	4	0	1	Not Stressed
Distress Pond-Big East River	3	0	0	Not Stressed
Hollow River	7	0	1	Not Stressed
Little Lake-Severn River	10	0	0	Not Stressed
Sparrow Lake-Severn River	4	0	0	Not Stressed
Lake St. John-Black River	1	0	0	Insufficient Data
Cache Creek-Black River	6	0	0	Not Stressed
Kahshe River	10	0	0	Not Stressed

WHAT DOES IT ALL MEAN?

Approximately 71% of the lakes sampled have stable or decreasing phosphorus concentrations (compared to over 98% in the 2018 Report Card). Of the remaining lakes, 23% have a slight increase in phosphorus concentrations and 5% have a statistically significant increase.

While overall Muskoka-area lakes continue to have excellent water quality, more recent data indicate that phosphorus concentrations are becoming less stable as we experience greater variation in weather from year to year, a trend that is likely to continue as our lakes respond to warmer temperatures and changes in precipitation patterns.

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 2023 Muskoka Watershed Report Card reports on a number of these stressors, including calcium, chloride, invasive species, and climate change.

There is also a growing recognition that blooms of cyanobacteria can, and do, occur in oligotrophic lakes (Reinl, 2021) due to their unique physiological adaptations that allow them to thrive under a wide range of environmental conditions, including low-nutrient waterbodies. Of the 21 lakes and bays that are listed in Schedule E2 of the Muskoka Official Plan as a result of having a confirmed cyanobacterial bloom (The District Municipality of Muskoka, 2018), at least 14 of them are classified as oligotrophic. Reinl (2021) suggests that while nutrients contribute to bloom formation and maintenance, there are several mechanisms that allow cyanobacteria to dominate across trophic states, including oligotrophic systems, and that that climate change processes, including lake warming, increased water column stability, and increased frequency and intensity of storm events, will probably favour cyanobacterial blooms in both oligotrophic and eutrophic lakes.

WHAT CAN YOU DO?

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 native vegetation along your shoreline will absorb nutrients from your property before they enter the water!

Check out the Federation of Ontario Cottagers' Associations' (FOCA) *A 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.

CHAPTER 3 – BENTHIC MACROINVERTEBRATES IN MUSKOKA

Author: Rachel Plewes

BENTHIC MACROINVERTEBRATES – WHAT ARE THEY?

Benthic macroinvertebrates, or benthos, is a grouping of small animals living in aquatic habitats. These creatures are small but 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 between 1 and 3 years and are in constant contact with lake sediments. They live in lakes and rivers crawling over rocks, logs, sticks and vegetation, or burrowed into the substrate.

WHY DO WE SAMPLE FOR BENTHIC MACROINVERTEBRATES?

Benthos is 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 area of water, they are easy to sample, and different species have different tolerances to disturbances and pollution. For these reasons, the benthic data collected is a result of local water conditions. A great example of this is spilling gas into a lake: 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 the spillage. So, when we collect samples, we can tell what the biological water quality is like by the presence or absence of various benthic species.

WHY ARE THEY IMPORTANT IN MUSKOKA?

Sampling for benthos is important in Muskoka because of the vast waterbodies present in this region. Benthic invertebrate communities vary due to distinct natural and anthropogenic habitat conditions of each lake. It's important to monitor the biological communities in these lakes to ensure the natural integrity and state of the lake is maintained, especially if the shorelines are developed. Healthy conditions of a lake support high species richness and abundance. If the 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.

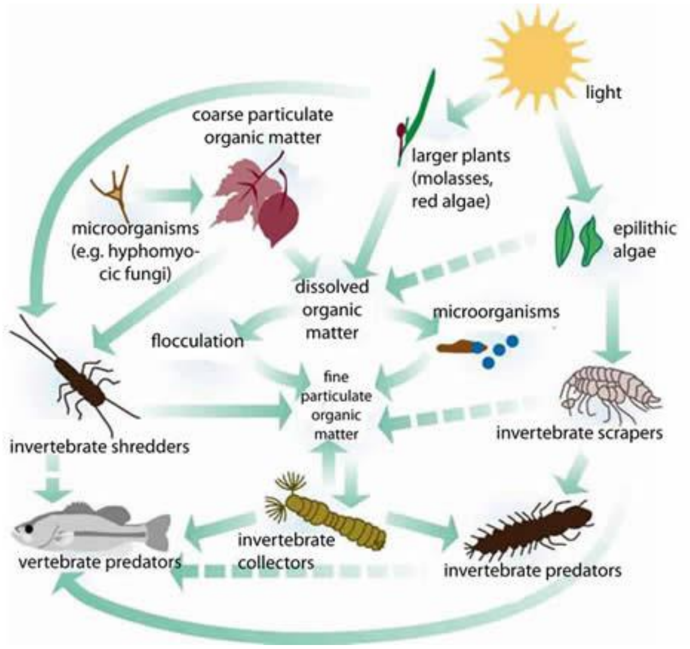

Figure 7. The role of benthic macroinvertebrates in aquatic food web (Source: USDA).

Benthos is important because they play a key role in the food web. Many fish rely on them as a food source, while some benthos help decompose organic matter that falls into the lake. Some make a meal out of other benthos, like dragonflies and fishflies.

HOW ARE BENTHOS BEING MEASURED AND REPORTED IN MUSKOKA?

Benthic macroinvertebrates in Muskoka are reported as the percentage of pollution sensitive species found in each sample per lake in the last ten years. These species include larval mayflies *(Ephemeroptera)*, dragonflies and damselflies *(Odonata)*, and caddisflies *(Trichoptera)*. Most species within these taxonomic groups, referred to as EOT, are very sensitive to pollution and habitat alterations. Their abundances should be prominent in healthy ecosystems, but their numbers will typically decline in response to stress imposed by human activities. Consequently, the relative abundance of these taxonomic groups, %EOT, is used as an indicator of pollution level. %EOT is one of the metrics used to evaluate ecological status (e.g., Bohmer et al., 2014). It is the sum of the number of organisms belonging to EOT groups divided by the total number of benthic organisms in the sample, multiplied by 100:

%EOT = (#mayflies + #dragonflies + #damselflies + #caddisflies)/total #benthics x 100

For instance, in a large-scale study, Bohmer et al. (2014) quantified the %EOT in central Baltic lakes, including lakes from Belgium-Flanders, Estonia, Germany, Lithuania, the Netherlands, and UK. They found that the lakes with *reference* and *good* ecological status had an %EOT typically greater than 50%. The lakes with *bad* status had a %EOT around 9.8% (median value).

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 on the upper surface of the abdomen. Once mature, mayflies will extend their wings and become terrestrial.

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.

Caddisfly larvae are also indicators of excellent water quality because they 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, in which they make cases of small stones or pieces of wood to wear, held together by silk they secrete.

DATA ANALYSIS

The District Municipality of Muskoka (DMM) works with local lake associations to monitor benthos through the DMM Biological Monitoring Program using the protocol developed by the Ontario Benthos Biomonitoring Network (OBBN) (Jones et al., 2005). The OBBN protocol recommends the collection of three 100-count sub-samples for each site using a traveling kick method. From 2012 to 2020, benthos samples comprised three 100-count sub-samples. To determine the %EOT, these three sub-samples were pooled into a single sample. However, starting in 2021, benthos samples collected at each site consisted of only one 100-count sample.

To date, DMM has continuously sampled 43 lakes across the watershed. Scientists at the Dorset Environmental Science Center (DESC) provided additional benthic data from sampling efforts undertaken since the mid 1970's through the Long-term Ecosystem Science Program. This program focuses on headwater lakes and streams located in south-central Ontario and 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 once per year.

%EOT metric was used to classify each lake sampled into three categories; Potential Concern (PC), Typical (T), and Insufficient Data (ID). The mean of %EOT from 2012-2022 was calculated for each lake. Some lakes have only one sample site whereas larger lakes usually have more than one sample site. The value 9.8% from the central Baltic lakes study (Bohmer et al., 2014) was used as a threshold to differentiate T lakes (%EOT ≥ 9.8%) from PC lakes (%EOT < 9.8%). Due to the high inter-annual variability in benthic invertebrate sampling (Jones 2018), lakes with less than 3 samples were classified as ID lakes.

PC indicates that the ecosystem of the lake is probably stressed at least in some parts. The cause of stress may result from point and/or non-point pollution. For example, shoreline development and associated activities can alter substrates and remove riparian vegetation that causes the degradation of benthic invertebrate habitat for EOT species. Acidic lakes (pH <6) that have minimally developed watersheds will also be classified as PC lakes. The acidity of these lakes, caused by historical acid deposition, prevents the establishment of sensitive EOT taxa.

RESULTS

Little Lake-Severn River Watershed (6 lakes sampled, 4 with sufficient data): Three of four lakes sampled with sufficient data are classified as PC lakes. These lakes are; South Muldrew Lake, Loon Lake, and Little Lake (Figure 8). Their %EOT range from 6.1-7.89% (Table 11). South Muldrew Lake-Paterson's Bay was classified as T (%EOT=19.5%). Turtle Lake had insufficient data (n=2) because it was added to the DMM monitoring program in 2018. North Muldrew Lake also has insufficient data (n=1) because it was only sampled in 2022.

Lake Rosseau Watershed (7 lakes sampled, 6 with sufficient data): Three of the lakes sampled with sufficient data are classified as PC lakes; Stewart Lake, Bruce Lake, and Bass Lake (Figure 8) Bruce Lake had the lowest mean %EOT (5.44%) (Table 11). Three Mile Lake, Lake Joseph, and Ada Lake (Figure 8) are classified as T lakes. Clark Pond was added to the DMM monitoring program in 2022 and has insufficient data (n=2).

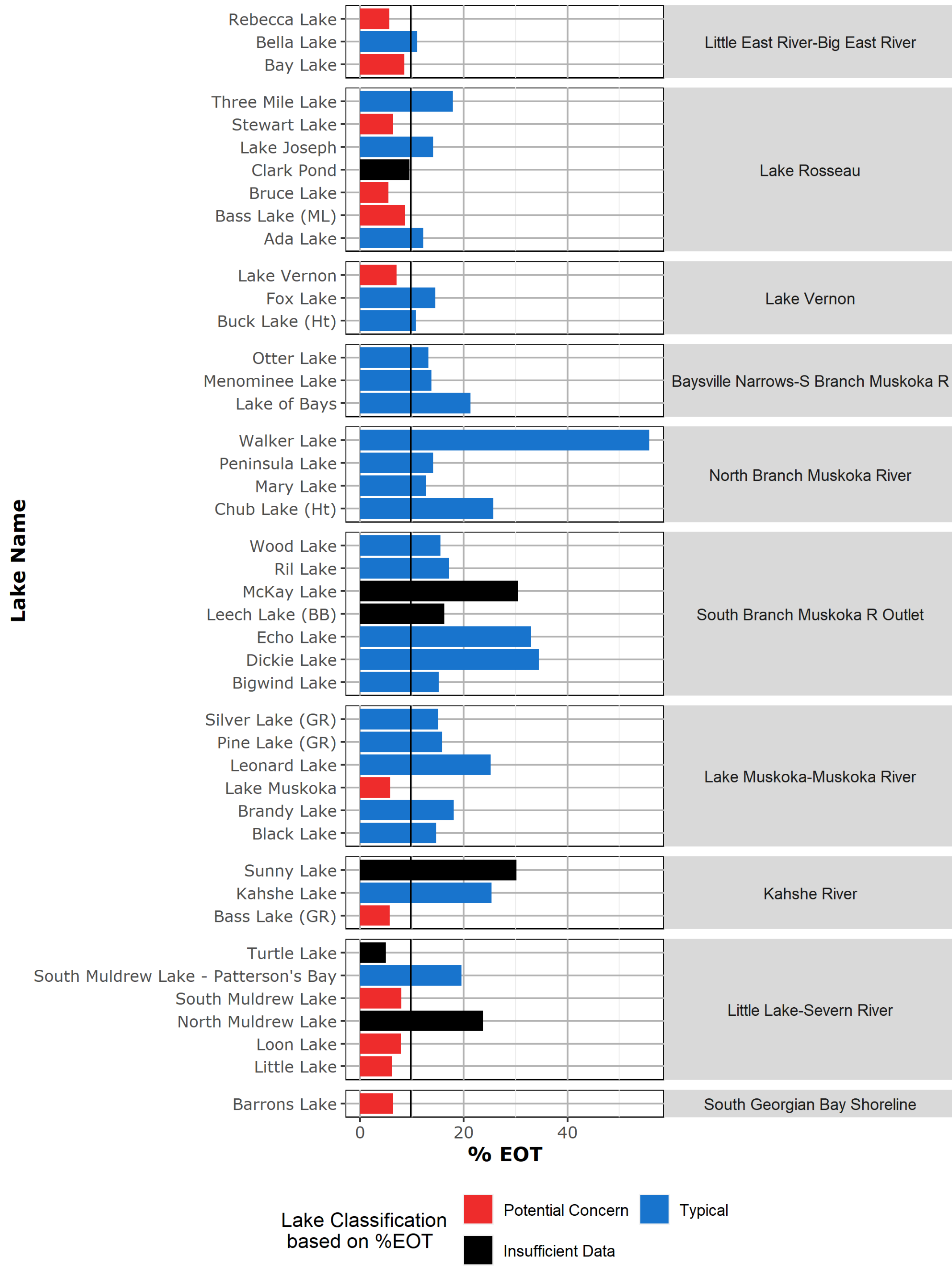

Figure 8. Mean %EOT for benthic invertebrate samples from 2012-2022. Black line corresponds to the 9.8% threshold for potential concern. Lakes with less than 3 samples were classified as insufficient data.

Only six of the 27 lakes sampled in other watersheds gave results indicating potential concern (Figure 8) %EOT was of potential concern for Lake Vernon, Lake Muskoka, Bay Lake, Rebecca Lake, Bass Lake (GR), and Barron's Lake (Figure 8). Overall, sampling has been conducted at relatively few sites within certain lakes. The number of lakes sampled in some watersheds was limited, including the South Georgian Bay Shoreline and the Little East River-Big East River Watershed.

While the data suggest most sites had typical composition of benthic macroinvertebrates, those sites that appear atypical suggests further attention to those sites, and additional sites within PC lakes will be needed to decide the true status of each lake. Our analyses have shown that the collection of benthic macroinvertebrates can be a useful way of characterizing sites, but the intensity of sampling, both number of samples per site and number of sites per lake has not been sufficient to draw firm conclusions.

Table 11. Summary of lakes sampled for benthic invertebrates from 2012-2022 with mean and standard deviation (SD) of %EOT and number of samples (n).

Lake	Mean % EOT	SD %EOT	n	# of Sites	Classification
Ada Lake	12.1	8.99	9	5	T
Barron's Lake	6.4	2.04	6	1	PC
Bass Lake (GR)	5.7	2.81	3	1	PC
Bass Lake (ML)	8.72	7.53	5	2	PC
Bay Lake	8.57	4.83	5	3	PC
Bella Lake	11	2.05	3	2	T
Bigwind Lake	15.2	12.4	5	3	T
Black Lake	14.7	8.02	4	2	T
Brandy Lake	18.1	8.17	8	2	T
Bruce Lake	5.44	3.78	6	2	PC
Buck Lake (HT)	10.8	5.63	5	3	T
Chub Lake	25.7	9.29	7	3	T
Clark Pond	9.5	4.25	2	2	ID
Dickie Lake	34.4	14.9	5	3	T
Echo Lake	33	10.4	4	2	T
Fox Lake	14.5	7.21	9	2	T
Kahshe Lake	25.4	10.3	4	3	T
Lake Joseph	14.1	4.04	3	2	T

Lake	Mean % EOT	SD %EOT	n	# of Sites	Classification
Lake Muskoka	5.78	3.65	8	2	PC
Lake of Bays	21.3	13.4	3	2	T
Lake Vernon	7.01	5.15	12	4	PC
Leech Lake (BB)	16.2	NA	1	1	ID
Leonard Lake	25.2	12.4	5	2	T
Little Lake	6.1	6.19	3	2	PC
Loon Lake	7.89	3.51	4	3	PC
Mary Lake	12.7	15.1	6	2	T
McKay Lake	30.4	NA	1	1	ID
Menominee Lake	13.7	3.66	7	4	T
North Muldrew Lake	23.7	NA	1	1	ID
Otter Lake	13.2	3.01	5	2	T
Peninsula Lake	14.1	11.3	6	2	T
Pine Lake	15.8	7.39	4	2	T
Rebecca Lake	5.6	1.72	4	2	PC
Ril Lake	17.1	5.87	10	4	T
Silver Lake	15.1	2.73	4	2	T
South Muldrew Lake	7.93	2.92	8	2	PC
South Muldrew Lake - Patterson's Bay	19.5	11.2	7	2	T
Stewart Lake	6.4	2.65	7	2	PC
Sunny Lake	30.2	10	2	1	ID
Three Mile Lake	17.9	16.4	7	2	T
Turtle Lake	4.97	5.05	2	1	ID
Walker Lake	55.8	15	9	3	T
Wood Lake	15.5	13.8	4	3	T

BB (Bracebridge) *HT (Huntsville)*

GR (Gravenhurst) *ML (Muskoka Lakes)*

WHAT DOES IT ALL MEAN?

Most of the lakes sampled (68%) have benthic invertebrate communities that are composed of a *typical* percentage of the sensitive EOT taxa. The remaining 32% of sampled lakes are classified as *potential concern* because of their low %EOT (< 9.8%) at sampled sites and should be further examined to identify potential stressors and clarify the extent to which the lake is atypical.

Shoreline development is a stressor for numerous lakes classified as *potential concern* in this study. By decreasing the structural complexity of aquatic habitats, shoreline development alters the community composition of benthic invertebrates (Urbanič et al., 2012). These changes can be signaled by a decrease or a low %EOT. Bass Lake (Gravenhurst, GR), Bruce Lake, Stewart Lake, Loon Lake, Lake Muskoka-Muskoka Bay, and Lake Vernon have >30% altered riparian areas (backlots). South Muldrew Lake and Rebecca Lake have moderate levels of altered riparian area (18.51-19.95%) but a high number of shoreline modifications (e.g., docks) that also impact benthic invertebrate habitat quality. Bass Lake (Muskoka Lakes, ML), Little Lake, and Bay Lake did not have shoreline surveys completed but, nonetheless, appear to have moderate levels of altered shoreline.

Other stressors could be at play in certain lakes, such as low concentrations of nutrients, low pH and high salinity from road salt application within the watershed. For instance, Barron's Lake has %EOT below the 9.8% threshold, despite having mostly natural riparian areas. Barron's Lake had a chloride concentration greater than 20 mg/L which indicates a potentially harmful level of chloride for sensitive aquatic life.

WHAT CAN YOU DO?

More data is always needed, especially in quaternary watersheds with few lakes sampled. You can get involved in monitoring the benthic macroinvertebrates in your lake through DMM'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 http://www.muskokawaterweb.ca/lake-data/muskoka-data/biological-monitoring-data.

Thank you to those lake associations involved with benthic monitoring.

CHAPTER 4 – CHLORIDE

Author: Dr. Neil Hutchison

Why would we be concerned about chloride in Muskoka waters? Chloride is most frequently encountered when it is applied as road salt to our roads in the winter to clear ice and snow quickly. Salt is simply sodium and chloride bonded together. What we may not be aware of is that in 1999 Environment Canada (Canadian Environmental Protection Act, 1999) declared road salt to be a substance which is toxic and dangerous to even physical aspects of the environment[1]. This declaration was accompanied by recommendations on how its use could be reduced but did not require any specific management responses.

We are all familiar with the bleaching of pine trees along our highways from the salt spray that is generated when traffic goes by. And we're all aware of the effects of salt on our shoes, our cars, and the paws of our dogs when they walk through salt in the wintertime. What we may be less aware of, however, is that this salt moves into the aquatic environment very readily.

Chloride is what is known as a conservative ion in that it does not react with other ions in the environment. As a result, it moves through soil in runoff water and is not taken up in significant amounts by vegetation. What runs off our roads, parking lots, and driveways will ultimately end up in the natural environment and that is frequently in our waters in Muskoka. Sodium in drinking water is also a problem for people that have heart issues and so we do have to watch that, although our lakes are well within safe levels.

Chloride itself is an issue because it is toxic to aquatic life. One of the results of road salt's declaration as a toxic substance was that the Canadian Council of Ministers of the Environment (CCME) developed a water quality guideline for chloride in freshwater (CCME, 2011). They

[1] *"a substance is toxic if it is entering or may enter the environment in a quantity or concentration or under conditions that (a) have or may have an immediate or long-term harmful effect on the environment or its biological diversity…"*

reviewed all the research on the toxicity of chloride and concluded that, if concentrations were below 120 milligrams per litre (or parts per million, ppm), that there was no significant threat to aquatic life. If that were the case, then we would not be worrying about road salt and chloride in Muskoka. The CCME work was based on studies of chloride toxicity to 30 vertebrate, invertebrate, and algal species was based on studies of chloride toxicity that were conducted in a wide variety of waters. Many of them are representative of waters located off the Canadian shield. These lakes have higher hardness and calcium content than lakes in Muskoka.

Calcium is an ion that helps aquatic life resist the effects of pollutants such as chloride. If there is lower calcium in our water, then things like chloride are more toxic. Research that has been done since 2011 (Arnott et al., 2020) shows that chloride concentrations as low as 10 or 20 milligrams per litre (parts per million) in low-calcium waters can damage sensitive aquatic life, particularly zooplankton. Thus, the low calcium waters of Muskoka make the aquatic life in our lakes particularly sensitive to chloride. As a result, in Muskoka we consider chloride concentrations above 10 ppm as potentially harmful to sensitive aquatic life. We note that many Muskoka waters have less than 1 ppm. These are lakes where there are no roads to add road salt and the concentrations are considered *baseline* or unaltered.

We are concerned that chloride coming into our low calcium waters from road salt applications is potentially harmful to aquatic life at current levels. We will present data on current chloride levels in our lakes, how they've changed from baseline conditions, how they have changed from our 2018 Report Card, and whether they pose a risk to aquatic life.

DATA SOURCES

Our analysis relies on water quality data that has been collected by the District Municipality of Muskoka (DMM) as part of their Lake System Health program. DMM samples approximately 90 lakes every year and repeats those measurements every second year for a total of approximately 200 lakes in their database. The lakes are sampled in May and early June. At this time, they have not yet stratified and so water quality is similar from the surface to the bottom, such that a grab sample taken from the surface provides a good representation of the chloride level throughout the lake. DMM sends the water samples to the Ministry of Environment Conservation and Parks (MECP) for analysis to strict laboratory standards and the Ministry provides the data back to DMM. The Report Card also uses data from the Lake Partner Program (LPP) of the Ontario MECP. These data are collected by citizen scientists (volunteers who collect samples) according to MECP protocols at generally the same time of the year as DMM and send the samples to MECP labs for analysis. As a result, this version of our watershed report card reports on chloride concentrations from 274 lakes or lake segments with records for some extending back to 2004: an enviable database.

HOW ARE WE INTERPRETING OUR CHLORIDE DATA?

We are relying on two basic metrics for presenting and interpreting the chloride data. One is the current chloride concentration based on samples taken between 2018 (the last report card) and 2022. If there were fewer than three samples in that time, we included samples from 2017 to keep our sample size to a minimum of 3 recent measurements.

- We classified the number of lakes that were: less than 1 ppm (considered to be unaltered) and between 1 and 10 ppm where 10 ppm is considered the threshold for potential damage to sensitive aquatic life. We also counted the number of lakes where concentrations exceeded 20 ppm for (lakes considered more seriously threatened) and have highlighted several lakes where the concentrations are very high.
- The second metric we used asked the question: Which lakes are increasing or decreasing in chloride? For this we had to recognize that not every lake has data going back long enough to get a good sample of this but, in general, for each lake, we took every measurement that was in our database, averaged them, and compared that to the average concentration measured over the last five years. An average of the most recent five years which was 0.5 mg/L higher than the historical record was indicative of increasing chloride concentrations and a recent average 0.5 mg/L lower indicated decreasing concentrations.

In some cases, low sample sizes (1 or 2 measurements) confounded our interpretation. Another concern was that some Muskoka lakes are not located on the Canadian shield. Southern parts of Muskoka such as the Severn River drainage and parts of the Georgian Bay drainage are in fact in areas where the bedrock and soils contain more calcium ("calcareous soils"). In these areas the natural levels of calcium and chloride would be higher independent of road salt application. In those cases, examination for any increasing trends and comparison of calcium and chloride levels was used to interpret any role of road salt in higher chloride levels.

RESULTS

Chloride data were available for 274 lakes or lake segments (e.g. several bays within one lake) and results for each lake are presented in Table 12. Chloride concentrations were <1 mg/L and thus considered unaltered in 80 of 274 (29%) of the lakes. Concentrations ranged from 1.0 - 9.99 mg/L in 127 (46%) of lakes. Concentrations exceeding 10 mg/L and considered potentially harmful were recorded in 67 lakes (24%) and in 36 of these, exceeded 20 mg/L. In eight lakes, six located in the South Georgian Bay Shoreline and two in the Sparrow Lake watersheds, enriched chloride concentrations could be attributed to natural sources, the influence of calcareous, off-shield drainage.

Table 12. Chloride in 274 lakes in Muskoka 2018-2022.

	n=	< 1.0 mg/L	1.0 – 9.99 mg/L	10 – 20 mg/L	> 20 mg/L
Number of lakes	274	80	127	31	36
Percent of lakes		29%	46%	11%	13%

The distribution of Cl concentrations across all lakes is shown in Figure 9. Concentrations exceeding 60 mg/L were recorded in;

- Burnt Lake (76.2 mg/L), adjacent to Hwy. 400;
- Roberts Lake (72.1 mg/L), adjacent to Hwy. 69 and Hwy. 400; and
- Jevins Lake (113 mg/L), downstream of Hwy. 11 and the south Gravenhurst commercial area.

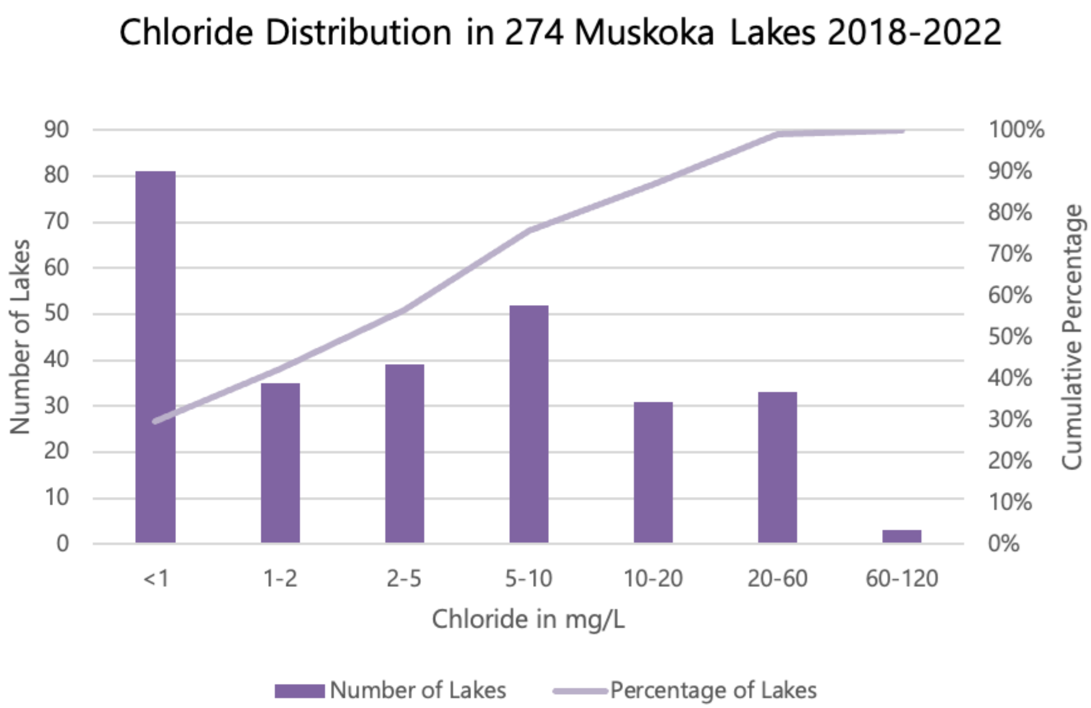

Figure 9. Chloride distribution across all sampled lakes.

Chloride concentrations had increased by more than 0.5 mg/L in 80 of 274 (29%) of the study lakes and had decreased by more than 0.5 mg/L in 13 (5%) lakes (Table 13, Figure 10). The increases exceeded 10 mg/L in Jevins Lake, which receives urban drainage from Hwy. 11 and the commercial area of southern Gravenhurst, and in Cornall Lake which is downstream of Jevins Lake. Increases exceeded 2 mg/L in five of the eight lakes that were "off-shield" indicating that, even in areas of calcareous bedrock and higher natural chloride concentrations, road salt contributed to the elevated chloride concentrations. Although chloride concentrations decreased in 13 lakes the reasons are unknown and likely relate to small sample sizes in which the influence of one year may be over-stated. Further monitoring is recommended.

Table 13. Changes in Chloride Concentration: 2018-2022 vs Historic Record.

	n=	+> 0.5	-> 0.5
Number of lakes	274	80	13
Percent of lakes		29%	5%

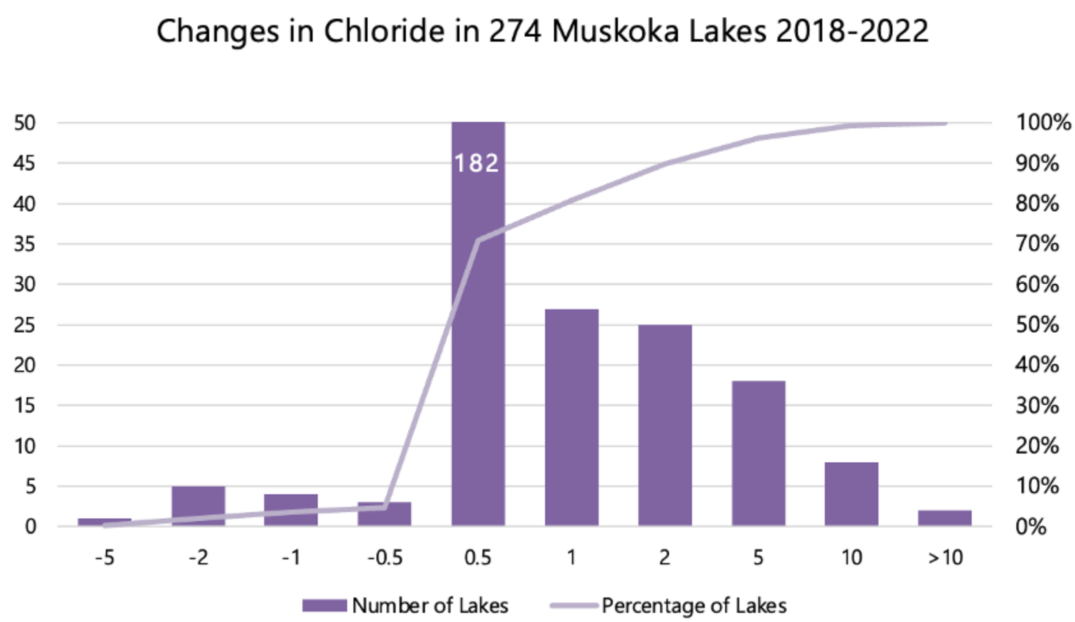

Figure 10. Changes in chloride concentration: 2018-2022 vs All Years.

Jevins Lake (Figure 11) reported the highest chloride concentration and the greatest increase of all the lakes included in the Report Card. The lake receives runoff from the commercial areas at the south end of Gravenhurst and from Highway 11. Figure 11 also shows the record of chloride increasing in Muskoka Bay, an iconic centrepiece of our Muskoka waters. The bay receives runoff from the urban and commercial areas of Gravenhurst and from Hwy 169.

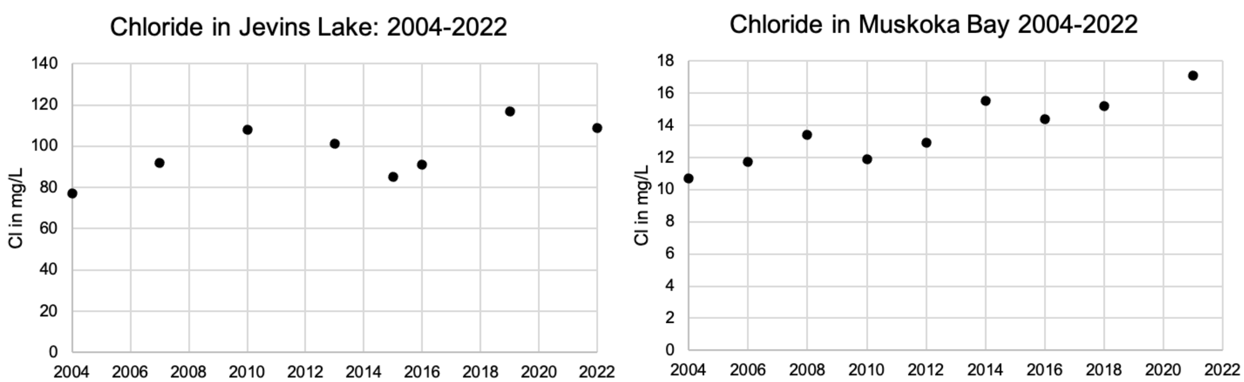

Figure 11. Chloride in Jevins Lake and Muskoka Bay.

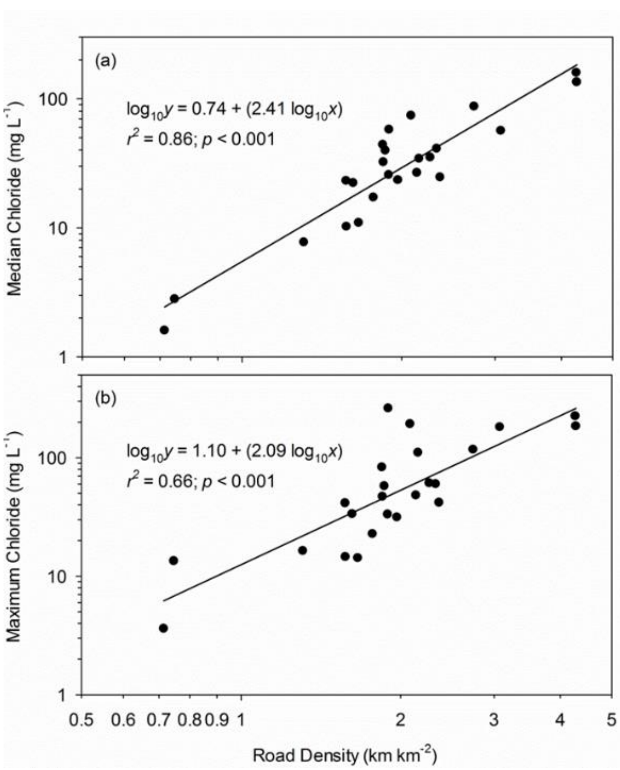

Figure 12. Road density and chloride in southern Ontario streams (from Todd & Kaltenecker, 2012).

Todd & Kaltenecker (2012) reported that road density is related to chloride concentrations in streams in heavily populated areas of southern Ontario (Figure 12). While mean chloride concentration showed no relationship with road density in the 18 Muskoka quaternary watersheds contained in our dataset there was a significant ($p<0.015$) relationship between road density and the percentage of lakes in a quaternary watershed in which chloride had increased in 2018-2022. (Figure 13). The use of average values for road density and chloride in each watershed, however, provides a very coarse analysis and further investigation using lake-specific measures of road density would provide a more accurate metric. Lake-specific estimates of road density are not available.

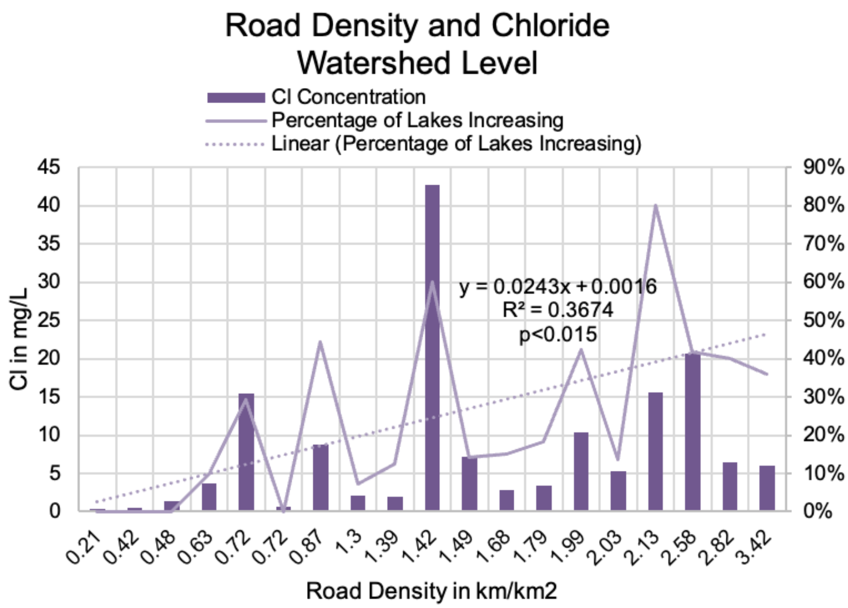

Figure 13. Road density and chloride in 18 Muskoka watersheds.

WHAT DOES IT ALL MEAN?

Road salt use has generated substantial increases in the concentrations of chloride, a toxic pollutant, in Muskoka's lakes. Chloride concentrations exceeded 1 mg/L and were therefore considered enriched in 193 of 274 (70%) lakes. Concentrations exceeded 10 mg/L and so were considered potentially harmful in 68 lakes (25%). In 36 of these, chloride concentrations exceeded 20 mg/L. The average chloride concentrations measured in 81 (29%) lakes have increased in the past five years, exceed 70 mg/L in three lakes and exceed 115 mg/L in Jevins Lake. Further investigation at a lake-specific level is required to determine the role of road density on chloride in Muskoka lakes.

While management actions are warranted to halt and reverse the increasing chloride in our lakes, the 2001 Environment Canada assessment report cautioned that *"Any measures developed as a result of this assessment must never compromise human safety; selection of options must be based on optimization of winter road maintenance practices so as not to jeopardize road safety, while minimizing the potential for harm to the environment…".* MWC should therefore support existing initiatives to monitor and document road salt sources and work with provincial and municipal governments and the public to reduce and optimize road salt application in Muskoka by government, businesses, and individuals.

CHAPTER 5 – FISH POPULATIONS IN OUR LAKES

Author: Steve Scholten

In previous report cards, we did not make much reference to the fishes which inhabit our waterways. These ecologically important components of our aquatic ecosystems are also important drivers of our recreational and tourism economy. Spending an early morning or a tranquil evening fishing in a canoe can be a highlight of time spent in Muskoka. Even in winter, there are fishing opportunities through the ice, and enthusiasts wait eagerly for the ice to be thick enough to put out their ice huts in time for the start of the ice-fishing season.

Most freshwater fishes require unpolluted water and suitable spawning sites, but rather than treating certain fish species as indicators of watershed health, we will tell the story of an alteration of management regulations now nearing completion. Because the fact that some fishing regulations are under review is partly a direct consequence of changes taking place in our Muskoka watersheds, changes that alter their suitability as fish habitat. In other words, the need for a change in fishing regulations is a sign our Muskoka watersheds are changing.

SOME BACKGROUND

Close to 100 species of fish make their homes in the lakes, rivers, streams, and wetlands of the Muskoka watersheds. Among them are well-known fishery species such as smallmouth and largemouth bass, walleye, northern pike, brook and lake trout, not to mention the pumpkinseed sunfish, that very first fish that every six-year-old catches and takes home proudly for dinner. The fishery species can be broadly divided into cold-water, cool-water and warm-water species. Cold-water species such as lake trout, brook trout, and lake whitefish require the deep, cold, well-oxygenated water characteristic of many of our lakes. They are competitively inferior to cool-water and warm-water species such as walleye and bass, species which also feed upon their eggs and juveniles. Several warm-water species, including smallmouth and largemouth bass and several sunfishes are invasive species in the Muskoka watersheds which have been expanding their ranges northward over at least the last 100 years as settlement progressed and more recently, as the climate warmed. These invasive species have also been helped in spreading through many of our lakes by individuals who have (usually illegally) added fish to lakes in which they do not already occur in the expectation they would improve fishing.

In Ontario, the Ministry of Natural Resources and Forestry (MNRF) has responsibility for sustainable management of recreational fishery species. MNRF scientists evaluate the status of each fishery species; whether populations are expanding or declining, whether fish are growing to a good size, whether they are healthy. Based on these evaluations, they set fishing regulations to manage when, where, how, and how many fish of each species a person may catch. They also set regulations to manage the use of live bait and to prevent the unauthorized transfer of live fish between water bodies. They are responsible, by means of these evaluations and regulations, for ensuring, so far as possible, that people will be able to continue to enjoy recreational fishing for decades to come. It's a daunting responsibility but one MNRF staff undertake willingly. MNRF's Provincial Fish Strategy describes the goal as to maintain *"healthy ecosystems supporting native self-sustaining fish communities, and fisheries that provide long-term ecological, social, economic, cultural and health benefits for the people of Ontario."*

Until 2005, MNRF attempted to manage recreational fisheries on a lake-by-lake basis, evaluating the status of fish populations in each lake and determining appropriate catch limits based on those. With the number of lakes in Ontario, this was an enormous task. The New Ecological Framework for Fisheries Management (OMNR 2005), introduced by MNRF in 2005 shifted management to a broader landscape level from the earlier emphasis on individual lakes. The key pillars of the framework were replacing existing fishing divisions with a set of 20 Fishery Management Zones (FMZ) across the province based on biological, climatic, and social considerations. The Muskoka watersheds lie within FMZ 15, which extends in a broad swath across central Ontario from Georgian Bay to the Ottawa River. The Muskoka watersheds represent about 1/7 of FMZ 15 extending from the western edge to about the centre of the zone and covering the middle third of the western half of the Zone. By shifting management to the FMZ scale, MNRF was able to streamline fishing regulations, monitor the main fishery species at the FMZ scale, and prepare fisheries management plans for each FMZ. MNRF also sought to enhance public engagement in the management process by forming Zone-based Fisheries Advisory Councils comprised of community volunteers, to provide advice to MNRF on various aspects of fisheries management.

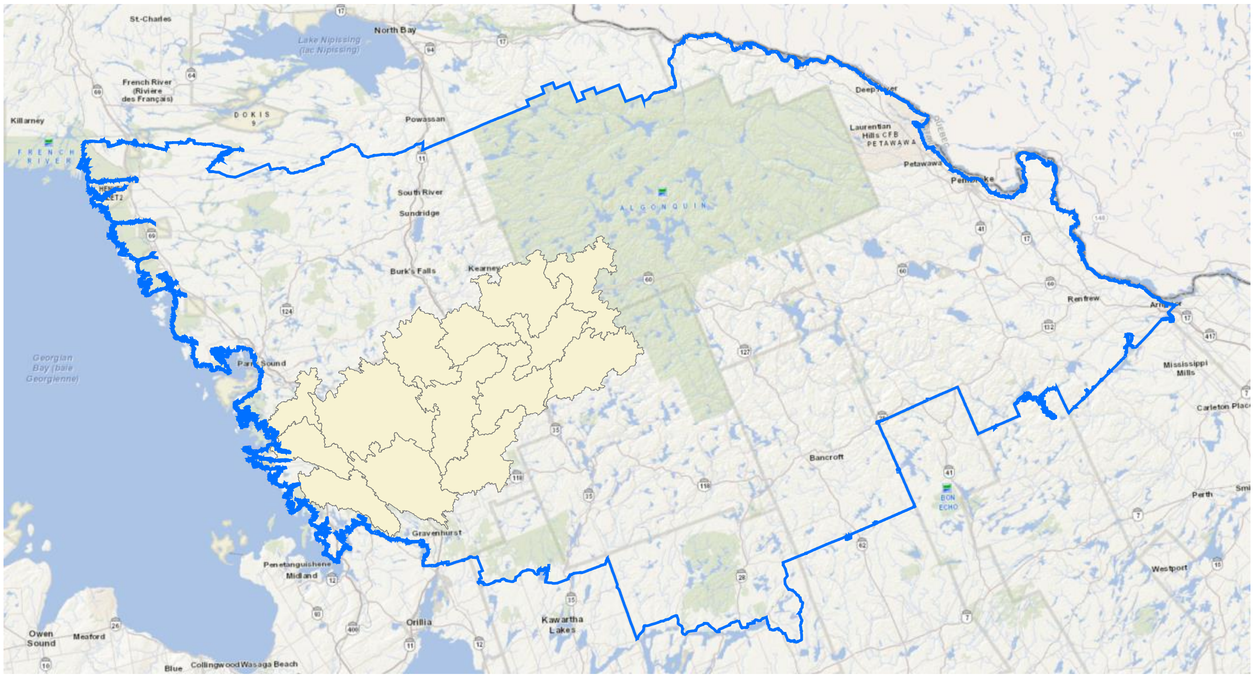

Figure 14. Fisheries Management Zone 15 (blue outline). Muskoka River watershed is shown in tan with grey outline.

In 2017, MNRF began the process to develop a new draft management plan and associated background information report for FMZ 15. The documents were posted on the Environmental Registry for public comment in the fall of 2022 (https://ero.ontario.ca/notice/019-5715). The background information report describes the status and trends of a broad suite of parameters on fish populations such as fish species distribution and abundance and stressors that impact them such as occurrence of invasives species, water quality, and fishing effort.

At this time, the plan is in draft form and may be subject to changes. However, some general statements can be made. Drawing on earlier strategies, the plan has a strong emphasis on conserving the primary native cold-water fish species; brook trout, lake trout, and lake whitefish. These species are sensitive to impacts from human-caused stressors that are expected to intensify in the future. Climate change is expected to reduce the amount and quality of habitat for cold-water species while favouring the cool-water and warm-water species that often compete with and even prey on trout and whitefish. Climate change is also a confounding or contributing factor to other stresses such as water quantity and quality and the spread of introduced species which also are expected to impact cold-water species increasingly. Here we illustrate the management challenges by considering lake trout *(Salvelinus namaycush)*.

LAKE TROUT IN THE MUSKOKA WATERSHEDS

Lake trout are an iconic fish species of the central Ontario shield landscape. They are a glacial relict species restricted to deep, cold, low productivity lakes; the type of lake that attracts people to the area. As a result, the things we do to these lakes often put our native lake trout populations at risk. The main stressors include the introduction of non-native species, nutrient enrichment from watershed and shoreline development, alteration of near shore habitat, climate change, and harvest of the fish themselves.

Since 2006, MNRF has maintained a formal list of lakes that are designated for lake trout management (OMNRF 2015b). Lakes are designated as *natural*, where populations are maintained by natural reproduction, and *put-grow-take* (PGT), where populations are maintained by artificial stocking. As of 2015, there were 55 natural and 19 PGT lake trout lakes in the Muskoka watershed (Appendix C). The greatest numbers of lakes occur in quaternary watersheds Baysville Narrows-South Branch Muskoka River, Distress Pond-Big East River, Hollow River, and Tea Lake-Oxtongue River in the eastern highland area of the watershed. Of those, 23 are natural lakes in Algonquin Park. However, the greatest concentration of surface area is in the Lake Muskoka-Muskoka River and Lake Rosseau watersheds which contain the large Muskoka Lakes. The PGT lakes tend to be smaller and naturally have less and poorer habitat for lake trout making them more likely to be impacted by various stressors. Notable exceptions include; the Huntsville Lakes (Vernon, Fairy, Peninsula) and Mary Lake, which despite being large and deep, do not currently support natural lake trout populations. That is thought to be primarily due to interactions with introduced non-native smelt in interaction with other factors, including low water clarity.

The introduction of this Background Report describes the phenomenon of shifting baselines and our inability to track slow environmental changes. Human activities started to change lakes in ways that would have impacted lake trout well before formal monitoring of fishery species began, so we simply do not know how many lakes originally supported populations of lake trout. Many lakes that are currently stocked on a PGT basis probably had native self-sustaining populations that have been lost due to the combined effects of overharvest, introduced species such as bass, water level manipulation, and other stressors. Also, there are a number of lakes that were managed for lake trout by stocking in the past, but no longer are. In many cases it isn't known whether they ever had natural populations of this fish, or if they were simply maintained by stocking. Overall, we know we have lost some naturally reproducing lake trout populations, but the extent of this decline isn't known.

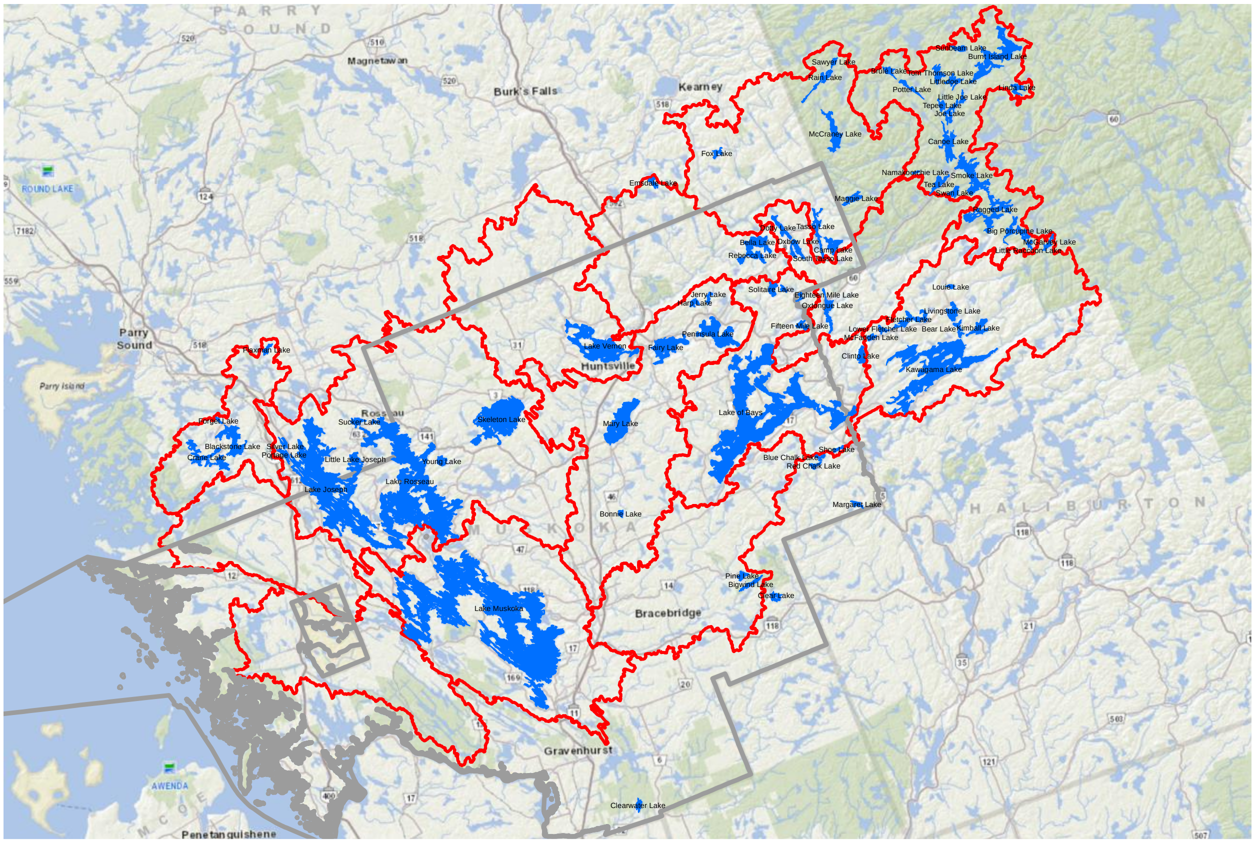

Figure 15. Map of lakes designated by the MNRF for the management of lake trout in the Muskoka River watershed and the District of Muskoka (2015).

What is known is that on-going climate change is expected to further worsen their long-term chances for survival and that the present levels of fishing will not likely be sustainable indefinitely. Present levels of fishing may have been sustainable when current fishing regulations were put in place in 2005, but environmental changes since then have already impacted this species.

Continuing climate change is expected to further reduce the amount and quality of habitat for lake trout reducing populations directly, but also making them more vulnerable to impacts from confounding factors. The most important direct effect is the lengthening of the season when a lake is stratified with a layer of warm water preventing oxygen from the atmosphere reaching the deeper, cold water. Reduced levels of dissolved oxygen in the deep water reduce the number of fish which can live there without exhausting oxygen supplies. A second direct effect, also caused by the lengthening of the period of the year when the lake is stratified as well as by warming of the surface waters, is a deepening of the thermocline, the transitional layer of water between warm surface waters and cold deep waters, which effectively reduces the volume of the deep-water habitat available for lake trout.

Indirectly, continuing climate change is likely to facilitate the competitive and predatory activities of cool- and warm-water species, such as bass, further harming lake trout populations. This is because the warming effects of climate change are expected to directly benefit populations of warm-water, and perhaps cool-water species.

Recognizing the multiple stressors facing lake trout, as well as the fact that evaluations showed they could not sustain current levels of fishing, the FMZ 15 plan had to explore ways to ease the cumulative pressures on their populations. The only real tool available for fishery managers to conserve fish populations is to manage the recreational fishery in ways that will reduce the amount of fish taken. In this way, resiliency of the fish to other stressors over which we have little local or direct control can be increased. The FMZ 15 plan, now in draft form, proposes a reduced length of the open season and establishing of minimum size limits based on the observed growth rate observed in each lake. These measures are expected to reduce overall mortality rates and improve abundance. Fish stocking in PGT lakes will continue to be used to divert fishing effort from natural lake trout lakes and provide additional fishing opportunities to support local communities and businesses. Stocking of viable natural populations will not be done because of the potential negative impacts of stocked fish. The plan also features a strong educational element to try to reduce the impacts of introduced species and habitat loss.

The changes being made to the regulations governing fishing for lake trout are a consequence of the fact that our lakes are changing in ways that make it more difficult for this species to survive. That they are necessary is another illustration of how the impacts of climate change ripple through the ecosystem in unexpected ways.

Muskoka Watershed Report Card 2023

CHAPTER 6 – HAZARDOUS ALGAL BLOOMS

Author: Geoff Ross

Algae are a diverse group of microscopic, single-celled or colonial, photosynthesizing organisms that occur in all moist or aquatic habitats. The mid-water algae or phytoplankton, are vital basal links in every lake food web. Through photosynthesis, they use solar energy, carbon dioxide, and water to build organic molecules that allow for their own growth and provide food to aquatic zooplankton, and ultimately to fish and other animals. In the process of photosynthesis, they generate significant amounts of oxygen that is released to the atmosphere. Every second breath you take provides you with oxygen originally placed into the atmosphere by phytoplankton in lakes and oceans. Phytoplankton belong to several distinct divisions or phyla such as the diatoms, the golden algae, and the green algae. Also included in the phytoplankton, but very different to other algae are the blue-green algae or cyanobacteria.

Unfortunately, on occasion, conditions can be particularly favorable for algal growth and reproduction. At these times, algal populations of any species can become quite large, resulting in a visible scum or *bloom* on the lake surface. These blooms can develop over just a few days and can disappear just as fast, as algal cells die and decompose. Severe blooms can deplete a lake of oxygen leading to fish kills and other serious disruptions to the lake ecosystem. They can also prove noxious, in appearance as well as odor, degrading our enjoyment of our lakes. In rare instances, cyanobacterial or blue-green algal species produce toxins that can cause serious health risks to people and animals drinking or bathing in the water. In Ontario, cyanobacterial blooms are considered Harmful Algal Blooms (HABs). These blooms often make the water look blue-green or olive-green, or like green pea soup or turquoise paint.

Not all cyanobacteria blooms produce harmful toxins, but their presence indicates the potential for the water to be dangerous for people and for animals. When a suspected algal bloom is reported, samples are taken for taxonomic analysis and subsequent testing for toxins by the Ontario Ministry of Environment Conservation and Parks (MECP). If a bloom is confirmed as resulting from cyanobacteria, the Simcoe Muskoka District Health Unit (SMDHU) will issue a Public Notice of a HAB, advising people and animals to avoid contact with the water. This is done as a precaution in advance of results confirming the presence of toxins actually being released.

The fact that HABs have been identified as cyanobacteria blooms via testing and analysis by scientists, and the fact that HABs can have serious implications, makes them useful as indicators of watershed health.

Typically, the root cause of HABs has been viewed as excessive nutrient concentrations, notably phosphorus, in the water. This creates the ideal conditions for various types of algae and cyanobacteria to bloom. Until quite recently, HABs in Ontario have been observed to be associated with high phosphorus concentrations in lakes and have been quite rare in the Muskoka watersheds.

As discussed in Chapter 2, phosphorus concentrations as measured by springtime surface water samples, are generally low in the Muskoka watersheds, and in many lakes, concentrations have been decreasing. There was little reason to expect that HABs might become more common here. And yet, HAB advisories have been increasing in Muskoka. Figure 16 below indicates the total number of HAB advisories issued for the District Municipality of Muskoka (DMM), by year, from 2009 to 2022. These were in all cases issued for cyanobacterial blooms.

The data in Figure 16, and the fact that increases in cyanobacterial HABs are occurring without observed increases in springtime phosphorus, is consistent with other data reported for Muskoka, Canada, and other countries (Favot et al., 2023).

The data in Figure 16 present total HABs for all lakes in DMM. None of these lakes has a reported HAB every year. The 11 HABs reported in 2021 came from 11 different lakes, many of which had no previous reports of HABs.

Clearly, something is changing in Muskoka. But what change is driving increased HABs, what are the implications, and how should we respond? The HAB advisories reported in Figure 16 depend entirely on reporting by the public. This initiates the sampling and analysis by MECP leading to the advisory issued by SMDHU. Perhaps the increase in advisories is solely due to increased concern and awareness by the public?

Favot et al. (2023) discuss this possibility using the wider province-wide dataset and conclude that increased awareness could be at most a contributing factor. A real increase in cyanobacterial HABs is occurring in oligotrophic lakes on the Canadian shield. And HABs sometimes occur on remote lakes with little human influence, such as Dickson Lake in Algonquin Park, which experienced a blue-green bloom in 2014. While something real is happening, scientists have not yet determined the precise mechanism driving the more frequent blue-green blooms. Several possibilities are being investigated, and all likely have links to climate change.

Given that increases in water temperature will generally cause increases in the growth of most kinds of algae, it appears possible that the increased frequency of HABs in Muskoka is a result of increased water temperatures resulting from climate change. However, the impacts of climate change go beyond just increased water temperature, including for example changes in wind speed that impact lake stratification, and changes in precipitation patterns that may impact phosphorus loadings via increased shoreline erosion. The latter could be introducing phosphorus that is not presently accounted for by current monitoring protocols. A longer season during which a lake is stratified can lead to reduced oxygen levels, and even anoxia, in the deeper part of the lake. Under anoxic conditions phosphorus and other nutrients trapped in the sediments at the bottom of a lake can be remobilized, becoming available for organisms living in the water column. Such a longer season has in fact been documented in Chapter 13, as the trend to a longer ice-free period due to climate change. Other possible drivers of increased HABs may or may not be linked to climate change. These include changes in food web structure and invasive species (Favot et al., 2023).

At the current time, we do not know enough about the causes of increased HABs to say with certainty why they are occurring, or how we should respond. The main conclusions to be drawn are;

- More research is required to determine the causes of the increase in HABs. The knowledge gained will be of key importance to determining how we should respond.
- Of particular concern, climate change is likely creating a range of new conditions under which our current practices for protecting the environment, from HABs and other threats, are no longer adequate. Further research is an essential tool for determining where and why this is happening, and what changes are needed.
- Such research might include, among other things, assessing the degree to which climate change is responsible for greater shoreline erosion, thus impacting phosphorus input to lakes in a manner that is not being identified through current monitoring protocols. This could indicate needed changes in phosphorus monitoring protocols and more stringent shoreline protection standards.

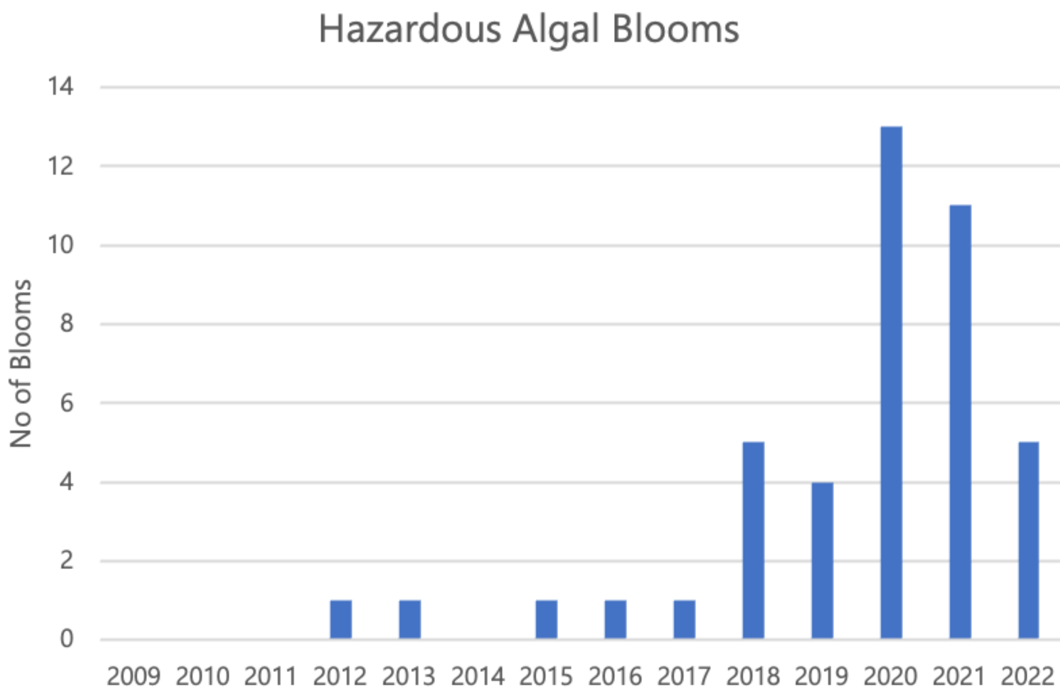

Figure 16. History of HAB advisories issued by Simcoe Muskoka District Health Unit (SMDHU) for waterbodies within the District of Muskoka (SMDHU, personal communication). No data available prior to 2009.

CHAPTER 7 – INTERIOR FORESTS

Author: Dr. Peter Sale

WHAT IS INTERIOR FOREST AND WHY IS IT IMPORTANT IN MUSKOKA?

The informative guide, now in its 3rd edition, *How much habitat is enough?* (Environment Canada, 2013), reviews an extensive literature on the use of habitat by various species. For forested habitat, this guide focuses on seven different attributes of the habitat. These are;

- the total amount of forest across the landscape (percent forest cover);
- the presence of large, contiguous patches of forest habitat;
- the shapes of forested areas (because a long, narrow forest will have more edge and less interior than a more circular patch of forest of the same area);
- the percentage of forest that is interior forest as opposed to forest edge;
- the proximity of patches of forest to each other;
- the extent to which roads and other features are fragmenting formerly contiguous forest;; and
- the quality of the forest habitat in terms of the degree to which it encompasses areas representative of old growth, younger aged forest, wetlands and so on.

Each of these attributes provides a separate assessment of the quantity, or the quality of the forest habitat available in a region, which in turn measure the adequacy of the forest habitat for supporting wildlife and providing ecological services. This Report Card explores three of these attributes; this chapter concerns interior forest, Chapter 8 relates to the fragmentation of forested landscape, and Chapter 14 deals with ecosystem integrity, another approach to assessing quality of an environment.

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.

While the environmental changes are gradual as one moves from the forest edge to the deep interior, interior forest has conventionally been defined as that forest at least 100 metres from a road or other edge. This convention is based primarily on study of forest birds, with some evidence from study of forest mammals and reptiles. Birds are commonly used in studies of forest health because they integrate biological, physical and chemical conditions required to support healthy populations when choosing where to nest (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).

In North American forests, interior-forest bird species begin to occur about 100 metres in from a forest edge (Dunford and Freemark, 2004; Nol et al., 2005; Weber et al., 2008). Nor is it just birds. Many of Muskoka's wildlife species also depend on interior forest habitat (Environment Canada, 2013). The development of roads, agricultural fields, houses and other human-made structures in otherwise forested landscapes create lots of forest-edge habitat, while reducing the amount of interior forest. In this way, these types of changes on the landscape alter the composition of species present as interior-forest species drop out. Diversity is reduced, and ecosystem quality is degraded.

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 the ability of a watershed to function naturally. 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.

For all these reasons, a measurement of the percentage of interior forest at least 100 metres from a forest edge is a useful indicator of forest quality, and therefore of ecological health. A region with large areas of contiguous forest (and therefore lots of interior forest) will support a richer, more diverse community of birds, other wildlife, and plants than will one with the same amount of forest, but much subdivided so forest-edge habitat is a higher proportion of the total. Data on bird species from five locations in southern Ontario show that there is a marked decline in number of bird species present when total forest cover on the landscape is reduced beyond 15% and the great majority of these losses of birds are interior-forest species (Environment Canada, 2013). Based on such studies, Environment Canada's recommendation for forests in Ontario is a minimum of 15% of the terrestrial landscape be in forest, with a minimum of 10% of the area in interior forests.

HOW IS INTERIOR FOREST MEASURED IN MUSKOKA?

While it may be true that interior forest bird species in southern Ontario continue to occur in places where forest comprises less than 15% of the landscape (with interior forests about 10%), it would be unwise, in the Muskoka watersheds, to use this level of deforestation as a threshold for degradation. This region had very high natural cover of forests prior to European settlement, and much of the landscape remains forested. We need benchmarks that reflect that very healthy condition, and we adopted such a set of benchmarks in previous report cards.

To determine the amount of interior forest in each quaternary watershed, we have followed the same procedure used in 2018, with the considerable help of the geoinformatics staff at the District Municipality of Muskoka (DMM). Using a land use layer from the Ontario Ministry of Natural Resources and Forestry (MNRF), 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 amount was calculated in hectares per quaternary watershed. This area of interior forest was then expressed as a percentage of total land area of each watershed (area not including area of lakes). Currently, interior forest across the Muskoka watersheds covers 61% of the land surface.

With advice from local ecologists, we have designated made-in-Muskoka benchmarks based on the interior forest indicator:

- Not Stressed: More than 50% of the land surface 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. The forest's capacity to provide ecosystem services will be strong.

- Vulnerable: Between 20% and 50% of the land surface of the quaternary watershed is interior forest. When 20% to 50% of the watershed land surface is interior forest, there has likely been moderate loss of habitat available for most interior species. However, amount remaining is unlikely to lead to loss of such species, and ecosystem services will continue to be provided. Invasive species may pose a greater risk.
- Stressed: Less than 20% of the land surface of the quaternary watershed is interior forest. Where there is less than 20% interior forest at the watershed scale, interior-forest bird species, and sensitive mammals will have reduced and possibly inadequate habitat and there will be more conflict with humans. Ecosystem services will likely have been diminished.

RESULTS

Table 14 summarizes the amount of interior forest habitat in each quaternary watershed. There is a total of 381,935 hectares of interior forest across the Muskoka watersheds, representing 61% of all land surfaces. At the quaternary watershed scale, interior forest cover varies from approximately 32% in the Sparrow Lake-Severn River Watershed to over 79% in the Distress Pond-Big East River Watershed.

Table 14. Amount (hectares) of interior forest habitat in each quaternary watershed.

Quaternary Watershed	Area of Interior Forest (ha)	Land area of Watershed (ha)	Interior Forest (%)	Grade
Baysville Narrows-South Branch Muskoka River	20,179	30,441	66.29%	Not Stressed
Blackstone Harbour	7,698	14,663	52.50%	Not Stressed
Cache Creek-Black River	21,607	30,481	70.89%	Not Stressed
Distress Pond-Big East River	33,881	42,631	79.47%	Not Stressed
Hollow River	25,660	34,331	74.74%	Not Stressed
Kahshe River	12,218	22,738	53.73%	Not Stressed
Lake Muskoka-Muskoka River	16,678	38,153	43.71%	Vulnerable
Lake Rosseau	35,062	62,036	56.52%	Not Stressed

Quaternary Watershed	Area of Interior Forest (ha)	Land area of Watershed (ha)	Interior Forest (%)	Grade
Lake St. John-Black River	17,638	34,785	50.70%	Not Stressed
Lake Vernon	22,446	33,839	66.33%	Not Stressed
Little East River-Big East River	17,820	25,270	70.52%	Not Stressed
Little Lake-Severn River	14,718	28,025	52.52%	Not Stressed
Moon River Bay	10,536	21,400	49.24%	Vulnerable
Musquash River	16,092	28,332	56.80%	Not Stressed
North Branch Muskoka River	25,892	44,034	58.80%	Not Stressed
Oxtongue River Outlet	19,597	24,987	78.43%	Not Stressed
South Branch Muskoka River Outlet	22,304	33,632	66.32%	Not Stressed
South Georgian Bay Shoreline	14,179	26,909	52.69%	Not Stressed
Sparrow Lake-Severn River	6,507	20,146	32.30%	Vulnerable
Tea Lake-Oxtongue River	21,221	28,783	73.73%	Not Stressed
Overall	381,935	625,616	61.05%	

** Calculated as total watershed area minus all lake surfaces present to yield total land area. 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 DOES IT ALL MEAN?

Most quaternary watersheds are graded as not stressed. Just three are graded vulnerable: Sparrow Lake-Severn River in the Severn River-Lake Simcoe watershed, and Moon River Bay and Lake Muskoka-Muskoka River in the Muskoka River watershed. Of these three, only Sparrow Lake-Severn River is very far below the 50% level judged as unstressed. The great majority of quaternary watersheds within the Muskoka watersheds have ample amounts of interior forest at present. Still, all should continue to be sustainably managed to retain these important interior forests, and efforts should be made to ensure that areas of forested land within Sparrow Lake-Severn River do not become further degraded.

WHAT CAN YOU DO?

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.
- 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).

CHAPTER 8 – FRAGMENTATION

Author: Dr. Glenn Cunnington

WHY ARE LARGE 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 lost is a particularly important, but difficult, question to answer.

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 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.

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. Tourism in Muskoka has evolved over time resulting in Muskoka being recognized as one of the premier vacation destinations in Ontario. It is the proliferation of nature across the Muskoka River Watershed that drives the local tourism-based economy (MacDougall, 2014). People flock to Muskoka from across the globe to take in the scenic views and participate in water-based recreational activities.

Long-term preservation of the things that make Muskoka what it is today require that fragmentation of landscape (i.e., the breaking apart of large undeveloped areas into smaller and smaller pieces) be minimized to allow large natural areas to be maintained in Muskoka. Considering these large patches of natural areas is key when planning for development.

In most of Ontario, conservation focus is primarily geared toward maintaining or expanding forest cover (Muskoka Watershed Council, 2018). Within Muskoka, forests are the most common land cover type; however, it is important to look beyond the simple total of forested land to ensure long-term conservation of the larger ecosystem. The way that different land cover types (e.g., wetlands, fields, rock barrens, etc.) are arranged across the landscape plays a primary role in the ability of an area to sustain diverse ecological systems that provide both habitat for wildlife as well as ecosystem services including carbon sequestration, clean air, and prime recreational opportunities.

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.

THE INFLUENCE OF FRAGMENTATION ON LARGE NATURAL AREAS AND WILDLIFE

Roads, which cover only a small portion of the landscape, can have profound negative effects on wildlife populations and water quality. For instance, in southern Ontario, no point in the landscape is greater than 1.5 km from a road (Crowley, 2006). Roads and other types of development dissect continuous areas of habitat, breaking them apart into smaller and smaller fragments. Movement between these fragments can be difficult for some species of wildlife leading to populations of the same species becoming increasingly small and isolated (Gibbs and Shriver, 2005). These isolated populations often have reduced genetic diversity (Lesbarrères et al., 2003) that can increase the chances that they will die off due to chance events (Bennett, 1991). 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 chloride and sediment concentrations. For additional details on chloride, refer to Chapter 4.

Large, relatively undisturbed areas are important for a healthy watershed and should remain in their natural state 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.

With development comes the need for supporting infrastructure (i.e., roads, hydro corridors, pipelines, etc.). 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 contributors to the fragmenting of habitat.

The recreational activities enjoyed by many seasonal residents can also lead to the degradation or fragmentation of 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 by increasing the extent to which humans push into the more remote portions of the watershed. These access routes also create opportunities for garbage to be left behind while also providing mechanisms for the spread of invasive species.

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 (i.e., sprawl). Muskoka's development along shorelines varies from low to high 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.

THE BENEFITS OF PROTECTING LARGE NATURAL AREAS

Maintaining large areas of contiguous natural areas is important to ensure that ecological processes, structure, and functionality are maintained. Large natural areas have been shown to help maintain wildlife populations and to ensure that adequate areas are available for use by many species (Fahrig, 2003; Obbard et al., 2010). Additionally, landscapes dominated by large unfragmented areas are known to have higher water quality, provide high quality wildlife habitat, and support diverse ecological communities (Desbonnet et al., 1994) compared to landscapes with limited natural areas. 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 Environmental 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, followed closely by 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 access key areas to perform critical parts of their life cycle including reproduction and maintaining healthy populations. When developments such as roads, utility corridors, and urbanized areas are constructed, they can functionally break apart these large natural systems resulting in loss of habitat as well as key habitat areas becoming isolated or inaccessible. The loss of connectivity within these natural systems can have considerable effects on wildlife and the health of the entire ecosystem. For additional information about ecological integrity, see Chapter 14. The benefits and services that large natural areas provide can become compromised or lost altogether because of habitat loss which is a common side effect of development.

HOW IS FRAGMENTATION MEASURED IN MUSKOKA?

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

Analysis of the fragmentation indicator was completed at a quaternary watershed level using GIS and layers obtained from the Province of Ontario and the District Municipality of Muskoka (DMM). 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;

- Patches less than 200 hectares in size.
- Patches 200 to 499 hectares in size.
- Patches 500 to 4,999 hectares in size.
- Patches 5,000 to 9,999 hectares in size.
- Patches 10,000 hectares in size or greater.

The focus of this analysis has been directed towards measures of the extent of natural areas that are greater than 200 ha in area in an effort to capture those portions of the watershed that provide major biodiversity benefits. For each quaternary watershed, the amount of natural area in each of the remaining four categories were then calculated to form the basis of the grading.

It is important to note that natural area classes may span more than one quaternary watershed. Therefore, it is possible to have a patch within a class in a watershed that appears to have less than the required area. For example, in the Baysville Narrows-South Branch Muskoka River, there are only 2,360 hectares of land in the 10,000 and above hectare class size (Table 15). This would indicate that only a portion of the larger natural area is in the Baysville Narrows-South Branch Muskoka River Watershed and the remaining portion would be in an adjacent 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 and Hobbs, 1999):

- Not stressed: at least 90% of the watershed is covered in natural areas greater than 200 hectares in size. These watersheds are characterized 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.

Finally, the distribution of each fragmentation class was compared across quaternary watersheds to review the extent of fragmentation in each area. As the size of quaternary watersheds vary across Muskoka, the relative proportion of each watershed covered by a given fragmentation class was calculated to allow for comparison.

RESULTS

Table 15. Provides the class size and area for each quaternary watershed, as well as the total percentage of natural area and its resultant grade.

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
Baysville Narrows - South Branch Muskoka River	200-499	822	2.55	5	63.93	Vulnerable
32,297	500-4,999	11,380	35.23	13		
	5,000-9,999	6,084	18.84	2		
	10,000+	2,360	7.31	3		
Blackstone Harbour	200-499	540	3.09	3		
17,446	500-4,999	5,436	31.16	4	65.47	Vulnerable
	5,000-9,999	5,447	31.22	1		
	10,000+	0	0	0		

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
Cache Creek - Black River	200-499	595	1.78	2	84.24	Vulnerable
33,519	500-4,999	9,129	27.24	6		
	5,000-9,999	11,847	35.34	2		
	10,000+	6,664	19.88	2		
Distress Pond - Big East River	200-499	1,536	3.31	6	83.96	Vulnerable
46,465	500-4,999	12,127	26.1	13		
	5,000-9,999	0	0	0		
	10,000+	25,350	54.56	1		
Hollow River	200-499	1649	4.37	5	79.02	Vulnerable
37,766	500-4,999	5,854	15.5	7		
	5,000-9,999	5,724	15.16	2		
	10,000+	16,685	44.18	1		
Kahshe River	200-499	819	3.45	6	66.79	Vulnerable
23,758	500-4,999	8,625	36.3	6		
	5,000-9,999	0	0	0		
	10,000+	6,423	27.04	2		

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
Lake Muskoka - Muskoka River	200-499	4290	10.63	15	45.13	Stressed
40,356	500-4,999	9,666	23.95	15		
	5,000-9,999	4,259	10.55	2		
	10,000+	0	0	0		
Lake Rosseau	200-499	3,508	5.38	10		
65,186	500-4,999	19,351	29.69	17	55.84	Stressed
	5,000-9,999	2,107	3.23	1		
	10,000+	11,432	17.54	1		
Lake St. John - Black River	200-499	604	1.6	3	69.7	Vulnerable
37,633	500-4,999	8,854	23.53	8		
	5,000-9,999	0	0	0		
	10,000+	16,773	44.57	2		
Lake Vernon	200-499	1,093	3.09	4		
35,375	500-4,999	16,938	47.88	11	72.53	Vulnerable
	5,000-9,999	172	0.49	1		
	10,000+	7,454	21.07	1		

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
Little East River - Big East River	200-499	266	0.97	1	70.47	Vulnerable
27,558	500-4,999	3,589	13.02	7		
	5,000-9,999	812	2.95	1		
	10,000+	14,753	53.53	1		
Little Lake - Severn River	200-499	3,488	10.48	12	59.61	Stressed
33,272	500-4,999	13,223	39.74	11		
	5,000-9,999	3,122	9.38	3		
	10,000+	0	0	0		
Moon River Bay	200-499	1120	4.67	4	77.31	Vulnerable
23,997	500-4,999	7,817	32.57	8		
	5,000-9,999	117	0.49	1		
	10,000+	9,499	39.58	1		
Musquash River	200-499	930	2.93	6	78.33	Vulnerable
31,747	500-4,999	8,297	26.13	10		
	5,000-9,999	12,228	38.52	3		
	10,000+	3,411	10.74	2		

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
North Branch Muskoka River	200-499	3306	7.24	13	54.92	Stressed
45,664	500-4,999	5,700	12.48	9		
	5,000-9,999	3,877	8.49	2		
	10,000+	12,193	26.7	4		
Oxtongue River Outlet	200-499	525	1.94	4	78.48	Vulnerable
27,015	500-4,999	7,652	28.32	7		
	5,000-9,999	4,059	15.02	2		
	10,000+	8,966	33.19	2		
South Branch Muskoka River Outlet	200-499	827	2.3	6	72.24	Vulnerable
36,003	500-4,999	9,091	25.25	10		
	5,000-9,999	843	2.34	1		
	10,000+	15,246	42.35	3		

Quaternary Watershed and Area (ha)	Class Size (ha)	Class Area (ha)	Area by Class (%)	# of Patches	Proportion of Quaternary Watershed Covered by Natural Areas (%)	Grade
South Georgian Bay Shoreline	200-499	1,640	5.39	7	66.15	Vulnerable
30,415	500-4,999	2,612	8.59	5		
	5,000-9,999	1,278	4.2	2		
	10,000+	15,246	47.97	2		
Sparrow Lake - Severn River	200-499	1183	5.59	5	32.11	Stressed
21,173	500-4,999	5,616	26.52	7		
	5,000-9,999	0	0	0		
	10,000+	0	0	0		
Tea Lake - Oxtongue River	200-499	3,259	9.48	12	80.52	Vulnerable
34,369	500-4,999	20,630	60.02	17		
	5,000-9,999	0	0	0		
	10,000+	3787	11.02	1		

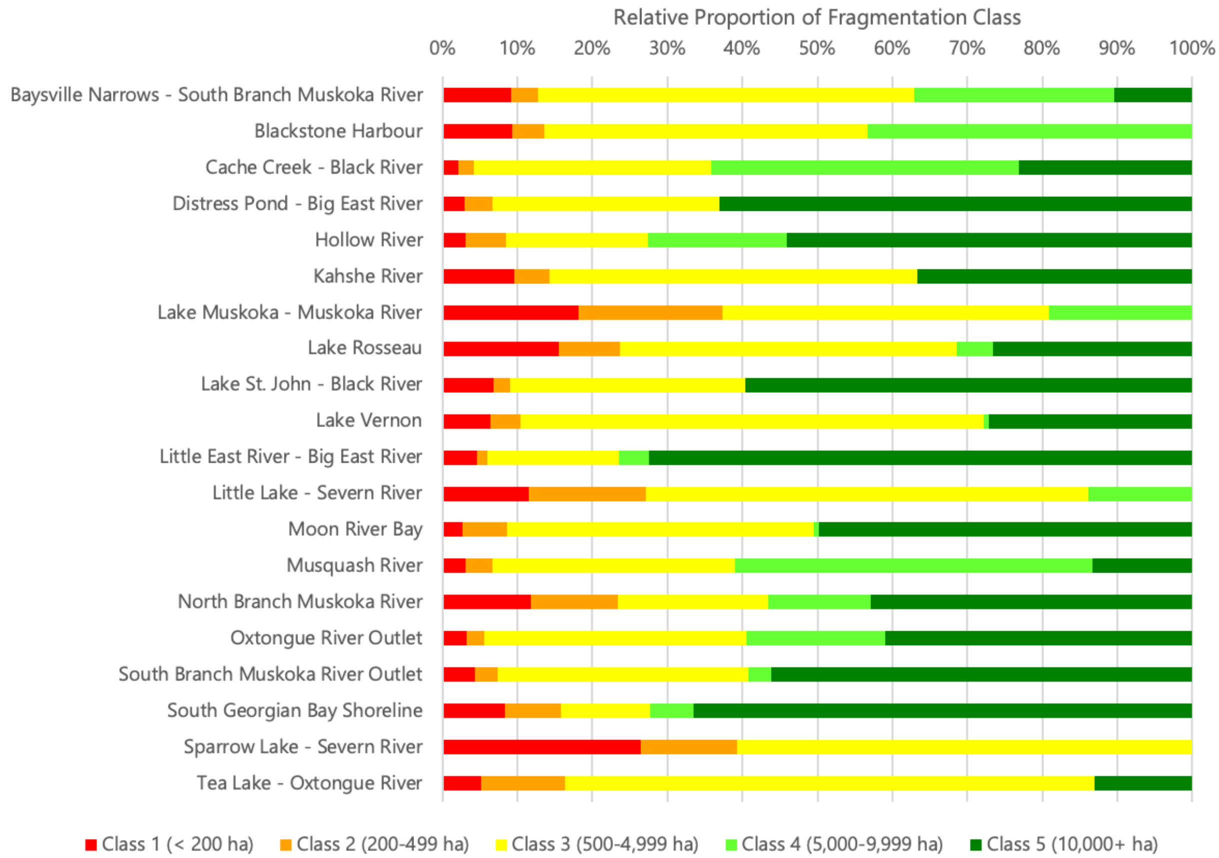

Figure 17. Relative proportion of each fragmentation class across quaternary sub-watersheds in Muskoka. Sub-watersheds with large proportions of Fragmentation Class 1 and 2 represent landscapes that have a high degree of fragmentation while areas dominated by Fragmentation Class 4 and 5 represent largely intact natural areas.

WHAT DOES IT ALL MEAN?

Across Muskoka, the majority of the quaternary watersheds have a *vulnerable* status indicating that the landscape within these areas has begun to be broken apart into smaller and smaller patches of contiguous habitat. Generally, the habitat loss is moderate and for the time being, connectivity of the remaining habitat patches is considered to be high. For some species that do not move great distances or rely on key habitat types within close proximity to each other, the existing level of fragmentation may be starting to have negative impacts. The good news is that for these areas that are *vulnerable* the degree of modification of the remaining habitat is considered to be low to moderate.

As was the case in the 2018 Report Card, both the Lake Muskoka and the Lake Rosseau quaternary watersheds continue to be *stressed* (Table 15). In 2023, three additional quaternary watersheds were identified as *stressed;* Little Lake-Severn River, Sparrow Lake-Severn River, and North Branch Muskoka River. Between 15% and almost 25% of these quaternary watersheds are comprised of patches of natural landcover types that are less than 200 ha in size (Figure 17). These areas are in the southern portion of Muskoka, as well as along a primary portion of the Muskoka River. Seasonal and year-round residential buildings and associated amenities dominate the landscape in the *stressed* portions of Muskoka. In this way, fragmentation also provides a measure of the extent of human impact on the larger landscape, pointing to portions of Muskoka where human development and encroachment are likely to be having the greatest impact on biodiversity and ecosystem health. This is in stark contrast to areas like the South Georgian Bay Shoreline, Little East River-Big East River, and the Hollow River which are dominated by large patches (i.e., > 5,000 ha, see Figure 17). As development often occurs incrementally, making loss of habitat difficult to detect until it has occurred on such a scale that the impacts are often irreversible, ongoing monitoring of areas with large components of contiguous natural landcover is important to the long-term viability of Muskoka's ecological communities.

WHAT CAN YOU DO?

- 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).
- If you are a landowner with forest property then investigate long term protection strategies such as Nature Reserves and Conservation Easement programs of the Muskoka Conservancy. https://www.muskokaconservancy.org/nature-conservation
- Limit the extent of development and clearing of natural vegetation on your property.
- Place development on your property close to existing roads thereby limiting the need for long driveways and extensive vegetation clearing.
- If you own large parcels of land, consider donating portions to conservation organizations rather than severing it into multiple smaller development lots.
- Support landscape level initiatives like Integrated Watershed Management to help bring broad scale planning and governance to the Muskoka River Watershed.
- Get more great stewardship ideas in Muskoka Watershed Council's *Living in cottage country: what you need to know* handbook.

CHAPTER 9 – HOW ARE MUSKOKA'S AVIAN SPECIES CHANGING?

Author: Aaron Rusak

This is a difficult question to answer, but a pressing one with the changing climate and increasing pressures on all species. Birds are colourful, loud, and noticeable within the various habitats, such as interior forests, found in Muskoka. In many ways, this makes them a much easier group of species to collect data for, and their presence or abundance can inform on watershed health. At present, though, there is a lack of reliable data for this region.

Breeding bird surveys can be easily repeatable, provided there are enough experienced observers. However, historical data for Muskoka is difficult to find. Much of our historical data for avian species is presence/absence data and doesn't offer any insights into overall population changes. Some of our other data is at a much larger scale and is difficult to apply to the Muskoka region. This makes long term forecasts or predictions about overall status of avian populations difficult, as the data just are not complete. There are a few conclusions that can be drawn from our existing data though and some interesting looks at some of the future data analyses we might be able to provide if more data are collected.

2023 is the third year of the third Ontario Breeding Bird Atlas, a province-wide effort to assess the current status of the breeding birds of Ontario that is compiled and published by Birds Canada. The past two atlases occurred in 1980 and 2000, each surveying bird species for a 5-year period using volunteers across the province to collect data. In the past two atlases, only presence/absence data was collected. This third atlas will also assess population sizes of species, which will allow a much better understanding of the current status of many breeding birds in Ontario and Muskoka. Some of the insights from the completion of this atlas will also provide us with foundational data that we can build upon in future studies. It will hopefully demonstrate current population sizes, changes in species composition, and other population dynamics across the province and locally.

In recent years, use of eBird, the web-based tool for citizen scientists to record, share, and review sightings of birds, has been growing rapidly, with thousands of checklists submitted every single year in Muskoka. eBird is free to use and managed by Cornell University's Laboratory for Ornithology.

Each checklist represents an individual's birding effort, with all the species observed in a given time and place being recorded. Although citizen science can have some errors, this has allowed large scale data collection that was not possible before. The amount of knowledge we have on the status of migrating and breeding birds has expanded considerably since eBird and other citizen science tools have become readily available, with noticeable growth over the last five years. These data are contributing to efforts to map breeding habitats and migration ranges in Muskoka and across the province, with eBird publishing migration maps for the majority of birds that breed and migrate through North America. Combining citizen science and the Ontario Breeding Bird Atlas, several species that were not known to breed in Muskoka have now been documented during the breeding season.

Although there is not yet enough foundational data to specify changes in population size, some of the mapping work has shown changes in breeding ranges of several species of birds. The reasons for these changes are not well-known, but a changing climate likely has some impact. Both red-bellied and red-headed woodpeckers have expanded their range into Muskoka, with several breeding locations now known in the area. Sedge wren and golden-winged warbler are other species that are being discovered more regularly in the region, either due to increased search efforts or breeding range changes. Bald eagles and peregrine falcons are breeding in locations they haven't been seen in many years as well, with records of the former appearing to become much more common. Breeding range contractions are also occurring though, with species like common nighthawk and eastern whip-poor-will disappearing from historical breeding habitats, likely due to forest regrowth. Unfortunately, much of this knowledge is not peer-reviewed, nor published, and is mainly observations from educated and knowledgeable birders. Buy-in from both scientists and citizen enthusiasts is going to be very important moving forward, to ensure that we can have some of these observations explored through a broader, more scientific lens.

In a changing climate, Muskoka may be one of the last refuges for some of these species, so these foundational data are crucial to better our understanding of how birds use our watersheds. Muskoka still has vast tracts of forested or otherwise undeveloped land, as well as many conservation reserves and parks which will allow at risk species to thrive if managed correctly. Community engagement is key, as conservation action can't be taken without sufficient data and knowledge. eBird and the Ontario Breeding Bird Atlas allow for anyone to submit bird data to help better understand the birds and habitats that Muskoka protects. If Muskoka is to become a last refuge for some species, we need to better understand our role in the protection of avian species. This of course creates additional questions on how we manage our land to better enhance the protections for birds. Do we create habitat for species at risk that are getting pushed into Muskoka from the south due to climate change? Or do we manage our forests for only the species that are currently here? Ultimately, we need to know what is here, and why our ecosystems are so vital to all the species that call them home, including birds. That requires engagements from birders, scientists, citizens, and governmental officials to make sure that the natural systems of Muskoka remain stable and protected for many years to come.

WHAT CAN YOU DO?

Discover the joy of bird watching, add your own sightings to the eBird database, and do your part to generate the more extensive data that needs to be compiled to facilitate quantitative assessments of Muskoka's bird species. eBird is at www.ebird.org.

CHAPTER 10 – INVASIVE SPECIES

Author: Dr. Peter Sale

In the 2018 Muskoka Watershed Report Card, we listed nine invasive species of concern in the Muskoka watersheds. Those species are still here and still proving damaging to our environment. One feature of invasives is that they are particularly difficult to eradicate once they have established themselves in a new location.

An invasive species is a non-native species which has dispersed, or been introduced, to a region and which is damaging to the continued well-being of at least some native species present there. Invasives are mostly introduced to new regions through human activity, intentionally or otherwise, and many aquatic invasives in Ontario have arrived here from Europe or western Asia via ballast water transported by commercial vessels that enter the Great Lakes. Many terrestrial invasives are small species easily transported unintentionally by road. Many species arrive and some become established, but to be called an invasive they must also out-compete, be an effective predator of, or in other ways damage native species they come in contact with.

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, off-roading, 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 via ballast water from international freighters, parts of Muskoka in proximity to Georgian Bay and Severn River are at a higher risk for aquatic invasive species than some inland lakes.

Beyond their impacts on native species, and therefore on the ecological systems they invade, invasive species can be economically damaging in many ways, and the costs of efforts to remove or control them can be substantial. While we are fortunate that the Zebra mussel cannot occur in the calcium-poor waters of Muskoka, the economic costs of its invasion of the Great Lakes region, via ballast water from Europe, have been enormous. Its economic impacts in the Great Lakes are due chiefly to the tendency it has to obstruct water intakes vital to many aspects of our industrial economy. It also has deleterious effects on fishery yields. In 2012, the Great Lakes Commission estimated its economic cost at US$300–$500 million annually in damages to power plants, water systems, and industrial water intakes in the Great Lakes region. And in 2022, Haubrock et al. calculated that the zebra mussel and its close relative the quagga mussel had a cumulative economic cost across North America since 1980 of US$49.9 billion. The zebra mussel continues to spread through waterways of North America, and the cost of keeping water intake pipes open and free-flowing continues to grow.

The zebra mussel is not uniquely economically costly. A recent global study by Anna Turbelin and others (2023) reports that the cumulative global economic cost of all invasive species since 1980 (US $1.2 trillion) is now second only to the cumulative cost of damage due to storms (US $1.9 trillion), and well ahead of costs for drought (US $244 billion) or wildfire (US $138 billion, all costs at 2020). Invasive species have important impacts both on our environment and on our economic well-being.

In the Muskoka watersheds, significant efforts and costs have been expended in attempts to control certain invasive species. Phragmites (*Phragmites australis subsp. australis*) is an invasive wetland plant that can out-compete native sedges, grasses, and other plants. It forms dense monocultures and can grow 4.5 metres tall, impeding movement of wildlife and reducing property values as well. It is often seen as small clumps in the drainage ditches along roadways as its seeds are spread on vehicles. From these roadside ditches it can spread into nearby wetlands. Phragmites is a well-established invasive, particularly in the western part of the Muskoka watersheds and along the shore of Georgian Bay.

The largest control program in our region has been undertaken by Georgian Bay Forever (GBF) with several partners over the last decade (Carpenter, 2022). Their approach is to cut Phragmites stems below the water level thereby drowning and killing the roots. This labor-intensive, but pesticide-free approach has been proving successful. In 2019 GBF developed a 5-year plan to aim for 90% eradication by 2025 of a set of 588 mapped stands. These include 514 sites in Georgian Bay Township and 69 sites in the Township of the Archipelago as well as sites further south. In 2022, all but eight Township of the Archipelago sites, and 65 of the Township of Georgian Bay sites were under treatment (being cut, or already cut and being monitored). GBF is on track to eliminate Phragmites from these 588 stands by 2025. The Muskoka Conservancy also regularly mounts volunteer efforts to remove Phragmites from wetland areas in the properties it manages. Such removal, whether by a municipality or by an NGO, is labour-intensive and therefore costly, but there are few alternatives for removing this species.

INVASIVE SPECIES IN OUR WATERSHEDS

The nine invasive species of particular concern in the Muskoka watersheds are listed in Table 16 Each is well distributed in the region, but data on the true distribution of invasives is sparse and biased by the fact that records depend largely on citizens reporting their sightings. Consequently, reports are more numerous in those parts of the watersheds most frequented by people. For that reason, we do not attempt a quaternary-scale analysis of distribution for this Report Card. The effective management of invasive species, like that of species at risk, depends on sightings being reported. All residents and visitors can help by downloading the relevant app and uploading their sightings of these species.

Table 16. The invasive species of greatest concern in the Muskoka watersheds.

Species Name	How It Got Here	Year First Sighted in Muskoka	Ecological Impacts
Spiny Waterflea	Ballast water of ships from Eurasia; spread through our watersheds on improperly cleaned recreational vessels and fishing gear.	1968	Since their main diet is other zooplankton and they are avoided as food by fish, they reduce food supplies for small fish including juvenile sport fish.
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 by competing for food sources. They are also linked to outbreaks of botulism type E

Species Name	How It Got Here	Year First Sighted in Muskoka	Ecological Impacts
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 plant 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 skin rash (phytodermatitis).
Eurasian Water Milfoil	International 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.

INVADING PATHOGENS ARE INVASIVE SPECIES TOO

In addition to the invasive species in Table 16, several pathogens have arrived in the Muskoka watersheds in recent years. Disease-causing microorganisms are also invasive species, although not readily detectable until they are well-enough established to be causing disease. In many cases, the arrival of novel pathogens appears to be a consequence of climate change: a warmer climate is permitting species to extend their ranges northward.

Lyme disease is caused by one such invading pathogen, the bacterium *Borrelia burgdorferi*. This pathogen is carried by the blacklegged tick *Ixodes scapularis*. A person bitten by an infected tick is at risk for developing Lyme disease. District health units in Ontario are monitoring the spread of blacklegged ticks which are expanding their range northward as climate ameliorates.

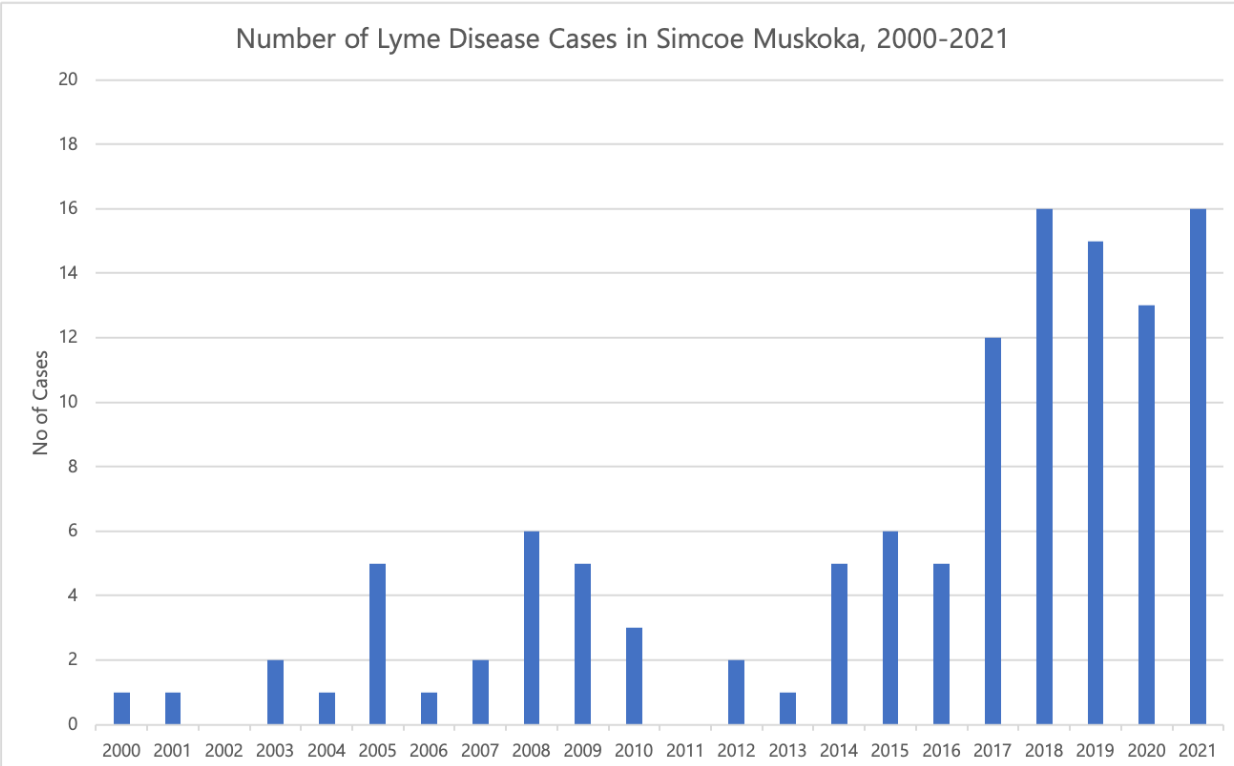

Figure 18. The incidence of reported cases of Lyme disease within Simcoe County and District Municipality of Muskoka. The incidence remains low (3 per 100,000 people per year in 2021) and the great majority of cases are in Simcoe County, but there is a clear trend with the incidence more than doubling since 2016.

Data Source: Integrated Public Health Information System (iPHIS) [2000-2021]. Ontario Ministry of Health, extracted 26 Jul 2022.
Note: Includes confirmed and probable cases. Case definition changed in 2009 and 2015.
https://www.simcoemuskokahealthstats.org/topics/infectious-diseases/i-p/lyme-disease

As of 2023, data suggest that Lyme disease has probably now arrived in Muskoka. The Simcoe Muskoka District Health Unit (SMDHU) mostly aggregates the data for the District Municipality of Muskoka (DMM) and Simcoe County, but while the overall incidence remains low (16 cases of Lyme disease, 3 per 100,000 people in 2021), it has more than doubled since 2016 and 36% of cases appear to have been contracted within this region (Figure 18). The great majority of cases have come from Simcoe County rather than Muskoka and the 2021 Ontario Lyme Disease Map shows only Simcoe County and not District of Muskoka as a 'risk area' for Lyme disease. Because Lyme disease takes up to a month to develop it can be difficult to determine where a person acquired the infection.

If Lyme disease is now entering the Muskoka watersheds, West Nile virus is a pathogen not far behind. West Nile virus is carried by mosquitoes and has a reservoir in bird populations. A mosquito which has fed on an infected bird can deliver the virus to a human. The SMDHU actively tracks cases of West Nile virus, but the incidence is even lower than that for Lyme disease. Apart from 2017, when 7 cases were recorded, the number of cases per year has been three or less since 2002, and many years, including the two most recent, record no cases. The higher incidence in 2017 was believed to be caused by a warm, wet summer which facilitated survival of both mosquitoes and the virus. The SMDHU anticipates that climate change will favour further increases in the prevalence of this pathogen in our region (SMDHU 2022).

HOW SHOULD WE INTERPRET THE OCCURRENCE OF INVASIVE SPECIES IN OUR WATERSHEDS?

Invasive species have been a fact of life for all regions occupied by humans ever since we began to move widely about the planet. At the turn of the 20th Century, European colonists actively introduced species in the belief they would 'improve' the environment. They brought garden plants, songbirds, rabbits, and foxes with them, hoping to make their new colonies a bit more like home. That is why there are rabbits in Australia, starlings in North America, and invasive flowering plants everywhere.

Humans slowly learned that introductions carried enormous economic and ecological risks, but with our global transportation systems in place, we remain the transport vector for the vast majority of long-distance invasions. We also continue to actively introduce, often with the intention of providing a predator or pathogen to control an earlier unfortunate introduction, and sometimes these introductions are themselves problematic. In the Muskoka watersheds there is a constant risk of introduction of invasive fish species by misguided anglers who believe they can improve the fishing by illegally dumping fish into lakes where they do not already occur. There is also the risk of inadvertent introductions by otherwise law-abiding boaters who forget to rinse and clean their boats when moving from one lake to another. These short-distance transport systems provide the final mile ensuring that once an invasive species has got to a region, it can rapidly get to most suitable habitats within that region.

But invasive species rarely improve an ecosystem, and they are one of the major threats to biodiversity as they out-compete native species. Sometimes they can prove substantially costly to control, interfering not only with ecosystem integrity but also with elements of the human economy. They can seldom be eliminated once established, so their costs become a permanent cost for the community.

The Muskoka watersheds have modest numbers of invasive species largely because the region is relatively lightly populated, and because individuals and municipalities have mostly done what they can to avoid introducing and to report sightings of introduced species. The growing intensity of human use of our watersheds increases the risk of invasions if we are careless. On the other hand, the growing number of eyes on the lookout for invasive species across our watersheds enhances our ability to detect invasions early when the chances of successful eradication are greater. We all have a part to play.

Climate change is now altering the rules making it easier for some species to invade and making it more difficult for some native species to resist: a warmer, wetter world does not make life easier and to the same degree for all species. Reducing the risk of invasions is the flip side of caring for species at risk. The more we can act to retain the integrity of our ecosystems by sustaining native species and battling invasives, the healthier our watersheds will be.

WHAT CAN YOU DO?

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 (www.eddmaps.org), or contact the Invading Species Hotline at 1-800-563-7711.

CHAPTER 11 – BEECH BARK DISEASE

Author: Javier Cappella

Beech bark disease is an example of a disease in a non-human species being caused by an invading pathogen. Its effects on our forests can be profound both ecologically and economically, and Westwind Forest Stewardship Inc., the not-for-profit with responsibility for managing crown land in the French-Severn forest, has undertaken substantial work to understand and to ameliorate the impacts of this disease. Westwind has provided the following information for this Report Card.

OVERVIEW

American beech is a common tolerant hardwood tree that is found in many tolerant hardwood stands in the Great Lakes-St. Lawrence Region. It is commonly found in stands dominated by Sugar maple and other tolerant hardwood species and is easily identified by its smooth gray bark. Beech is highly valued for its contribution to wildlife habitat, in particular providing mast (hard fruit i.e., beechnuts) as an important fall food for many species. Beechnuts have more nutritional content for wildlife than even red oak acorns. Black bears leave claw marks in the thin smooth bark of the tree when they climb into the crowns to forage for beechnuts on the branches. Beech directly and indirectly contributes to biodiversity. Beech is not considered a particularly high valued tree for wood products, although it makes excellent firewood.

Beech bark disease (BBD) has been present for a century in eastern Canada although entry into Ontario has been much more recent. It was first confirmed in the Muskoka area in 2010. Two different organisms form the BBD, which only affects American beech; a beech scale insect and a neonectria pathogen *(Neonecria faginata).* The scale insect feeds by inserting feeding tubes into the outer bark cells allowing the pathogen to enter and become established. The infection can go as deep as the cambium layer. The pathogen causes death to the cells and as more cells are killed, branches and finally whole sections of the tree weaken and die. The lag time between scale infestation and appearance of fungal infection varies from 2 to 5 years, however, local observations suggest the shorter time periods are more common.

Individual scale insects are difficult to see. However, they cover themselves with a white waxy coating which is easily spotted, especially when populations increase. It is not uncommon to see large sections of Beech tree trunks covered in white.

The scale spreads when the tiny crawler stage of the beech scale insects moves on wind currents or attached to wildlife. Spread can be assisted by the movement of firewood, especially during the crawler stage, in mid-summer to late fall.

In fall, the pathogen produces small, bright red fruiting bodies called perithecia, which erupt through the bark. Initially these occur in lemon-shaped clusters but as the infection progresses, they coalesce into large, sunken areas on main branches and the bole of the tree. BBD can kill Beech trees, however, as the trees are weakened, secondary pathogens may also be able to successfully attack and cause mortality.

The Ontario Forest Research Institute (OFRI) (2012) advises that scattered large beech trees are not attacked by the beech scale. These trees are disease resistant, as the canker fungus only infects scale-infested trees. There is also some evidence that a very small portion of beech trees might be resistant to the scale insect (1-4%), and therefore not affected by the canker fungus. It is also possible that some trees may be susceptible to the scale insect but resistant to the fungal pathogen. The extent of this is unknown but OFRI (2012) reports any resistance or tolerance is minimal.

IMPACTS OF BEECH BARK DISEASE

- Beech bark disease kills a majority of American beech trees across the forest landscape where it is present and is therefore a threat to local forest biodiversity. The loss of a major component of the tree canopy has forest management and wood supply impacts in managed forests. The loss of beechnut production, which has a high caloric content, will have an impact on wildlife. Mature beech trees often provide high quality cavities for bird nesting and animal denning. Dead and dying beech provide poorer quality and less desirable cavity nest opportunities.
- Beech-snap is a term that describes how large branches or whole mature beech trees break off at the stem, even before it is obvious that they are dying. Beech trees in the forest often

grow in clusters, mass mortality due to BBD results in a large hole in the canopy, affecting cover for wildlife and increasing light levels below.

- BBD is unique in that the disease that kills its host also contributes to the successful germination and proliferation of a second generation of the host. i.e., as mature trees are killed. Beech regeneration tends to proliferate in a vigorous manner, sometimes called Beech jungles or beech thickets. These young beech seedlings and saplings are often beech root sprouts. The host root provides resources to the beech saplings to take advantage of the additional light from the parent beech trees dying.
- Because these beech saplings have the same genetic makeup as the parent trees from which they sprout, they will not have genetic resistance or tolerance to beech scale or the fungal pathogen. They tend to dominate the understory and eventually midstory of tolerant hardwood stands where BBD has caused damage to the beech overstory. They outcompete most other species including sugar maple, yellow birch and other wood species that should be forming a large part of the future forest canopy. The expectation is then that the young beech trees will not allow other species to mature but will be killed themselves by BBD before they contribute to the mature forest canopy cover that is typical of the Great Lakes-St. Lawrence forest regions tolerant hardwood forests. It is expected that there will be a short period of time in which the second generation of beech trees become sexually mature and produce beechnuts before succumbing to the BBD themselves. In addition to outcompeting other tree species, they also shade out other forest plants. In upper state New York, studies showed a 50% reduction in species richness, including fern species, that are found in these stand conditions.

BEECH BARK DISEASE TREATMENT OPTIONS

PREVENTION

- Do not transport beech firewood or logs from infested stands to uninfested areas between mid-summer and late-fall to prevent beech scale infestations from becoming established in new areas.
- Use harvest systems that minimize injuries to beech root systems. Root injury can cause extensive root sprouting, especially if roots are injured in spring.

TREATMENT

- At the forest level there are no effective treatments against the scale insect nor the *Neonectria* pathogen although individual horticultural and urban trees can be treated with insecticides and fungicides.
- Forest management efforts focus on targeting most beech trees for removal. Salvage of BBD impacted trees can retain some value of the tree before the trees become hazard trees. However, due to the quick decline of the trees, there is little time from onset of disease before the wood has no economic value.
- In addition to removal of diseased trees, it is important to use beech regeneration control techniques to deal with the secondary impact of the disease, the generation of an abundant and vigorous beech understory. If beech trees are left, they will produce root shoots (and beechnuts for seed) before they die.
- Available beech regeneration control techniques include;

Brush saw and/or chainsaw: To manage young beech tree regeneration, the use of a motorized brush saws with a circular blade, chain saws, or other cutting devices cut the plant off above the ground is the most effective approach. Brush saws are effective for smaller beech up to 8 cm while a chainsaw is required for larger beech trees.

Brush saw treatment with a herbicide applied to the cut stump: The same stem felling is carried out as with the saw only, except that a specific herbicide (glyphosate or triclopyr) is applied to the cut stump to control resprouting.

Stem specific herbicide treatments including; basal bark treatment with triclopyr, "Hack N' Squirt", and cut stump treatment: Each of these methods is labor-intensive and involves careful application of triclopyr (garlon) or glyphosphate herbicide to individual stems or small trees to kill the tree and to limit or eliminate the root's capacity to produce new sprouts. Workers must be licensed pesticide applicators.

Broadcast spraying of herbicide: The herbicide, usually glyphosphate, is sprayed from ground level onto the foliage of small trees and saplings, killing the trees and their roots. Non-target trees and other plants will also be affected so cautious application is required.

REGENERATING TO NON-BEECH TREES/SUPPLEMENTAL PLANTING

In managing BBD, the overall objective of regeneration or supplemental planting is to reduce the amount of beech in the understory and midstory so that other species of trees may be in a more competitive position to grow and form part of the mature forest canopy.

Depending on circumstances there may already be healthy young non-beech trees growing among the Beech, or there may be few healthy non-beech trees present. Having other species already established is the optimal condition. In this case, removal of the diseased beech acts as a forest tending action. It releases the established desired species of tree from competition by beech, increasing the chance of success and decreasing the time for these non-beech trees to dominate the stand.

In cases where there are few healthy non-beech trees present, the beech removal acts as a site preparation action but a new crop of young trees must be established. While these new trees are being established, new beech seedlings may also be becoming established, especially when there are larger beech trees remaining in the stand.

Tolerant hardwood forests are very well suited to natural regeneration. The number of tree species that can be found is relatively large compared to other forest types in Canada. In addition to beech, sugar maple, yellow birch, red oak, black cherry, basswood, red maple, and white ash are hardwood trees typically found in tolerant hardwood stands. Some conifer trees may be found in these stands with eastern hemlock being the most common, however, white spruce, white pine, and red spruce are often associated species. While these species all share many attributes with respect to requirements for light and soil type, they each have specific growing conditions for which they are best suited.

All trees can be either planted or naturally regenerated depending on the suitability of the site and availability of seed trees. In Canada, most regeneration of tolerant hardwoods uses natural regeneration while artificial regeneration is commonly used for conifers. Not all species are reliably found at tree nurseries so seedling availability can be a limiting factor. Hardwood species often cost more to produce and have lower probability of survival as seedlings due to various factors including browsing by animals such as deer. Hardwood species successfully germinate naturally to produce thousands of trees per hectare significantly increasing the probability of enough trees surviving to maturity. Conifer tree planting is often less expensive, and a single conifer seedling has a higher probability of surviving into maturity then a single hardwood seedling.

In the context of managing BBD, artificial regeneration has several benefits over natural regeneration. If timed correctly, planted trees may have a competitive advantage over new Beech seedlings becoming established, the sensitivity to specific soil exposure conditions of some species is reduced, and there is greater predictability in timing of seed crops.

Tree planting also can be done to augment natural regeneration. However, natural regeneration may aggressively out-compete planted trees. For example, naturally regenerated sugar maple may shade out a planted oak tree.

MONITORING

Tending of the planted, or to some extent, naturally regenerated trees may be required. This may involve control of future beech, control of less desirable trees over planted trees, or control of non-woody vegetation including grasses, raspberries, and other herbaceous plants. As with any forestry-related activities, professional foresters and other forestry consultants are good resources to assist in deciding how to proceed.

CHAPTER 12 – SPECIES AT RISK IN MUSKOKA

Author: Dr. Peter Sale

In 2018, the Muskoka Watershed Council (MWC) Report Card reported species at risk as an indicator of watershed health. Species at risk are plants and animals that that have been judged to be threatened with extinction, extirpation, or endangerment in a region, so the number of species at risk should reflect the risk of declining biodiversity in the watershed. Loss of biodiversity is significant to the health of the watershed.

It all seems straightforward, however, the data on species at risk are incomplete for several reasons and the results may be misleading. To begin with, the number of species at risk is a poor index of biodiversity loss. Biodiversity is not just the number of species but also the diversity within species and the variation in species present from one place to another within the region. There can be substantial loss of biodiversity in an ecosystem without any species being at risk of extinction. In addition, the process by which a species is determined to be a species at risk does not result from an unbiased assessment of the status of all species present. And yet, the existence of species at risk is another message that our environment is less healthy than it might be, we cannot simply ignore them!

Think of the ecosystem, our Muskoka watersheds, as an aircraft, and all the species living here as the rivets holding it together. Losing one rivet is unlikely to cause the plane to crash, but how many rivets can be lost before that crash occurs? This chapter presents what we know about species at risk in the Muskoka watersheds, how their status might be changing, and what we as individuals can do to help prevent their loss from the landscape.

Since our 2018 Report Card, there have been several changes in the list of species at risk that occur in the Muskoka watersheds. Has the situation improved or gotten worse? Sorry, it's more complicated than that. We need to recognize that a global biodiversity crisis is occurring.

WHAT ARE SPECIES AT RISK AND WHY ARE THEY IMPORTANT IN MUSKOKA?

The official list of species at risk in Ontario (SARO) is a list of species of plants and animals that have been determined to be threatened with extinction, extirpation, or endangerment in the province. In other words, the SARO list comprises species that have been professionally evaluated for their ability to persist in this province. In this regard, the SARO list is comparable to other lists of species judged to be in danger in other regions: Canada's Species at Risk Public Registry of species judged at risk in Canada, the USA's Endangered Species List of species judged at risk under the Endangered Species Act, the IUCN Red List of Threatened Species, judged to be at risk worldwide, and so on.

In all these cases, species are listed because they have been determined to be at risk because of the natural and human-induced threats that they face, including;

- Habitat loss: the replacement of natural habitat by agricultural, industrial, urban, or other human-built environments.
- Habitat fragmentation: the splitting of areas of contiguous natural habitat into smaller, separated parts such as by roads constructed through natural areas and by any form of development that alters or divides portions of natural habitat.
- Enhanced competition, predation, or disease resulting from introduced and/or invasive species.
- Traffic mortality.
- Direct killing or harassment by humans.
- Illegal or excessive harvesting including poaching and overhunting.
- Pollution, especially from chemicals released to the environment.
- A changing environment that is becoming less suitable for them.

In Ontario, species thought to be at risk are brought to attention of the Committee on the Status of Species at Risk in Ontario (COSSARO), an expert panel of up to 12 members. Available evidence is reviewed, and a decision made. If a species is classified as at risk by COSSARO, it is added to Ontario's List of Species at Risk (https://www.ontario.ca/laws/regulation/080230) in one of four categories, as defined in Table 17. Species on the list are reviewed and reclassified as needed from time to time.

Table 17. Species at Risk Categories.

Category	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 but is facing imminent extinction or extirpation.
Extirpated	A native species that no longer exists in the wild in Ontario but exists elsewhere.

Extinction is a normal part of evolution. Species have been going extinct for millions of years. Over the last 500 million 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 90% of species lost); the most recent was at the end of the Cretaceous (approximately 75% of species lost, including all remaining dinosaurs except birds). Extinctions have always occurred at much slower rates between these mass extinction events, but today the global extinction rate is about 1000 times greater than the long-term average. While the causes of extinction vary depending on the species, many scientists are now concerned that we are entering another mass extinction event. This one is being caused by human activities such as loss and fragmentation of habitat, pollution, over-harvest, and climate change.

A list of species at risk tells us that there are species in our local environment that are at imminent risk of extinction. In 2023 the SARO list includes 237 species; 50 species of special concern, 56 threatened, 115 endangered, and 16 listed as already extirpated in Ontario. This is a substantially lower number of species at risk than we reported in 2018, primarily because COSSARO re-evaluates species from time to time as more data become available and many species that were on the list are now deemed to not be at risk. Most of the listed species occur in more southern parts of Ontario where urbanization and agriculture have had the greatest impacts on natural systems.

SPECIES AT RISK IN THE MUSKOKA WATERSHEDS

Located at the southern edge of the Canadian shield, the Muskoka watersheds are 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. Among the species occurring here, 48 species are on the SARO list (District Municipality of Muskoka, Georgian Bay Biosphere Reserve).

Before going further, note that COSSARO designates species to be at risk, or not, in Ontario. While COSSARO does examine population performance at local scales, it does not specify whether a species' populations are doing well or otherwise in specific regions within Ontario. If a SARO species occurs in our watershed, it may be at risk of dying out here, or its local populations might be doing quite well and could help to sustain its populations elsewhere through dispersal. We should do what we can to assist it even when local populations seem to be sustaining themselves.

The SARO species known to occur in the Muskoka watersheds are tallied in Table 18. Six species (forked 3-awned grass, rusty-patch bumblebee, northern brook lamprey, western chorus frog, eastern milk snake, and Henslow's sparrow) included in our 2018 Report Card are no longer included. Eight other SARO species (American ginseng, black ash, spotted wintergreen, American bumblebee, northern sunfish, evening grosbeak, wood thrush, and yellow rail) have been added. Another six species on the list have had their status changed since our 2018 Report Card. Four of these six (lake sturgeon, massasauga rattlesnake, red-headed woodpecker, and Algonquin (eastern) wolf) are now more critically endangered than before, while the fox snake and barn swallow have improved status. As further discussed below, the additions and deletions since our 2018 Report Card are due to changes in actual status, or new records of a SARO species in our region, or errors in the 2018 Report Card.

Table 18. The 48 species at risk occurring in the Muskoka watersheds in 2023. The status at time of our 2018 Report Card is shown in brackets.

Type	Common Name	Habitat	Status
Plant	American Ginseng	Understorey plant in rich, well-drained soils of mature deciduous forests	Endangered (Omitted by error in 2018)

Type	Common Name	Habitat	Status
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	Black Ash	Shade-intolerant wetland tree	Endangered (New SARO addition Ontario)
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	Spotted Wintergreen	Dry oak-pine woodland habitats	Threatened (Omitted in error, 2018)
Insect	American Bumblebee	Open grasslands and meadows	Special Concern (New addition Muskoka)
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
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	Endangered (Special Concern)

Type	Common Name	Habitat	Status
Fish	Northern Sunfish	Shallow vegetated areas in warm, slow-flowing rivers, streams and in lakes	Special Concern (Omitted in error, 2018)
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	Threatened (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 Ribbonsnake	Close to water	Special Concern
Reptile	Massasauga Rattlesnake	Tall grass prairie, bogs, marshes, shorelines, forests, alvars	Endangered (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
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

Type	Common Name	Habitat	Status
Bird	Barn Swallow	Open barns, under bridges, in culverts	Special Concern (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 Whip-poor-will	Deciduous or mixed open forests with little or no underbrush	Threatened
Bird	Eastern Wood-pewee	Forest edges	Special Concern
Bird	Evening Grosbeak	Open, mature, mixed wood forests	Special Concern (New SARO addition Ontario)
Bird	Golden-winged Warbler	Shrubby fields, woodland edges, abandoned farm fields, wooded swamps	Special Concern
Bird	Least Bittern	Wetland habitats with cattails and open pools and channels	Threatened

Type	Common Name	Habitat	Status
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	Endangered (Special Concern)
Bird	Wood Thrush	Mature deciduous and mixed forests	Special Concern (Omitted by error, 2018)
Bird	Yellow Rail	Deep among reeds and sedges of wetlands	Special Concern (New Addition Muskoka)
Mammal	Eastern Small-footed Myotis (Bat)	Under rocks, rock outcrops, buildings, under bridges, caves, mines, or hollow trees	Endangered
Mammal	Eastern (Algonquin) Wolf	Deciduous or mixed forests near a water source	Threatened (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

Table 19. The six species listed in 2018 but now considered to be either not occurring in the Muskoka watersheds or no longer at risk in Ontario. Previous status is shown in parentheses.

Type	Common Name	Habitat	Status
Plant	Forked Three-awned Grass	Open, bare ground or sparsely covered grassy areas	Does not occur in Muskoka (Endangered)
Insect	Rusty-patched Bumble Bee	Mixed farmlands, urban settings, savannah, open woods and sand dunes	Does not occur in Muskoka (Endangered)
Fish	Northern Brook Lamprey	Clear, cool-water streams with soft substrates including silt and sand	Does not occur in Muskoka (Special Concern)
Amphibian	Western Chorus Frog	Marshes or wooded wetlands for close proximity to both terrestrial and aquatic habitats	Not at risk (Threatened)
Reptile	Eastern Milksnake	Old fields, pine forest, open deciduous woodland, rock barrens, sand dune	Not at risk (Special Concern)
Bird	Henslow's Sparrow	Abandoned farm fields, pastures, wet meadows	Does not occur in Muskoka (Endangered)

WHAT DOES IT ALL MEAN?

Taken at face value, the status of species at risk could be seen as relatively stable since 2018. A list of 46 species in 2018 has grown to 48, with six species removed and eight added (four of the eight should have been there in 2018). Two other species have been given less dire classifications, and four species have been reclassified as more critically endangered. Several things argue against complacency, however.

- COSSARO reviews many species for which insufficient data are available to evaluate whether or not they are at risk; these are set aside.
- COSSARO is a committee of up to 12 people. It has a limited capacity to evaluate species brought forward.
- COSSARO is politically constrained to not list species at higher risk levels if they are doing well in neighbouring jurisdictions such as Manitoba or New York, even though their numbers may be declining in Ontario. Groups and individuals only bring forward species that have attracted interest.

Notice that the list contains only three insects but 20 birds. This is not because birds are at greater risk of extinction than insects: it's because people care about birds a lot more than they do about the thousands of insects that occur in Ontario. The official list of species at risk is a list of those species that people have become concerned about. It does not accurately reflect the reality of what is happening to our biodiversity.

Even for the whole of Ontario, the SARO list includes only lichens, plants, molluscs, insects, fish, amphibians, reptiles, birds, and mammals. We have numerous species that do not belong to one of these groups and some of them are surely at risk. This is not a problem unique to Ontario. Even global databases of species at risk of extinction are compiled in the same haphazard way, relying on interested individuals to bring forward species for consideration and evaluation (Lepczyk et al., 2022).

The six species removed from the SARO list for Muskoka, since our 2018 Report Card (Table 19), have not been removed because they have recovered and are thriving. Species like the forked 3-awned grass, the rusty-patch bumblebee, and the northern brook lamprey probably never occurred in Muskoka and should never have been on the local list. The western chorus frog has larger populations in southwestern Ontario but has long been quite rare on the Canadian shield. There is evidence of genetic differentiation between these regions and the shield populations may be a distinct species. COSSARO reasoned that the genetic differences were not definitive, treated it as a single species, and removed it from the list because of the healthy southwestern populations. It perhaps should be considered at risk in Muskoka, but the rule is if a species is not declared at risk for the province, it cannot be declared at risk for a region within the province unless it has been formally identified as part of a distinct population.

The milk snake has been removed from the list because healthy populations of this relatively secretive species exist in many parts of southern Ontario, including Muskoka. It has not recovered since 2018 and it should never have been classified as at risk. Henslow's sparrow remains listed as Endangered in Ontario, but it has been removed from the Muskoka list because there have been no recent sightings here. Muskoka is at or beyond the northern limit of its range in the province so whether the lack of sightings means it is now extirpated here or was never here in the past is uncertain.

The list of species at risk in Ontario and the list for Muskoka are both useful. But they should not be interpreted as factually complete lists: they are indicative, not definitive. And the rules governing whether a species is listed or not have elements that are logically consistent, but not necessarily biologically logical.

GLOBAL BIODIVERSITY LOSS – ARE WE DOING ENOUGH?

Globally, scientists now estimate that species are going extinct at a rate at least 1,000 times faster than the long-term average of 1 species per million species per year (Pimm et al., 2014). Over 40,000 species are listed as threatened worldwide, which equates to about a million species threated with extinction over the next 100 years (Diaz et al., 2019). A recent evaluation suggests over half the currently threatened species worldwide will require active and targeted recovery efforts if extinctions are to be avoided (Bolam et al., 2023). Listing species at risk is not sufficient, even if the lists were complete, which they are not. And the global problem of biodiversity loss can only be dealt with by solving it locally for specific species in many different places.

What does this mean for the Muskoka watersheds? We need to ask ourselves whether we really care about these struggling species in our midst. Are we doing all that we could do to enable their populations to thrive? Does their possible loss even matter to us?

What could we do that is not already being done? The good news is that provincial ministries attempt to track sightings of species at risk, while keeping such information confidential to prevent illegal collection and sale as exotic pets, and both provincial and municipal governments take some steps to conserve such species.

In recent years, improvements to roads in our region have been timed to avoid conflict with nesting turtles and have included the installation of fencing and underpasses (culverts) to permit turtles, other reptiles, and small animals to cross roads safely. About ten years ago, in undertaking improvements to Muskoka Road 10 (MR10) and Muskoka Road 48 (MR48), the District Municipality of Muskoka (DMM) identified risks to nesting turtles and ensured roadwork was scheduled for periods outside the nesting season. As well, on MR48, three underpasses were installed using 1.8m diameter culverts with the lower 25% filled with natural substrate.

The culverts are about 400 m apart, and fine mesh diversion fencing was installed on both sides of the road to guide turtles and other small animals towards the culverts. More extensive fencing and larger culverts were used when the Ontario Ministry of Transport (MTO) undertook improvements to Highway 400 over the past decade. Square-section culverts, primarily for drainage, had been used when the highway was upgraded around 2000. In 2014, fine-mesh exclusion fencing was installed along both sides of the highway connecting five existing culverts in a 3.3 km section south of Go Home Lake Road. From 2016 to 2017, fine-mesh exclusion fencing as well as large animal fencing was installed on both sides of a 9.6 km section south of the Lake Joseph Road interchange. These fences divert animals to the eight 1.8m square-section culverts along this section and a single 4m square culvert accessible to larger animals. The primary objective for the fine-mesh fencing of Highway 400 was protection of nesting turtles and snakes. During 2022 to 2024, DMM is upgrading Fraserburg Road (MR14) which had been impassable during the severe 2019 flood. With the Ontario Ministry of Natural Resources and Forestry (MNRF) providing input to planning, DMM is looking to schedule the roadwork well outside the nesting season for turtles, and to provide suitable sandy fill in appropriate locations to encourage nesting away from the road surface. Each of these cases is an example of a government authority undertaking specific actions that help to conserve SARO species in Muskoka.

WHAT CAN YOU DO?

Ontario has clear requirements in law governing how or if development can occur on lands where SARO species are present, and our municipalities do what they can to protect such species when development projects are being approved. But laws on the books do not automatically lead to compliance by those who prefer to use their land without regard to the requirements of other species.

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 other important species such as the Algonquin (eastern) wolf, lake sturgeon, and bobolink. Declining populations of all species, particularly those at risk, may impact humans in numerous ways.

High biodiversity is the basis of ecosystem resilience and the foundation of the human economy. We 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 tourism and recreation-based economy. The loss of native bees and other 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, limiting the food available for wildlife. Given the changes in lake chemistry taking place in this region, we also need to attend to the status of important lake food-web species, such as *Daphnia* and other zooplankton species that are unlikely to ever find their way onto a SARO list. Losses of such species could have important consequences for more visible parts of our lake ecosystems.

If we are serious about reducing the rate of extinction, we must up our game individually because of the forecasted effects of climate change, let alone other environmental stressors, that keep creating new challenges for all our native species. The recovery of many at risk species can be aided by habitat protection. In the Muskoka watersheds, we need to encourage all landowners to maintain natural environments wherever possible on their property. They will be rewarded with abundant wildlife and the background music that birds, frogs, and insects provide us for free.

We also need to become better informed about the biodiversity crisis that our list of 48 species at risk hints at, and, in particular, about how the loss of diversity as species disappear detracts from the ecosystem's capacity to be resilient in the face of various stressors. Thinking of the ecosystem, our Muskoka watersheds, as an aircraft, and all the species living here as the rivets holding it together can be helpful. Losing one rivet is unlikely to cause the plane to crash, but how many rivets can be lost before that crash occurs?

As well as being better informed about our species at risk, we need to be more alert to their occurrence, and we need to take the time to report our sightings via the several on-line portals that now exist as apps on cell phones. That way governments have better information on where protection is needed for which species. As well, we citizens could demand full enforcement of existing law, as well as stronger laws to protect biodiversity. Biodiversity provides the fabric that enables our ecosystems to function. Our ecosystems sustain our own lives.

Several portals that facilitate reporting sightings are;

- 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 ran the **Ontario Reptile and Amphibian Atlas** Program (www.ontarionature.org/protect/species/herpetofaunal_atlas.php), in which citizen scientists could help track reptiles and amphibians. That program has now ceased although the site contains much useful information and directs visitors to the Natura Heritage Information Centre and iNaturalist.
- **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.

CHAPTER 13 – WEATHER AND CLIMATE

Authors: Dr. Richard Lammers, Chris Cragg, David Parsons

Along with human alterations to the natural environment, weather and climate control many of the changes we see in Muskoka. This chapter presents several sections describing;

- Trends in the long-term observations of temperature and precipitation,
- Ice-on and ice-off dates for lakes in Muskoka,
- The meteorological conditions and pre-conditions required for spring floods, and
- A discussion of climate change impacts and what you can do.

LONG-TERM TEMPERATURE AND PRECIPITATION TRENDS IN MUSKOKA

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 already a reality in Muskoka (Sale et al., 2016), and our understanding of its current and future effects is improving with time. The indicators used in this chapter focus on physical changes the Muskoka Watershed has undergone due to climate change, measured by temperature and precipitation.

Muskoka Watershed Council (MWC) has reported on climate change several times. In 2007 and 2018, climate was featured in the Muskoka Watershed Report Card. In 2010, MWC 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 over long time periods in the Muskoka River 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 and the increase in air temperature. While climate change is a planet-scale process, impacts and changes are felt by individuals and so examination of local-scale measurements can clarify our understanding of local climate change and the resulting local consequences for the Muskoka watersheds. Two useful measurements are temperature and precipitation from observational weather stations. These data are collected year-round by the Canadian federal government and, for some meteorological stations have been collected for over a century. The temperature and precipitation measurements can be downloaded from historical records spanning as far back as the 1880s (https://climate.weather.gc.ca), providing us with very long-term local trends. Such local weather data is fundamental to our understanding of climate change and represents a key measure within the scientific community (IPCC, 2021). Changes in temperature and precipitation affect our land, lake, and river ecosystems, lake freeze-up and break-up times, wildlife patterns, flooding, drought, and human health.

Data Sources: The longest meteorological record in Muskoka comes from several stations in Beatrice, located in central Muskoka, with precipitation beginning in March 1876 and complete temperature records beginning in January 1878. Until recently the long-term record was split among multiple stations established successively through time in the vicinity of Beatrice, however, researchers at Environment and Climate Change Canada (ECCC) have joined the records of these different stations and adjusted and harmonized the data to make a single time series for temperature (Vincent et al., 2020) and precipitation (Mekis and Vincent, 2011). This new data set, known as the Adjusted and Homogenized Canadian Climate Data (AHCCD), was specifically designed for exploring climate change. The entire available record of the Beatrice AHCCD station number 6110606 was used for this report. The Muskoka airport station, with only temperature data and a much shorter time frame, was excluded.

Data processing: Data files for precipitation (daily rain, snow, and total precipitation) and temperature (daily minimum, maximum and mean temperatures) along with available documentation were downloaded from the ECCC data server (ECCC, 2022).

Indicator selection: A list of climate indicators was assembled based on existing scientific papers, reports and websites. A total of 22 temperature-based and 19 precipitation-based indices were identified (a complete list available from R.B. Lammers). This list was then reduced to those indices that were considered understandable and interpretable by most people and straightforward to calculate (see Williams and Eggleston, 2017; and Trewin et al., 2021 for a discussion of indices for communication). These indices were calculated, graphed, and presented to the MWC Report Card Sub-committee for comments. Based on this feedback, the indices were selected for presentation in this background report.

Disclaimer: The reader should bear in mind several caveats when interpreting the meteorological data presented here. First, these results are derived from one location in Muskoka and for any given weather event there is great variation between locales. For this reason, we chose robust climate indices that are likely to be similar to those at other meteorological stations in the region. Second, these data represent historical observations and do not automatically imply these changes will follow the same trends into the future. Third, the time period selected for calculation of the trends will have an impact on the slope values. The shorter the time period, the more sensitive the trend will be to occasional extreme records. For this reason, we have chosen to examine trends only over the maximum timeframe available to ensure more stable trend lines.

RESULTS

Numerous indices were plotted for the two fundamental meteorological variables widely collected, temperature and precipitation. Indices covering annual, seasonal, and monthly time periods were generated and the following section discusses those indices where we see the larger changes over time.

TEMPERATURE CHANGES

The largest change over time in seasonal temperatures was in the seasonal mean (average) of the daily maximum temperatures in the winter (the 90 days of January, February, and March) and in the fall (the 92 days of October, November, and December). Based on the trend line, mean daily maximum temperature in the winter has increased over 1 °C per 100 years (Figure

19) and by just under 1 °C per 100 years in the fall (Figure 20). These increases in seasonal maximum temperature were driven by strong positive trends in the months of February and March in the winter and November and December in the fall. The tendency of days to become warmer was less pronounced at other times of the year. Daily minimum temperature trends were lower than daily maximum temperature trends except in December when it was equal to the daily maximum temperature trend.

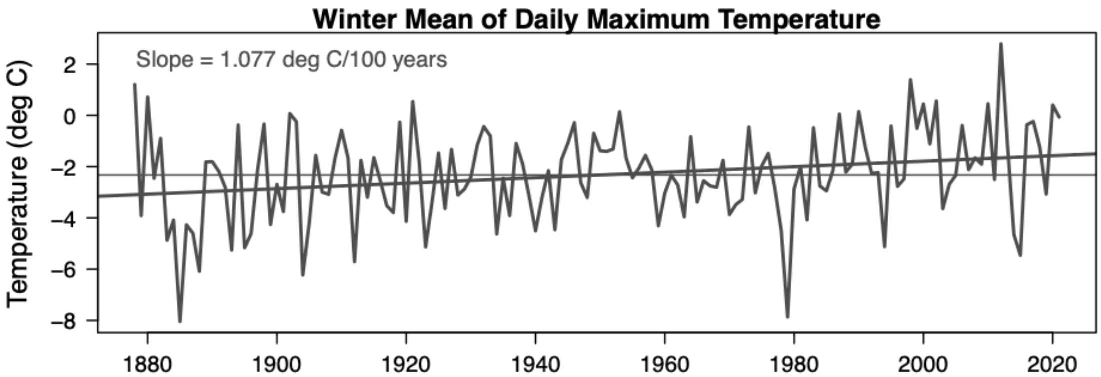

Figure 19. Seasonal mean of daily maximum temperatures for winter (January, February, and March) with trend line and change over time. The thin horizontal lines show the average over the full time series and the thick inclined lines show the slope of the linear regression line (trend).

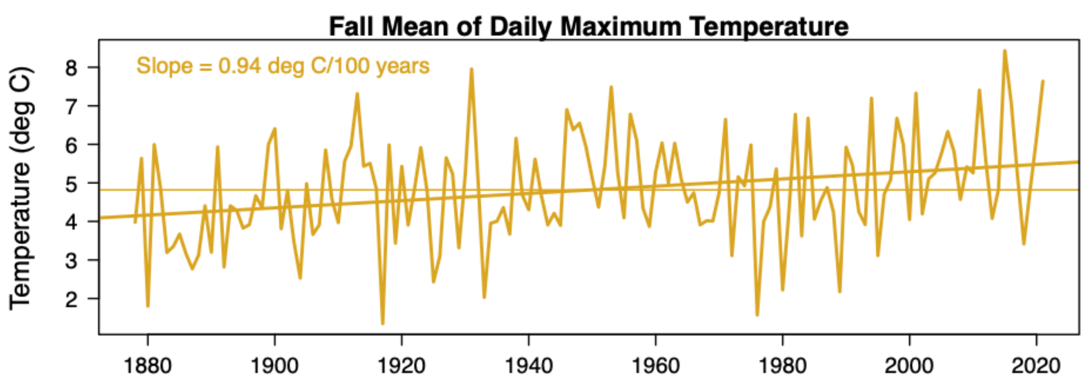

Figure 20. Seasonal mean of daily maximum temperatures for fall (October, November, and December) with trend line and change over time. The thin horizontal lines show the average over the full time series and the thick inclined lines show the slope of the linear regression line (trend).

Another way of looking at changing temperature is through a count of days in each year where the temperature exceeds some threshold value. Two different measures are used here: *summer days:* the number of days in each year where the daily maximum temperature is greater than 20 °C (Figure 21) and *icing days:* the number of days in each year where the daily maximum temperature is less than 0 °C (Figure 22). The summer days index shows an increase of over 7 days per 100 years and the icing days index sees a decline of over 9 days per 100 years. For icing days, we treated years as extending from 1st July to 30th June so that the count of icing days would be for a single cold-season.

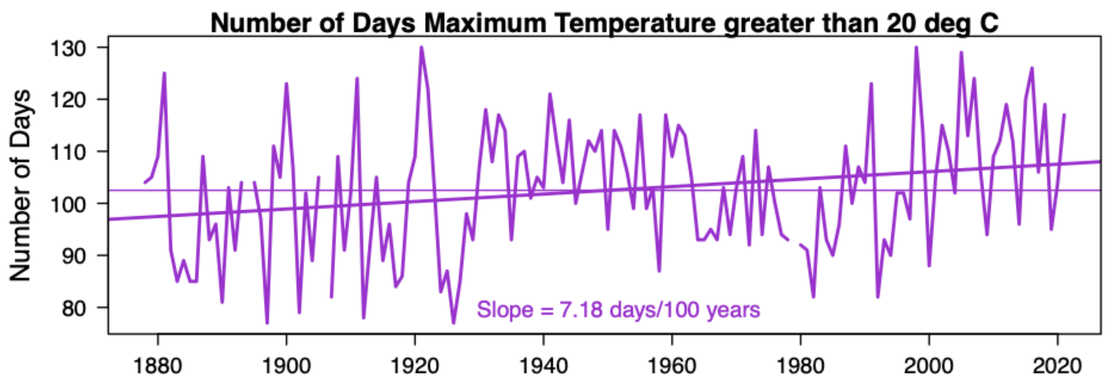

Figure 21. Summer days: the number of days in each year that daily maximum temperature is greater than 20 °C. The thin horizontal line shows the average over the full time series and the thick inclined lines show the slope of the linear regression line (trend).

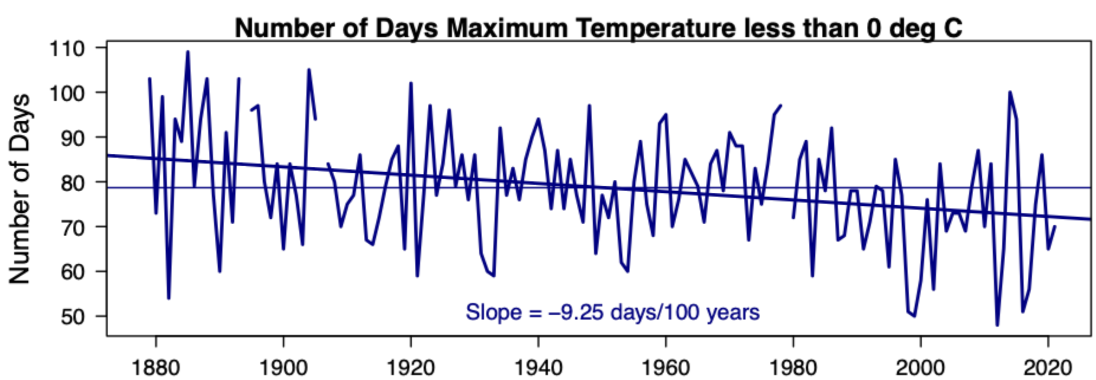

Figure 22. Icing days: the number of days each winter that maximum temperature is less than 0 °C. The thin horizontal line shows the average over the full time series and the thick inclined lines show the slope of the linear regression line (trend).

PRECIPITATION CHANGES

The second fundamental meteorological variable is precipitation, which is divided into rain and snow. Total annual precipitation (Figure 23) and the total annual rain component (Figure 24) both show increases over the 140-year record. Total annual precipitation averages 1,121 mm per year with 71.4%, or 801 mm per year arriving as rain and the rest as snow but the graph shows an increasing trend in rainfall and in total precipitation. The amount of snow does not appear to have increased (Figure 25). Both total precipitation and rain alone have increased approximately 1.3 mm per year over the 140 years. The total increase is almost entirely due to rain as the snow trend is negligible.

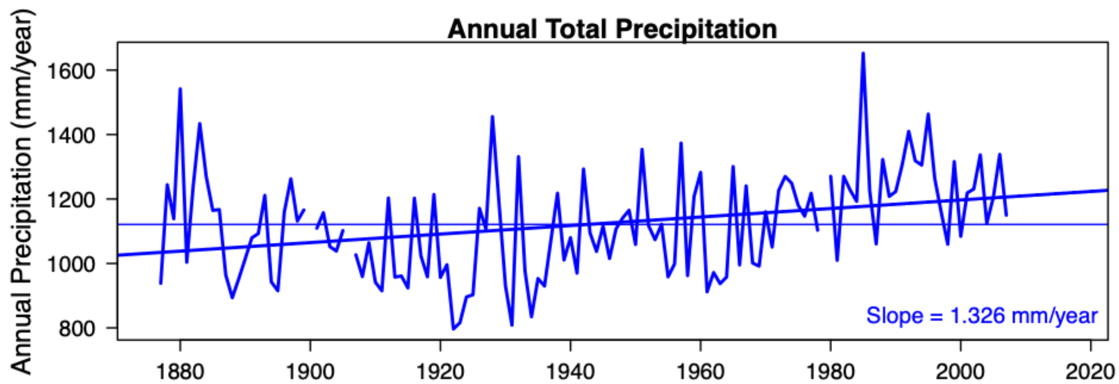

Figure 23. Annual total precipitation (rain plus snow). The thin horizontal line shows the average over the full time series and the thick inclined lines show the slope of the linear regression line (trend).

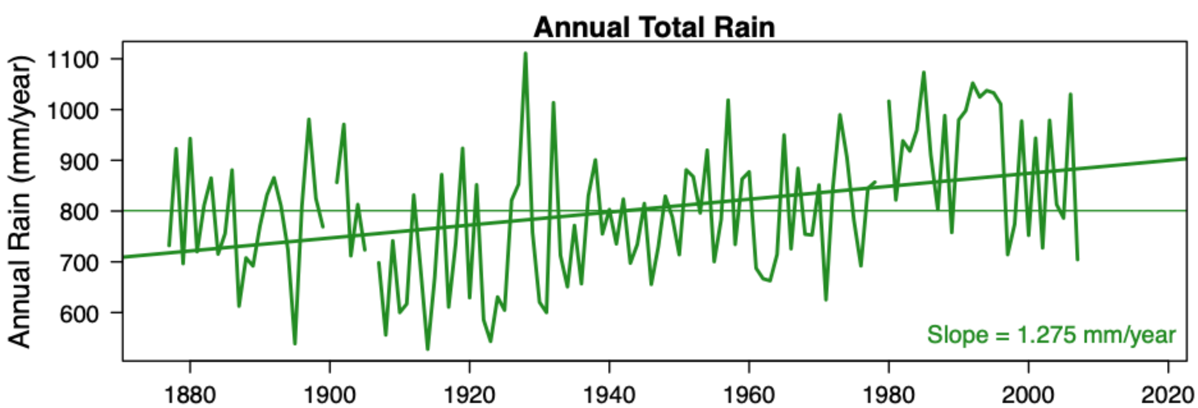

Figure 24. Annual total rain. The thin horizontal line shows the average over the full time series and the thick inclined line shows the slope of the linear regression line (trend).

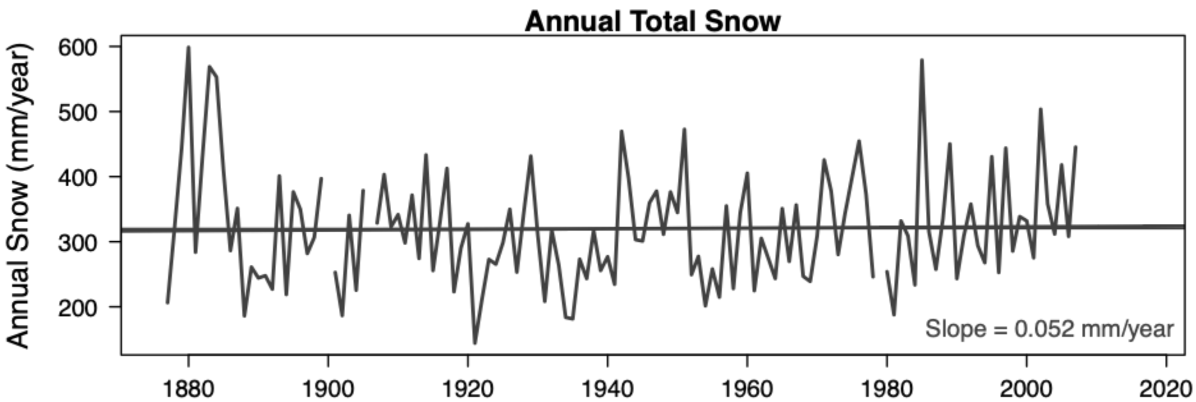

Figure 25. Annual total snow. The thin horizontal line shows the average over the full time series and the thick inclined line show the slope of the linear regression line (trend). The lower trend line overlaps the horizontal average line.

Other characteristics of precipitation can be seen through the *annual precipitation days* index, a count of the number of days in each year with any precipitation (Figure 26). For the annual precipitation days index the daily precipitation must be greater than 1 mm per day to count as rain. This index shows an increase of 0.36 days per year representing 36 additional days of precipitation over a span of 100 years.

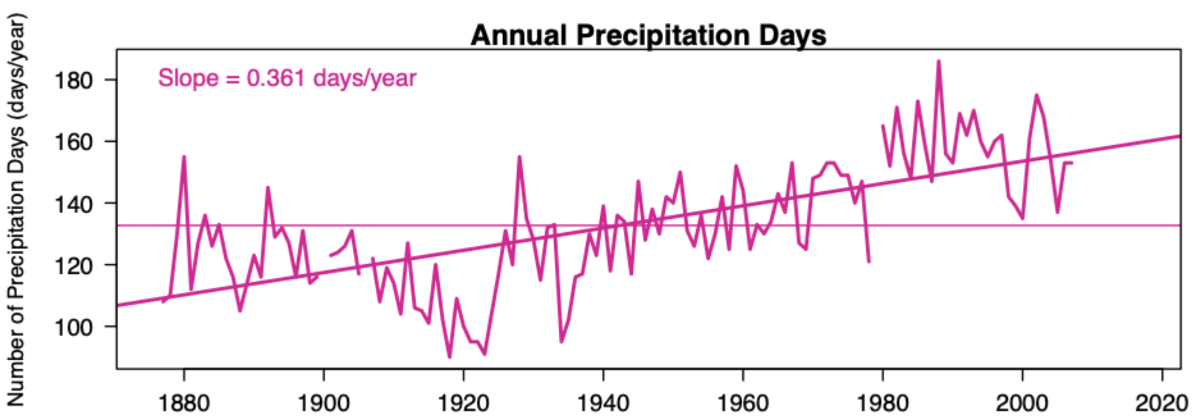

Figure 26. Number of days each year with precipitation greater than 1 mm per day. The thin horizontal line shows the average over the full time series and the thick inclined line shows the slope of the linear regression line (trend).

WHAT DOES IT ALL MEAN?

Temperature is important for controlling rain/snow mix and the timing of snow melt. Temperature also governs water loss in Muskoka through evapotranspiration. Precipitation is important as it is the supplier of water for the entire system. Changes in our climate will not just lead to changes in the weather because these changes will have a wide range of impacts on our environment and our lives, including on our lakes, our forests, and our health.

In reviewing the long-term climate trends, we see that Muskoka has been getting warmer and wetter. The greatest warming occurred primarily from late fall to the end of winter. An increase in the number of warm days suggests we may be getting more heat waves (Figure 22), however there is no observed increase in the number of days with daily maximum temperature greater than 30 °C (not shown). Therefore, Muskoka has seen an increase in warm summer days, but little increase in the very hot days that can impact ecosystem and human health. The decrease in the number of days when daily maximum temperatures are below 0 °C indicates a larger number of days in which the snowpack is likely to be melting. What happens to the water during a mid-winter snow melt event remains an open question. If the meltwater refreezes deeper in the snowpack, then the snowpack becomes denser, and that water remains available for the spring freshet. If the meltwater enters the river system in mid-winter, then some of the spring freshet is released earlier in the winter, thus reducing high water levels in the spring.

The increased temperatures (Figures 20 and 21) and the shift of snow into December and January (not shown) point to a narrower snow season length. The increase in annual total precipitation is driven almost entirely by the increase in rain with the snow trend remaining nearly constant (Figure 25) suggesting that in the shorter snow season, winter snowfalls are more frequent and/or heavier.

There is an increase in the number of precipitation days per year (Figure 26). This indicates the possibility of increasing precipitation frequency: however, further work would be required to better understand these changes.

If these observed long term trends continue through to the end of the 21st Century, then Muskoka is on a course to see much more than 1 °C of warming in the fall and winter. However, the current expectation is that warming will be much greater than this as climate model results show winter temperatures are anticipated to increase by 2 to 7 °C across a range of climate scenarios (Figure 4.6 in Bush and Lemmen, 2019). These same model results indicate summer warming to be in the range of 1 to 7 °C (Figure 4.7 in Bush and Lemmen, 2019). If Muskoka follows the more extreme scenarios, then the temperature changes will be much more extreme than those we have experienced in the last 140 years.

Estimates of changes in precipitation to the end of this century are much more variable in the climate models. Annual precipitation changes in Muskoka are estimated to remain the same or increase by up to 20% with more precipitation in the winter and less in the summer (Figures 4.17, 4.18, 4.19 in Bush and Lemmen, 2019). The historical changes observed in the precipitation record fall within this range.

WINTER ICE

Lake ice-on and -off dates for selected lakes have been compiled by the Dorset Environmental Science Centre (DESC) since 1975 and were reported in the 2018 Report Card. The data comprise ice-on (Figure 27) and ice-off (Figure 28) dates from which the number of days during which the lake is completely ice-covered can be calculated (Figure 29). The ice-on or ice-off date is charted by its calendar day number. For example, in a non-leap year, December 1st is day number 335 out of 365. Most of the data is from Grandview Lake, located outside of Baysville, ON.

ICE-ON DATES

Initially in the DESC data, the day on which ice covered the lake, occurred in November or early December (Figure 27). Since 1996, with 2018 being the exception, ice coverage now begins in December. The trendline for ice-on dates suggests that lake ice is forming later in the year by approximately 3.8 days over 10 years.

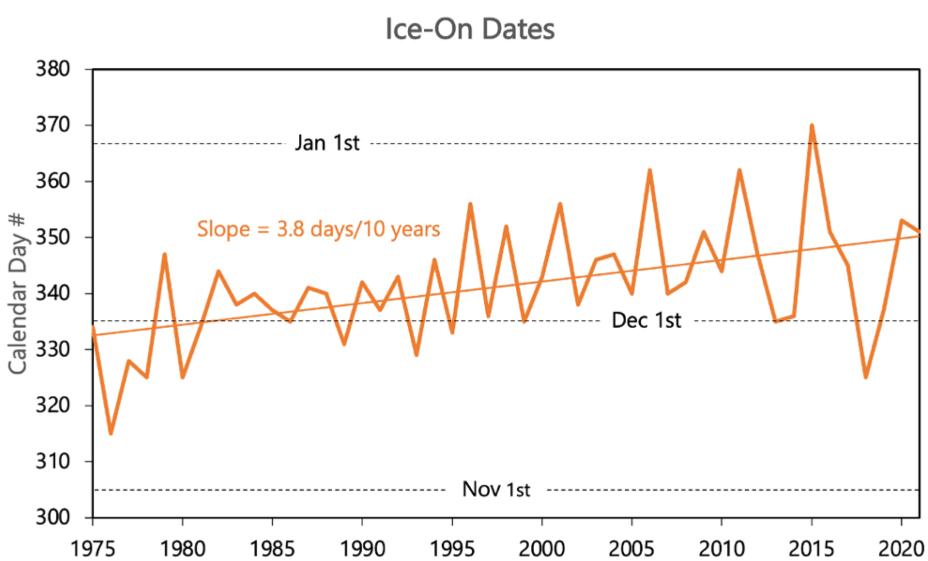

Figure 27. Ice-on Dates since 1975: Dates are represented as the numerical day of the year with January 1st equal to day 1. The straight line through the data is the linear regression of ice-on date, with a shift towards later dates of 3.8 days per 10 years. Unpublished DESC data.

ICE-OFF DATES

Since 1975, ice-off dates appear to be occurring slightly earlier in the year (Figure 28), however the degree of change since 1975 is less than the change in ice-on date. On average, the ice is leaving the lake approximately 0.6 days earlier over a 10-year period.

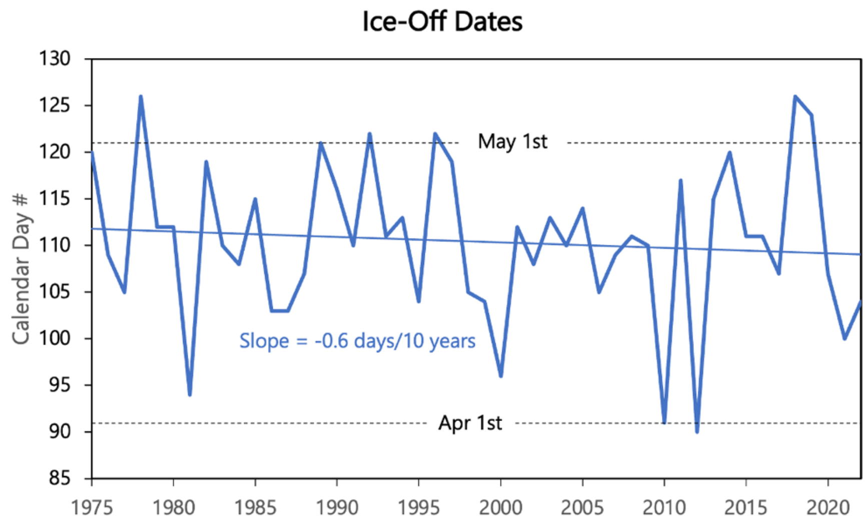

Figure 28. Ice-off Dates since 1975: Dates are represented as the numerical day of the year with January 1st equal to day 1. The straight line through the data is the linear regression of ice-off date, a very small shift towards earlier dates of 0.6 days per 10 years. Unpublished DESC data.

ICE COVER

As a result of lake ice forming later in the year and melting earlier in the following year, the number of days of ice coverage has decreased at a rate of 4.4 days over 10 years (Figure 29).

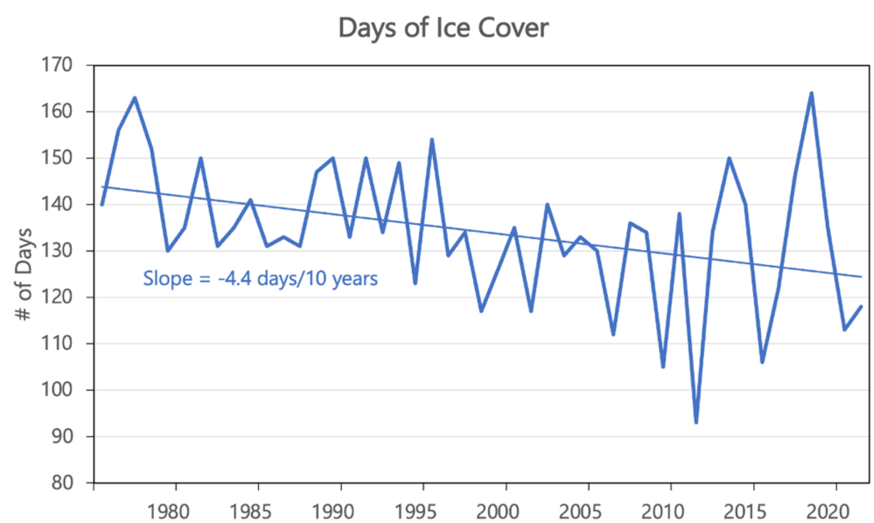

Figure 29. Days of Ice Cover since 1975: The number of days of winter ice cover. The straight line through the data is the linear regression of winter ice cover showing a decrease of 4.4 days per 10 years. Unpublished DESC data.

STORMS AND THEIR CONNECTION TO MUSKOKA FLOODS

Heavy rainstorms during snowmelt are a key contributor to spring flooding. These storms rise in the American south-west and are usually labelled Colorado lows or Texas lows. Increasing temperatures can enable these storms by warming the waters in the Gulf of Mexico or Pacific Ocean which increases evaporation allowing more moisture to escape into the atmosphere for northward transport. Such storms were contributors to the Muskoka floods in 2013 and 2019 (Table 20) and yielded a near-miss flood in 2023.

Table 20. Flood Events & Spring Heavy Rainfall in Muskoka for selected years 1985-2023: Rows, in bold, represent the year of Lake Muskoka flooding events. Rows, in italics, are flooding near-misses.

Year	Snow (SWE)	Heavy Rain >50 mm	More Rain >25 mm (1 week)	Flooding (Elevation)*
2023	*176 mm*	*66 mm*	*Yes, but 10 days later*	*Near Miss (225.95 m)*
2019	**187 mm**	**58 mm**	**Yes**	**Yes (226.45 m)**
2016	**82 mm**	**55 mm**	**Yes**	**Yes (226.04 m)**
2013	**134 mm**	**76 mm**	**Yes**	**Yes (226.25 m)**
2008	*194 mm*	*46 mm*	*No*	*Near Miss [225.93 m]*
2007	87 mm	57 mm	No	No [225.72 m]
1998	125 mm	57 mm	No	No
1985	**202 mm**	**59 mm**	**Yes**	**Yes**

** Flood elevation for Lake Muskoka is 225.97 m*

When a heavy snowpack, rapid melting and subsequent heavy rain combine, the total amount of water released in the watershed exceeds the capacity of the lakes and rivers to contain it. When this happens, water spills over the lake shorelines and riverbanks and submerges roads, structures, docks, and boathouses. Study of these past floods has helped identify these risk factors. The flooding risk looks like a decision tree (Figure 30).

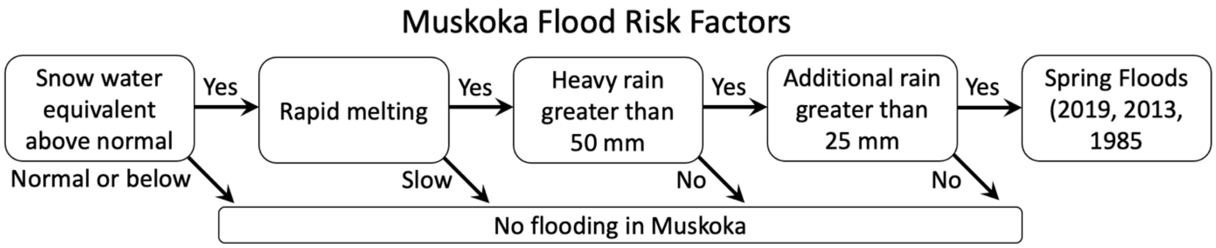

Figure 30. Muskoka flood risk factors showing the sequence of events and conditions that are required to produce flooding in Lake Muskoka.

In sequence, if there is enough snow, if it melts quickly, if heavy rain falls during the melt period, and if further significant rain also falls before the watershed drains then these components combine. If they result in 250 mm to 300 mm of water accumulation, then the watershed cannot contain this amount of water, nor can it release the water downstream fast enough due to physical constraints in the geography and we get flooding. On the other hand, if any of these factors are not present, or do not occur in close proximity in time, then flooding is avoided.

How much snow is a concern and how do we measure it? Typically snow cores are taken at several locations around the watershed by the Ontario Ministry of Natural Resources and Forestry and the amount of water in the melted core is recorded. This measure is called snow water equivalent. Past flooding records have shown that flooding becomes possible when there is 150 mm or more of snow water.

Next, the snow must melt rapidly to become a problem. Slow melting enables the melt water to be carried by our rivers and streams and delivered to Georgian Bay, so there is no problem. The Muskoka River Water Management Plan (Ontario Ministry of Natural Resources, 2006) tells us that dangerous melting occurs when two or more days have peak temperatures exceeding 10 ^{o}C.

The next step in the flood risk decision tree is heavy rain falling on the already melting snow. This both swells the volume of water and accelerates the speed of the melt. Past records show heavy rain as being more than 50 mm over a two-day period. Typically, Muskoka gets high rainfall when cross-continental storms, known as Colorado Lows or Texas Lows, transport "atmospheric rivers" of water from either the Pacific Ocean or the Gulf of Mexico. Environment Canada reports (Bush and Lemmon, 2019) that the frequency and intensity of such storms is increasing due to climate change (Figure 31).

This is already being experienced in Muskoka. The number of storms producing >51 mm rain in the 20-year period from 2000 to 2019 was double the number in the preceding 30 years (Table 21).

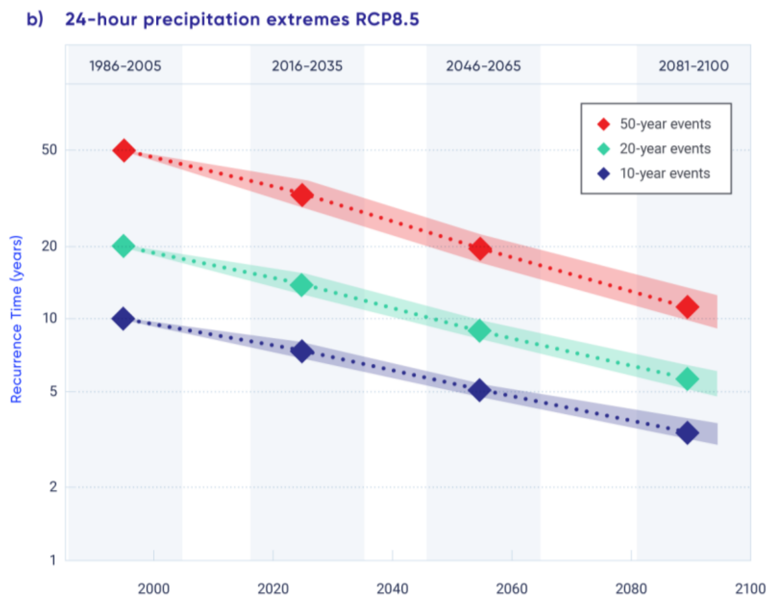

Figure 31. Predicted 24-hour precipitation extremes for a high warming future scenario. Recurrence time is the average amount of time between these extreme precipitation events. Reproduced from Bush and Lemmen (2019), figure 4.20.

Table 21. 20-year and 30-year storm frequency in Muskoka.

Time Period	# Spring Storms >51 mm	# Spring Storms >25 mm
2000 – 2019 (20 years)	6	31
1970 – 1999 (30 years)	3	30

In addition to strong storms, climate change is enabling persistent rainy weather by weakening the Jet Stream. This produces stuck or blocked weather patterns characterized by an Omega Wave shape jet Stream (Figure 32). The implication of these weather pattern changes is an increased risk of flooding during high snowfall years in Muskoka.

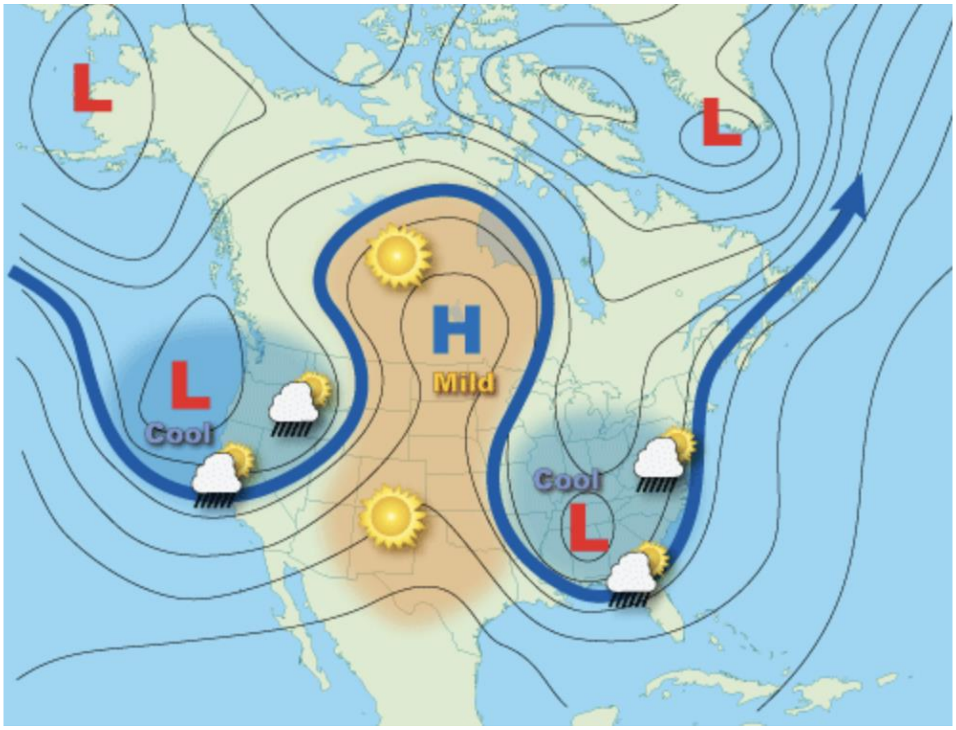

Figure 32. Blocked weather patterns leading to high rainfall or drought.
https://www.noaa.gov/jetstream/upper-air-charts/basic-wave-patterns

Lastly in the decision tree, subsequent significant rainfall of 25 mm or more can add to the water volume vying for space within watercourses and lakes of the watershed. If this occurs within a week of the previous melt and storm then it adds to the water volume before the watershed has a chance to drain, exacerbating the situation.

What happened in 2023? For Lake Muskoka, the flood zone starts when water in the lake rises to an elevation of 225.97 m. Table 20 shows, for Lake Muskoka in 2023; snow water near 2019 levels, heavier rain than 2019, melting temperatures in the 20 ºC range and a near-miss flooding event because the subsequent rain arrived more than one week later allowing some of the lake water to drain. Nevertheless, many shoreline properties built at lower levels were submerged. Additionally, ice out occurred early so there was no ice damage during high water.

These combined factors allow us to understand, identify and, in some cases prepare for, spring floods.

YOU, ME, AND CLIMATE CHANGE

HOW MIGHT CLIMATE CHANGE IMPACT OUR LIVES?

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. 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, stormwater management, and the need for road salt application, which will increase the chloride which is now at harmful levels in many of our lakes and streams. Read Chapter 4 to better understand the impact of chloride on our environments.

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.

WHAT CAN YOU DO?

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. See Climate Action Muskoka (https://www.climateactionmuskoka.org) and the District of Muskoka Climate Action Plan (https://www.muskoka.on.ca/en/environment/muskoka-s-climate-action.aspx) for more guidance.

- **Local monitoring programs:** District of Muskoka's Biological Monitoring Program, Ontario's Lake Partner Program, NatureWatch, and other programs supported by your Lake Association or community. Make use of the available data from sources such as the Muskoka Water Web http://www.muskokawaterweb.ca.
- **Reduce your carbon footprint:** Be energy efficient by buying energy efficient vehicles, when possible, hang your laundry outside 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 for 18% 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:** Write to your area politicians at all levels of government and demand action to address climate change issues.

CHAPTER 14 – ECOSYSTEM INTEGRITY AND MEASURING WATERSHED HEALTH

Author: Kevin Trimble

This Report Card is our attempt to measure the health of our watersheds, but what do we mean by *watershed health*? We depend on a healthy ecosystem for our own well-being and enjoyment, but individual indicators, like water quality or forest cover tell only part of the story and may miss critical elements of overall health.

It is particularly difficult to grasp whether the overall health of our ecosystem is changing because the Muskoka region is a high-quality, world-class destination with only about 4% of its area occupied by urban development and agriculture (Dougan, 2023). This is an environment in remarkably good condition and small changes in that condition may be difficult to see. Still, with several stressors acting on our watersheds, subtle changes may be threatening this high-quality environment. An assessment of overall health is needed.

WHAT IS AN ECOSYSTEM?

Let's start at the beginning. A watershed is an ecosystem, a collection of numerous species of plants, animals, and microorganisms living in an environment (we are one of those species). Every one of those species interacts either directly or indirectly with all the other species and with the non-living components of its environment; the water, the nutrients, and the weather. Together, these interactions determine whether that species is prospering (becoming more abundant) or suffering (becoming less abundant or even disappearing from the ecosystem). In addition, each species performs critical functions for the maintenance of the whole system, so the many interactions also determine the state of the ecosystem. With numerous species present, the number of interactions can be mind-boggling (King, 1993). The various interactions mean that there are usually changes happening in this complex, dynamic system, indeed, it is common to speak of ecosystems as existing in a state of dynamic stability. Those changes may lead to change in overall ecosystem health if they push the state of the system away from its optimum condition.

Understanding the structure of an ecosystem, the myriad interactions among its species and their environment, and how the state of that ecosystem will change from minute to minute or decade to decade is a fundamentally difficult task. That is the task which occupies the lives of ecologists regardless of whether they are seeking to evaluate the productivity of fish populations in a lake, the status of populations of a species at risk, or the health of an ecosystem. Robert May, the famous Australian ecologist, said "ecology is not rocket science – it's much harder than that".

WHAT IS ECOSYSTEM HEALTH?

So, what is ecosystem or watershed health? We can draw an analogy with another complex system, the human body. There are healthy people and less healthy people, and health professionals are in the business of evaluating the states of these complex human systems. A healthy individual is in a state in which the various interactions among the components of their body lead to positive outcomes such that an individual is likely to continue living, perhaps to grow, to have children, and to live a quality life. An unhealthy individual is in a state where the various interactions among the components of their body are not leading to positive outcomes. This individual may have an illness that is curable or one that is life-threatening, but in any event is leading a life which is of lesser quality.

Health professionals do not have simple thermometer-like instruments that measure health. They use thermometers and a host of far more complex instruments to evaluate different attributes of the human system such as; temperature, blood pressure, cognitive function, vision, muscle strength, balance, etc., to assess whether an individual is healthy or not. Each of these attributes is an indicator of one aspect of health.

If human health is a difficult concept to define precisely, ecosystem health is even more difficult to define. Many ecologists, who generally prefer the term *ecosystem integrity*, have admitted this difficulty. Regier et al. (1993) listed at least forty attributes of ecosystems with high integrity, dealing with presence of specific groups of associated species, spatial and temporal contexts, trophic networks (food webs and nutrient pathways), physical landscape patterns, levels of persistence, and cyclical processes. Ecosystems are extremely complex, but at the same time, quite vulnerable. However, those with high integrity are less vulnerable than others.

To define *ecosystem health* as *ecosystem integrity* does not solve our problem, but it brings us a bit closer to understanding. The word *integrity* as well as referring to qualities of honesty, rectitude, or decency in a person, may refer more generally to the property of being unimpaired, undivided, or complete, and it is in this context that ecologists use it to define ecosystems.

Sometimes *high ecosystem integrity* is simplistically equated to *high biodiversity*. By itself, biodiversity is not a useful surrogate for ecosystem integrity since biodiversity may increase when land use practices convert a relatively homogeneous natural system into a patchy mosaic of degraded habitats of several different types. Overall, the mosaic may support more species, even though the environment has been degraded. Ecosystem integrity certainly involves diversity, but it also includes aspects of system resilience, persistence, and resistance (Holling, 1985). Each of these terms has specific meanings in ecology.

Resilience, resistance, and persistence are all measures of stability which is the tendency of an ecosystem to retain its current state over time. The integrity of an ecosystem certainly relates to its ability to maintain or to return to a state that can be maintained through time. Ecosystem components are always changing, maturing, being disturbed, recovering, and adjusting to long term climatic shifts, but high integrity ecosystems have generally been capable of maintaining a functional organization, even after occasional disturbances.

Given that there are always stressors acting on ecosystems, it follows that ecosystems that retain (high resistance), or quickly recover (high resilience) their former state when perturbed are more stable (high persistence) than others. One of the characteristics of ecosystems that have been degraded by pollution, by over-harvest, by fragmentation, or in other ways, is that they are less stable (less persistent) and show greater alterations of state (less resistance and resilience) in response to stressors. In other words, these degraded systems eventually lose their ability to retain a healthy state or recover from disturbances.

The Muskoka watersheds, like all ecosystems, exist in dynamic stability. The relationships among their component species are continually changing, oscillating, changing back to the way they were, while the overall state of the ecosystem remains fairly close to some equilibrium state. Sometimes particularly strong stressors lead to more extensive departures from this equilibrium with eventual recovery. And very rarely, impacts are so strong that the ecosystem is shifted far from its equilibrium state and may take a very long time, if ever, before it recovers or achieves some new equilibrium.

In human-dominated landscapes much of the landscape is substantially altered from its natural state. In such circumstances, ecosystem integrity also includes the ability to maintain basic structure (perhaps by using connections between patches of habitat to sustain populations of critical species) and persistence of minimum populations and communities of its most critical species assemblages.

Biodiversity, stability, resilience, and an ability to retain basic ecosystem structure are just a few of the components of ecosystem integrity, but they generally give an ecosystem the ability to;

- continue to organize and operate under normal conditions (dynamic stability);
- cope with changes, to find a functional operating state under stress (resistance and resilience); and
- continue evolving and developing to continue the process of self-organization.

Although previous paragraphs attempt an objective discussion of ecosystem integrity, it is undeniable that humans look at ecosystem health from an anthropogenic or selfish point of view. Many scientists agree that this further complicates our understanding beyond pure ecological science. Particularly in human-dominated landscapes, consideration needs to be given to our values, our interpretations of what ecological integrity is, and the specific services the ecosystem provides us. In this sense, our preferred definition of integrity may also include an ability to continue providing the same ecological services we demand of it or to stay in the condition we desire. What state do we see as healthy? In response to our impacts, an ecosystem may shift toward a new state that has integrity, but it may not be a state that we desire, nor depend on for our own health.

ECOSYSTEMS CAN LOSE THEIR INTEGRITY – WHAT THEN?

Ecosystems are adapted to fluctuations in local conditions, and even some extreme events. They show dynamic stability of structure in the face of these. But if, over time, conditions such as seasonal weather patterns become too erratic, or undergo more frequent extremes, the systems and processes in the ecosystem may be unable to retain stability or provide sufficient resilience to recover from perturbation. As King (1993) writes, “If a structural component, such as a critical species [or habitat], of the ecosystem is lost, the corresponding functional elements of the system may be compromised if they are already no longer resilient enough to compensate.” In such situations, the ecosystem is losing integrity (or declining in health).

The challenge we now face is that humans are capable of disturbing ecosystems at much larger or faster scales (spatial, temporal, and functional) than ecosystems are adapted to. Our actions are testing the resilience and dynamic stability, and ecosystems are being shifted far from the states that are normal for them. In some cases, tipping points can be reached that result in relatively abrupt or even catastrophic change (Kay, 1993). These are cases of lost ecosystem integrity.

While our actions do not yet appear to have markedly reduced ecosystem integrity in the Muskoka region, tipping points are not easy to detect before the sudden shift in ecosystem structure happens. While algal blooms so far have been transient departures of lake ecosystems from their normal state, they happen rapidly and can alter the lake substantially. It is plausible to anticipate an analogous type of rapid shift in ecosystem state, but one that would be far more long-lasting or even permanent. This new state could be one that no longer meets our expectations for recreation and aesthetics. In managing the Muskoka watersheds, we should be aiming to manage to retain or enhance ecosystem integrity as a way of safeguarding against such undesirable changes in status.

INDICATORS OF ECOSYSTEM INTEGRITY

It should now be clear that a simple indicator of ecological integrity (or ecosystem health) is no more likely than a simple indicator of human health. An indicator of the overall integrity of an ecosystem would capture productivity, diversity, habitat structure, population fluctuations, and availability of good quality water and soils, etc. It would also include ecosystem complexity, stability, and resilience (Munn, 1993). Such an indicator, if it existed, would provide an early warning that human activity is jeopardizing the ability of the system to function. Alternatively, it would show positive effects of sound environmental management (Noss, 1995).

The best current indicators of overall ecosystem integrity are multi-dimensional and still primarily theoretical, and many are further complicated by the additional need to include human social values as well as ecological (Burkhard et al., 2008). They are not yet ready for routine use.

Hutchinson Environmental Sciences Ltd. (2023) recently compiled a report on Watershed Health Indicators for the Muskoka River Watershed for the District of Muskoka. They summarized several similar studies, all indicating that metrics of ecosystem health must be accessible and understandable by the public if they are to be useful. These metrics include use of appropriate spatial and time scales (watershed scale over several decades vs a small community over a few years). They summarize some key attributes of a health indicator as ideally providing an unambiguous cause and effect relationship between environmental stressors and ecosystem response; and representing a range of physical, chemical, and biological attributes of the ecosystem. However, they do not end up with a single indicator of overall health. Dale et al. (2004) take a similar approach while adding that indicators also must capture the complexities of the ecosystem. This makes an over-arching indicator of ecological integrity or health much more complicated to develop and articulate.

The Ontario Biodiversity Council uses a summation of multiple indicators as part of its *State of Ontario Biodiversity* project (https://sobr.ca/indicators/index-of-indicators/). These are used to assess progress toward fifteen primarily socio-economic biodiversity targets for the province, recognizing that biodiversity is only a partial surrogate for overall system health. For each Great Lake, the numbers of green, yellow, and red indicators are gathered in bar charts to, in combination, show the overall status of the lake's ecosystem. A number of metrics also measure the extent of various types of landcover and ecological features. They also summarize several social metrics, such as the proportion of private companies incorporating environmental programs in business reporting, and the trends in use of biodiversity programs in schools and government policies. This is a large scale and complex project with many coordinated monitoring programs, but it still does not produce one over-arching indicator of ecosystem integrity.

Noss (1995), in reviewing ecosystem integrity, considered changes in road density a key measurable indicator of threats to ecosystem health in terrestrial environments. He added that the status of species or guilds that play keystone or umbrella roles in ecosystems would likely be another type of indicator. An example of this might be ongoing assessment of large, wide-ranging species, such as wolf, bear, or moose, and the ability of the landscape to continue to support viable populations of those species. Habitat selection modelling has been used on these types of species to assess the potential impacts of resource development in Canada's northern boreal region. Others have suggested that structural habitat elements, such as the size-age structure of mature forests, be used instead of attempting to monitor ecosystem functions.

Finally, Burkhard et al. (2008) reviewed a range of different types of ecosystem health indicators, all of which are surrogates for various ecological aspects of health. Several also include human-centered aspects of continued ecosystem service provision. Two of these, the Holistic Ecosystem Health Indicator (HEHI) from Costa Rica, and the NRCS Indicator Selection Model, developed by the U.S. Dept. of Agriculture, are applicable as conceptual frameworks to inform a discussion of ecological integrity. The former combines weighted rankings of other ecological and social variables in scoring hierarchies, while the latter uses sets of questions to focus on specific aspects of ecosystems. Burkhard et al. (2008) do not recommend any particular approach over others.

Ecosystem science does not yet have a method, or an instrument, to measure ecosystem health. Instead, we measure a range of attributes of the complex ecosystem and, much like medical professionals, we evaluate these to judge ecosystem health. The variables that have been monitored as part of the Muskoka Watershed Report Card, in combination with metrics from many other monitoring programs in the region, could all contribute to a notion of overall integrity or ecosystem health. If these metrics could be combined in a model with a single answer, we would know the overall ecosystem integrity and monitor it through time. But no practical model or tool exists. Therefore, an objective overview of trends in multiple overlapping groups variables is the only practical way to discuss this complicated subject.

REFERENCES

Beacon Environmental (2012). How much disturbance is too much? Habitat conservation guidance for the southern Canadian shield. Unpublished Report, Prepared for Environment Canada, Markham, Ontario.

Bennett, A. F. (1991). Roads, roadsides and wildlife conservation: a review. In; Nature Conservation 2: The Role of Corridors. Edited by Saunders, D.A. and Hobbs, R.J. London, UK: Surrey Beatty and Sons.

Böhmer, J., K. Arbaciauskas, R. Benstead, W. Gabriels, G. Porst, B. Reeze, and H. Timm (2014). Water Framework Directive intercalibration technical report. Central Baltic Lake Benthic Invertebrate Ecological Assessment Methods; Joint Research Centre of the European Commission: Ispra, Italy, 77.

Bolam, F.C., J. Ahumada, H.R. Akçakaya, T.M. Brooks, W. Elliott, S. Hoban, L. Mair, D. Mallon, P.J.K McGowan, D. Raimondo, J.P. Rodriguiz, D. Roe, M.B. Seddon, X. Shen, S.N. Stuart, J.E.M. Watson, and S.H.M. Butchart (2023). Over half of threatened species require targeted recovery actions to avert human-induced extinction, Frontiers in Ecology and Evolution 21 (2): 64-70.

Burke, D., K. Elliott, K. Falk, and T. Piraino (2011). *A land manager's guide to conserving habitat for forest birds in southern Ontario.* Ministry of Natural Resources and Forestry.

Burkhard, B., F. Muller and A. Lill (2008). Ecosystem Health Indicators. In Sven Erik Jorgensen and B.D. Fath (Ed.). Ecological Indicators. Vol [2] of Encyclopedia of Ecology, 5 vols. Pp. [1132-1138]. Oxford: Elsevier.

Bush, E. and D.S. Lemmen, editors (2019). Canada's Changing Climate Report; Government of Canada, Ottawa, ON. 444 p. https://changingclimate.ca/CCCR2019/ accessed 2023-06-01.

Canadian Council of Ministers of the Environment (2011). Scientific Criteria Document for the Development of the Canadian Water Quality Guidelines for the Protection of Aquatic Life CHLORIDE ION PN 1460 ISBN 978-1-896997- 77-3 PDF https://ccme.ca/fr/res/2011-chloride-ceqg-scd-1460-en.pdf.

Canadian Environmental Protection Act (1999). Priority Substances List Assessment Report - Road Salts. 181 pp. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/ewh-semt/alt_formats/hecs-sesc/pdf/pubs/contaminants/psl2-lsp2/road_salt_sels_voirie/road_salt_sels_voirie-eng.pdf.

Carpenter, N. (2022). Invasive Phragmites Eradication for the Health of our Water and Wetlands 2022 Report, Georgian Bay Forever. Downloaded 11 May 2023 from https://www.georgianbayforever.org/phragmites.

Crowley, J.F. (2006). Are Ontario reptiles on the road to extinction? Anthropogenic disturbance and reptile distribution within Ontario. Unpubl. M.Sc. thesis, University of Guelph, Guelph, Ontario.

Dale, V.H., P. Mulholland, L. Olsen, J. Feminella, K. Maloney, D. White, A. Peacock and T. Foster (2004). Selecting a Suite of Ecological Indicators for Resource Management. In L. Kapustka et al. (eds). Landscape Ecology and Wildlife Habitat Evaluation: Critical Information for Ecological Risk Assessment, Land-Use Management Activities and Biodiversity Enhancement Practices. ASTM STP 1458. West Conshohocken, PA.

Desbonnet, A., P. Pogue, V. Lee, and N. Wolff (1994). Vegetated buffers in the Coastal Zone - A summary review and bibliography. Coastal Resources Centre Technical Report No. 2064. University of Rhode Island Graduate School of Oceanography. Narragansett, RI. 72 pages.

Diaz, S., J. Settele, E.S. Brondizo, H.T. Ngo, J. Agard, A. Arneth, P. Balvanera, K.A. Brauman,S.H.M. Butchart, and C.N. Zayas (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. Science 366 (6471): doi.org/10.1126/science.aax3100.

Dougan and Associates (2022). Muskoka River IWM Natural Capital Inventory. Phase 2 Final Report. Prepared for the District Municipality of Muskoka with funding from the Province of Ontario. 80p.

Dunford, W. and K. Freemark (2004). “Matrix matters: Effects of surrounding land uses on forest birds near Ottawa, Canada.” Landscape Ecology 20(5): 497-511.

ECCC (2022). Daily Adjusted and Homogenized Canadian Climate Data, Environment and Climate Change Canada, https://crd-data-donnees-rdc.ec.gc.ca/CDAS/products/EC_data/AHCCD_daily, data accessed 2022-12-23.

Eimers, C. (2016). *Cumulative Effects Assessment and Monitoring in the Muskoka Watershed.* Trent University. Canadian Water Network.

Environment Canada (2013). *How Much Habitat is Enough? Third Edition.* Toronto, Ontario: Environment Canada.

Fahrig, L. (2003). Effects Of Habitat Fragmentation On Biodiversity. Annual Review of Ecology, Evolution, and Systematics 34:487-515.

Gibbs, J. P. and W. Shriver (2005). Can road mortality limit populations of pool-breeding amphibians? Wetlands Ecology and Management 13:281-289.

Haubrock, P.J., R.N. Cuthbert, A. Ricciardi, C. Diagne, and F. Courtchamp (2022). Economic costs of invasive bivalves in freshwater ecosystems. Diversity and Distributions, https://doi.org/10.1111/ddi.13501.

Holling, C.S. (1985). Resilience of Ecosystems: local surprise and global change. Pages 228-269 in T.F Malone and J.G. Roederer (eds.). Clobal Change. Proceedings of a symposium sponsored by the International Council of Scientific Unions (ICSU), Ottawa 1984. Cambridge Univ. Press. Cambridge.

Hutchinson Environmental Sciences Ltd. (2016). *Revised Water Quality Model and Lake System Health Program Prepared for District Municipality of Muskoka* by Hutchinson Environmental Services Ltd. Retrieved from https://muskoka.civicweb.net/document/27675.

Hutchinson Environmental Sciences Ltd. (2022). Watershed Health Indicators - Muskoka River Watershed. Comprehensive Summary Report. Prepared for the District Municipality of Muskoka with funding from the Province of Ontario. 82p.

IPCC (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2409 pp. doi:10.1017/9781009157896.

Jones, C., K.M. Somers, B. Craig, and T.B. Reynoldson (2005). Ontario Benthos Biomonitoring Network: Protocol Manual. Ontario Benthos Biomonitoring Network On-line Documents. Environment Canada. http://obbn.eman-rese.ca/obbn/docs/english/OBBN_Protocol_Manual_V1-0_December_2005.pdf.

Jones, F. C. (2018). The ecology of lakes and rivers in the southern boreal shield: water quality, community structure, and cumulative effects (Doctoral dissertation, Laurentian University of Sudbury).

Kay, J.J. (1993). On the nature of ecological integrity. Pages 201-214 in S. Woodley, J. Kay and G. Francis (eds.). Ecological Integrity and the Management of Ecosystems. St. Lucie Press. USA.

King, A.W. (1993). Considerations of scale and hierarchy. Pages 19-46 in S. Woodley, J. Kay and G. Francis (eds.). Ecological Integrity and the Management of Ecosystems. St. Lucie Press. USA.

Lepczyk, C.A., B.T. Klingbeil, R.A. Christoffel, D.T. Rutledge, and C.H. Flather (2019). Human perception relates to when endangered species are listed. Frontiers in Ecology and Evolution 21 (2): 71-76.

Lesbarrères, D., A. Pagano, and T. Lodé (2003). Inbreeding and road effect zone in a Ranidae: the case of the Agile frog, *Rana dalmantina Bonaparte*, 1840. Comptes Rendus Biologies. 326: S68-S72.

MacDougall, M. (2014). Development and evaluation of a periphytic diatom biomonitoring platform for the assessment of cumulative effects in lakes of the Muskoka River Watershed, Ontario, Canada. M.Sc. Thesis, University of Waterloo, Waterloo, Ontario.

McIntyre, S. and R. Hobbs (1999). A framework for conceptualizing human effects on landscapes and its relevance to management and research models. Conservation Biology 13: 1282-1292.

Mekis, É., and L.A. Vincent (2011). An overview of the second generation adjusted daily precipitation dataset for trend analysis in Canada. *Atmosphere-Ocean*, 49(2), 163-177, doi:10.1080/07055900.2011.583910.

Munn, R.E. (1993). Monitoring for ecosystem integrity. Pages 105-115 in S. Woodley, J. Kay and G. Francis (eds.). Ecological Integrity and the Management of Ecosystems. St. Lucie Press. USA.

Muskoka River Water Management Plan (2006) Final Plan Report. http://www.muskokawaterweb.ca/water-101/water-quantity/mrwmp

Muskoka Watershed Council (2018). Muskoka Watershed Report Card (Background Report). 98 pages.

Nol, E., C. M. Francis, and D. M. Burke (2005). "Using distance from putative source woodlots to predict occurrence of forest birds in putative sinks." Conservation Biology 19(3): 836-44.

Noss, R. (1995). Maintaining ecological integrity in representative reserve networks. Discussion Paper. World Wildlife Fund (U.S. and Canada). 77p.

Obbard, M.E., M.B. Coady, B.A. Pond, J.A. Schaefer, and F.G. Burrows (2010). A distance-based analysis of habitat selection by American black bears (Ursus americanus) on the Bruce Peninsula, Ontario, Canada. Canadian Journal of Zoology 88:1063-1076.

Ontario Biodiversity Council (2023). State of Ontario's Biodiversity: Indicators (https://sobr.ca/indicators/index-of-indicators/).

Ontario Forest Research Institute (2012). Beech Bark Disease in Ontario: A Primer and Management Recommendations, Forest Research Note #71, 8pp. https://dr6j45jk9xcmk.cloudfront.net/documents/2851/stdprod-096009.pdf.

Ontario Ministry of the Environment, Conservation and Parks (2010). *Water Quality in Ontario.*

Palmer, M.E., N.D. Yan, A.M. Paterson, and R.E. Girard (2011). Water quality changes in south-central Ontario lakes and the role of local factors in regulating lake response to regional stressors. *Canadian Journal of Fisheries and Aquatic Sciences, 68*, 1038-1050. doi:10.1139/f2011-041.

Pimm, S.L., C.N. Jenkins, R. Abell, T.M. Brooks, J.L. Gittleman, L.N. Joppa, P.H. Raven, C.M. Roberts, and J.O. Sexton (2014). The biodiversity of species and their rates of extinction, distribution, and protection, Science, 344 (6187): doi.org/10.1126/science.1246752.

Regier, H.A. (1993). The notion of natural and cultural integrity. Pages 3-18 in S. Woodley, J. Kay and G. Francis (eds.). Ecological Integrity and the Management of Ecosystems. St. Lucie Press. USA.

Reinl, K. L.-W. (2021). Cyanobacterial blooms in oligotrophic lakes: Shifting the high-nutrient paradigm. *Freshwater Biology, 66*, 1846-1859. doi:10.1111/fwb.13791.

Riverstone Environmental Solutions (2011). Large Natural Areas: A Literature Review – Muskoka Watershed Council. 32 pages.

Sale, P., R. Lammers, N. Yan, N. Hutchinson, K. Trimble, P. Dinner, P. Hurrell, J. McDonnell, and S. Young (2016). Planning for Climate Change in Muskoka. A Report from the Muskoka Watershed Council. Muskoka Watershed Council, Muskoka, Canada, 52 pages, http://www.muskokawatershed.org/wp-content/uploads/ClimateChange_Muskoka-2016.pdf.

Schiefer, K. (2008). Water quality survey of Blackstone, Crane, Healey and Kapikog Lakes. Report prepared for the Township of the Archipelago. Retrieved from http://archipelago.municipalwebsites.ca/Editor/images/DOCUMENTS/ENVIRONMENT/Water/2 008_Blackstone_Crane_Healey_Kapikog_WaterQuality_Report.pdf.

South Muskoka District Health Unit (2022). Simcoe Muskoka HealthSTATS webpage on West Nile virus. Downloaded 8 May 2023. https://www.simcoemuskokahealthstats.org/topics/infectious-diseases/q-z/west-nile-virus.

The District Municipality of Muskoka (2018). *Muskoka Official Plan.* Bracebridge.

Todd, A.K. and M.G. Kaltenecker (2012). Warm season chloride concentrations in stream habitats of freshwater mussel species at risk Environ. Poll. 171: 199-206.

Trewin, B., A. Cazenave, S. Howell, M. Huss, K. Isensee, M.D. Palmer, O. Tarasova, and A. Vermeulen (2021). Headline indicators for global climate monitoring. *Bulletin of the American Meteorological Society*, 102(1), E20-E37.

Turbelin, A.J., R.N. Cuthbert, F. Essl, P.J. Haubrock, A. Ricciardi, and F. Courchamp (2023). Biological invasions are as costly as natural hazards. Perspectives in Ecology and Conservation, in press March 2023.

Urbani, G., V. Petkovska, and M. Pavlin (2012). The relationship between littoral benthic invertebrates and lakeshore modification pressure in two alpine lakes. Fundamental and Applied Limnology-Archiv furHydrobiologie, 180(2), 157.

Vincent, L.A., M.M. Hartwell, and X.L. Wang (2020). A third generation of homogenized temperature for trend analysis and monitoring changes in Canada's climate. *Atmosphere-Ocean*, 58(3), 173-191, DOI: 10.1080/07055900.2020.1765728.

Weber, T. C., P. J. Blank, and A. Sloan (2008). "Field validation of a conservation network on the eastern shore of Maryland, USA, using breeding birds as bio-indicators." Environmental Management 41(4): 538-50.

Williams, M., and S. Eggleston (2017). Using indicators to explain our changing climate to policymakers and the public. *WMO Bull.*, 66, 33–39.

ACKNOWLEDGEMENTS

This Muskoka Watershed Report Card has benefited from the generosity of countless people who shared their time and expertise and, in doing so, made this Report Card as accurate and comprehensive as possible. Muskoka Watershed Council sincerely thanks the following for their valuable comments, suggestions, guidance, and drafting of chapters throughout the development of the 2023 Muskoka Watershed Report Card:

Patricia Arney	Dr. Neil Hutchinson	Rachel Plewes	Dr. Peter Sale
Javier Cappella	Dr. Richard Lammers	Megan Rae	Steve Scholten
Chris Cragg	Jess Lario	Julia Rodgerson	Kevin Trimble
Dr. Glenn Cunnington	David Parsons	Geoff Ross	Rebecca Willison
Jo-Anne Goodwin	Stuart Paul	Aaron Rusak	

Funding provided by:

APPENDICES

APPENDIX A – 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: Lake Huron; third order: Muskoka River; fourth order: 19 subwatersheds in our region of interest.

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.

APPENDIX B – TABLE OF LAKES AND QUATERNARY WATERSHEDS

Table 22. List of lakes by name, municipality, Ontario Watershed Boundaries (OWB) code, and quaternary watershed.

Lake Name	Municipality	OWB Code	Quaternary Watershed
#7 Lk	Bracebridge	02EC-09	Cache Creek-Black River
#8 Lk	Bracebridge	02EC-09	Cache Creek-Black River
Ada Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Adams Lk	Georgian Bay	02EB-01	Moon River Bay
Alder Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Allen Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Alport Bay	Bracebridge	02EB-04	Lake Muskoka-Muskoka River
Andrews Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Angel Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Arbuckle Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Armishaw Lake	Seguin	02EB-09	Lake Rosseau
Arrowhead Lk	Huntsville	02EB-10	Little East River-Big East River
Ashball Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Atkins Lk	Bracebridge	02EB-06	North Branch Muskoka River
Axe Lk	Huntsville	02EB-08	Lake Vernon
Axle Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Baby Joe Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Baden-Powell Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Barkway Lk	Gravenhurst	02EC-13	Kahshe River
Barnes Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Barrett Lk	Muskoka Lakes	02EB-03	Musquash River
Barron's Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Bartlett Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Bass Lk	Gravenhurst	02EC-13	Kahshe River
Bass Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Bastedo Lk	Muskoka Lakes	02EB-03	Musquash River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Baxter Lk	Georgian Bay	02EC-01	Little Lake-Severn River
Bay Lake	Perry	02EB-10	Little East River-Big East River
Beanpod Lake	Kearney	02EB-10	Little East River-Big East River
Bear Lake	Algonquin Highlands	02EB-13	Hollow River
Bear Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Bear Lk	Muskoka Lakes	02EB-03	Musquash River
Bear Lk	Georgian Bay	02EB-03	Musquash River
Bearpaw Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Bearshead Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Beaton Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Beattie Lk	Huntsville	02EB-06	North Branch Muskoka River
Beaver Lake	Severn	02EC-02	Sparrow Lake-Black River
Beers Lake	Seguin	02EB-02	Blackstone Harbour
Beetle Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Bella Lk	Lake of Bays	02EB-10	Little East River-Big East River
Ben Lk	Gravenhurst	02EC-13	Kahshe River
Bena Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Benson Lk	Lake of Bays	02EB-10	Little East River-Big East River
Bentarm Lake	Minden Hills	02EC-09	Cache Creek-Black River
Bentshoe Lakes	Minden Hills	02EC-09	Cache Creek-Black River
Berrycan Lake	Minden Hills	02EC-09	Cache Creek-Black River
Big East Lk	Bracebridge	02EC-09	Cache Creek-Black River
Big East River	Lake of Bays	02EB-10	Little East River-Big East River
Big East River	Lake of Bays	02EB-10	Little East River-Big East River
Big East River	Lake of Bays	02EB-10	Little East River-Big East River
Big East River	Lake of Bays	02EB-10	Little East River-Big East River
Big East River	Lake of Bays	02EB-10	Little East River-Big East River
Big Hoover Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Big Orillia Lk	Bracebridge	02EC-09	Cache Creek-Black River
Big Otter Lk	Muskoka Lakes	02EB-03	Musquash River
Big Porcupine Lake	Algonquin Highlands	02EB-14	Tea Lake-Oxtongue River
Big Stephen Lk	Lake of Bays	02EB-06	North Branch Muskoka River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Bigwind Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Bing Lk	Huntsville	02EB-10	Little East River-Big East River
Bird Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Birdie Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Bittern Lake	Perry	02EB-08	Lake Vernon
Bivouac Lake	Dysart et al	02EB-13	Hollow River
Black Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Black Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Black River	Bracebridge	02EC-04	Lake St. John-Black River
Black River	Bracebridge	02EC-04	Lake St. John-Black River
Blackberry Lake	Minden Hills	02EC-09	Cache Creek-Black River
Blackmoore Lk	Bracebridge	02EC-13	Kahshe River
Blackstone Harbour	Archipelago	02EB-02	Blackstone Harbour
Blackstone Lake	Archipelago	02EB-02	Blackstone Harbour
Blackstone River	Archipelago	02EB-02	Blackstone Harbour
Bloody Lake	Algonquin Highlands	02EB-13	Hollow River
Blue Chalk Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Blue Jay Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Blue Lagoon	Georgian Bay	02EB-03	Musquash River
Bluebell Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Blueglass Lake	Minden Hills	02EC-09	Cache Creek-Black River
Bluejay Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Bogart Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Bonita Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Bonnie Lk	Bracebridge	02EB-06	North Branch Muskoka River
Boot Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Boundary Lk	Lake of Bays	02EB-10	Little East River-Big East River
Bowers Marsh	Muskoka Lakes	02EC-01	Little Lake-Severn River
Brandy Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Brennan Lake	Seguin	02EB-02	Blackstone Harbour
Bridge Lake	Kearney	02EB-10	Little East River-Big East River
Bright Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Brooks Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Brophy Lk	Georgian Bay	02EB-03	Musquash River
Brotherson's Lk	Muskoka Lakes	02EB-03	Musquash River
Bround Lake	Archipelago	02EB-02	Blackstone Harbour
Brown Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Brownie Lake	Algonquin Park	02EB-10	Little East River-Big East River
Browns Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Browns Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Browns Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Browns Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Bruce Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Brûlé Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Brush Lake	Seguin	02EB-09	Lake Rosseau
Buchanan Lake	Algonquin Highlands	02EB-13	Hollow River
Buchanan Lk	Huntsville	02EB-06	North Branch Muskoka River
Buck Lake	Severn	02EC-02	Sparrow Lake-Black River
Buck Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Buck Lk	Huntsville	02EB-08	Lake Vernon
Buck Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Buck River	Huntsville	02EB-08	Lake Vernon
Buckhorn Lk	Georgian Bay	02EB-01	Moon River Bay
Bunn Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Burns Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Burnside Lake	McMurrich-Monteith	02EB-08	Lake Vernon
Burnt Island Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Burnt Lake	Seguin	02EB-02	Blackstone Harbour
Burr Lake	Seguin	02EB-09	Lake Rosseau
Burrows Lake	Severn	02EC-01	Little Lake-Severn River
Burwash Lk	Georgian Bay		
Butterfly Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Cabin Lake	Kawartha Lakes	02EC-13	Kahshe River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Cain Lk	Muskoka Lakes	02EC-01	Little Lake-Severn River
Camel Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Camp Lk	Lake of Bays	02EB-12	Distress Pond-Big East River
Campstool Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Canoe Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Carcass Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Cardwell Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Carter Lake	Seguin	02EB-09	Lake Rosseau
Cashel Lake	Algonquin Park	02EB-10	Little East River-Big East River
Cassidy Lk	Muskoka Lakes	02EB-01	Moon River Bay
Chain Lk	Huntsville	02EB-06	North Branch Muskoka River
Charcoal Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Chub Lk	Huntsville	02EB-06	North Branch Muskoka River
Chub Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Cinder Lake	Minden Hills	02EC-09	Cache Creek-Black River
Circular Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Clara Lake	Algonquin Park	02EB-10	Little East River-Big East River
Clark Lk	Huntsville	02EB-10	Little East River-Big East River
Clark Pond	Muskoka Lakes	02EB-09	Lake Rosseau
Claude Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Clayton Lake	Algonquin Highlands	02EB-13	Hollow River
Clear Lake	Seguin	02EB-02	Blackstone Harbour
Clear Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Clear Lk	Bracebridge	02EC-09	Cache Creek-Black River
Clearwater Lk	Huntsville	02EB-06	North Branch Muskoka River
Clearwater Lk	Gravenhurst	02EC-02	Sparrow Lake-Black River
Clinto Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Clubbe Lake	Seguin	02EB-09	Lake Rosseau
Cod Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Coffee Lake	Kearney	02EB-10	Little East River-Big East River
Coldwater Lk	Georgian Bay	02EB-03	Musquash River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Compass Lake	McMurrich-Monteith	02EB-08	Lake Vernon
Concession Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Conger Lake	Archipelago	02EB-02	Blackstone Harbour
Cooper Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Coot Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Corbier Lake	Archipelago	02EB-02	Blackstone Harbour
Cornall Lk	Gravenhurst	02EC-02	Sparrow Lake-Black River
Corson Lk	Georgian Bay	02EB-01	Moon River Bay
Cotter Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Cougar Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Cowan Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Cranberry Lake	Severn	02EC-01	Little Lake-Severn River
Crane Lake	Archipelago	02EB-02	Blackstone Harbour
Cream Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Cripple Lake	Kearney	02EB-10	Little East River-Big East River
Cross Corner Lake	Dysart et al	02EB-13	Hollow River
Crosson Lk	Bracebridge	02EC-09	Cache Creek-Black River
Crotch Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Crotchet Lake	Kawartha Lakes		
Crown Lake	Algonquin Highlands	02EB-14	Tea Lake-Oxtongue River
Crumby Lake	Algonquin Highlands	02EB-13	Hollow River
Crystalline Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Dagger Lake	Algonquin Highlands	02EB-13	Hollow River
Dale Lake	Algonquin Park	02EB-10	Little East River-Big East River
Dan Lk	Lake of Bays		
Dark Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Davies Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Deer Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Devine Lk	Huntsville	02EB-06	North Branch Muskoka River
Dick Lake	Seguin	02EB-09	Lake Rosseau
Dickie Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Dividing Lake	Algonquin Highlands	02EB-13	Hollow River
Docker Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Doe Lk	Gravenhurst	02EC-13	Kahshe River
Dot Lk	Lake of Bays	02EB-10	Little East River-Big East River
Dotty Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Doughnut Lk	Lake of Bays	02EB-10	Little East River-Big East River
Draper Lake	Seguin	02EB-09	Lake Rosseau
Dreamhaven Lk	Huntsville	02EB-07	Baysville Narrows-S Branch Muskoka R
Drummer Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Dumbell Lake	Severn	02EC-01	Little Lake-Severn River
Dump Lake	Kearney	02EB-10	Little East River-Big East River
Dunn Lk	Huntsville	02EB-07	Baysville Narrows-S Branch Muskoka R
Dunstan Lake	Kearney	02EB-10	Little East River-Big East River
Dusk Lake	Kearney	02EB-10	Little East River-Big East River
Dyson Lake	Seguin	02EB-09	Lake Rosseau
Eagle Lk	Georgian Bay	02EB-01	Moon River Bay
East Brophy Lk	Muskoka Lakes	02EB-03	Musquash River
East Buck Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
East Duffy Lk	Muskoka Lakes	02EB-01	Moon River Bay
East End Lake	Algonquin Park	02EB-10	Little East River-Big East River
East Jeannie Lakes	Algonquin Highlands	02EB-13	Hollow River
East Jeannie Lakes	Algonquin Highlands	02EB-13	Hollow River
Eastell Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Eastern Lake	Severn	02EC-01	Little Lake-Severn River
Echo Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Echo Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Eighteen Mile Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Eiler Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Ellis Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Emsdale Lake	Kearney	02EB-10	Little East River-Big East River
Ennis Lk	Bracebridge	02EB-06	North Branch Muskoka River
Erkett's Pond	Lake of Bays	02EB-10	Little East River-Big East River
Ermine Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Ernest Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Eu Lake	Algonquin Park	02EB-10	Little East River-Big East River
Fair Lake	Seguin	02EB-09	Lake Rosseau
Fairy Lk	Huntsville	02EB-06	North Branch Muskoka River
Fairy Lk	Georgian Bay		
Falcon Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Fawn Lk	Bracebridge	02EC-13	Kahshe River
Fawn Lk	Huntsville	02EB-06	North Branch Muskoka River
Feline Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Fen Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Fenton Lk	Georgian Bay	02EB-01	Moon River Bay
Fifteen Mile Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
First Lake	Seguin	02EB-02	Blackstone Harbour
Fischer Lk	Georgian Bay	02EB-01	Moon River Bay
Fisher Lake	Algonquin Highlands	02EB-13	Hollow River
Fitzell Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Flatrock Lk	Georgian Bay	02EB-03	Musquash River
Flaxman Lake	Seguin	02EB-02	Blackstone Harbour
Fleming Lk	Huntsville	02EB-06	North Branch Muskoka River
Fleming Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Fletcher Lake	Algonquin Highlands	02EB-13	Hollow River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Flossie Lk	Lake of Bays	02EB-10	Little East River-Big East River
Fly Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Fogal Lake	Archipelago	02EB-01	Moon River Bay
Foote Lk	Lake of Bays	02EB-10	Little East River-Big East River
Foreman Lk	Georgian Bay	02EB-01	Moon River Bay
Forget Lake	Seguin	02EB-02	Blackstone Harbour
Fowler Lk	Lake of Bays	02EB-10	Little East River-Big East River
Fox Lake	Kearney	02EB-10	Little East River-Big East River
Fox Lk	Huntsville	02EB-08	Lake Vernon
Furrow Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Gagnon Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Galbraith Lk	Georgian Bay		
Galla Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Gartersnake Lk	Bracebridge	02EC-13	Kahshe River
Gaskills Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Georgian Bay	Georgian Bay		
Geri Bay	Severn	02EC-01	Little Lake-Severn River
Gerow Lake	Seguin	02EB-09	Lake Rosseau
Gibbs Lk	Bracebridge	02EB-06	North Branch Muskoka River
Gibson Lk	Georgian Bay	02EB-03	Musquash River
Gibson River	Georgian Bay	02EB-03	Musquash River
Gilleach Lk	Bracebridge	02EB-06	North Branch Muskoka River
Gloucester Pool	Georgian Bay	02EC-01	Little Lake-Severn River
Go Home Bay	Georgian Bay		
Go Home Lk	Georgian Bay	02EB-03	Musquash River
Go Home River	Georgian Bay	023C	South Georgian Bay Shoreline
Golden City Lk	Huntsville	02EB-08	Lake Vernon
Goldstein Lk	Georgian Bay	02EB-01	Moon River Bay
Goodman Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Gooley Lk	Georgian Bay	02EB-01	Moon River Bay
Gosling Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Gover Lk	Georgian Bay	02EB-01	Moon River Bay
Grandview Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Grape Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Grass Lake	Severn	02EC-02	Sparrow Lake-Black River
Grawbager Lk	Georgian Bay	02EB-01	Moon River Bay
Gray Lk	Georgian Bay	02EB-03	Musquash River
Greenish Lk	Lake of Bays	02EB-10	Little East River-Big East River
Greens Lk	Huntsville	02EB-10	Little East River-Big East River
Greenwood Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Grindstone Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Groundhog Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Grouse Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Groves Lk	Huntsville	02EB-06	North Branch Muskoka River
Guide Lake	Algonquin Park	02EB-10	Little East River-Big East River
Gull Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Gullfeather Lk	Bracebridge	02EC-09	Cache Creek-Black River
Gullwing Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Gun Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Guskewau Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Haggart Lk	Georgian Bay	02EB-01	Moon River Bay
Halfway Lk	Bracebridge	02EB-06	North Branch Muskoka River
Haller Lk	Huntsville	02EB-08	Lake Vernon
Hamer Lake	Seguin	02EB-09	Lake Rosseau
Hardup Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Hardy Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Harp Lk	Huntsville	02EB-06	North Branch Muskoka River
Hart Lake	Kearney	02EB-10	Little East River-Big East River
Hart Lk	Muskoka Lakes	02EB-03	Musquash River
Harts Lk	Muskoka Lakes	02EB-03	Musquash River
Harvey Lake	Algonquin Highlands	02EB-13	Hollow River
Head River	Ramara		
Healey Lake	Archipelago	02EB-01	Moon River Bay
Healey Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Heck Lk	Lake of Bays	02EB-10	Little East River-Big East River
Hellangone Lk	Georgian Bay	02EB-01	Moon River Bay
Helve Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Hendersons Lk	Huntsville	02EB-08	Lake Vernon
Heney Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Henshaw Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Herb Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Herdman Lk	Georgian Bay	02EB-03	Musquash River
Heron Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Hesners Lk	Muskoka Lakes	02EB-03	Musquash River
High Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Hillman Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Hilly Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Hines Lake	Seguin	02EB-02	Blackstone Harbour
Hinterland Lake	Algonquin Highlands	02EB-13	Hollow River
Hobo Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Hoc Roc River	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Hollow River	Algonquin Highlands	02EB-13	Hollow River
Horse Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Horseshoe Lake	Seguin	02EB-02	Blackstone Harbour
Horseshoe Lake	Severn	02EC-01	Little Lake-Severn River
Hosiery Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Hot Lake	Algonquin Park	02EB-10	Little East River-Big East River
Hungry Lake	Kearney	02EB-10	Little East River-Big East River
Hunter's Lake	Kawartha Lakes	02EC-04	Lake St. John=Black River
Hurst Lake	Seguin	02EB-09	Lake Rosseau
Hutcheson Lake	Archipelago	02EB-01	Moon River Bay
Indian River	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Indian River	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Ingrams Lake	Algonquin Highlands	02EB-13	Hollow River
Insula Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Irvine Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Island Lk	Muskoka Lakes	02EB-03	Musquash River
Island Lk	Bracebridge	02EC-13	Kahshe River
Islet Lake	Algonquin Park	02EB-10	Little East River-Big East River
Islet Lake	Algonquin Park	02EB-10	Little East River-Big East River
Ivy Lk	Bracebridge	02EC-13	Kahshe River
Jean Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Jeannie Lake	Algonquin Highlands	02EB-13	Hollow River
Jenkin Lk	Georgian Bay	02EB-01	Moon River Bay
Jerry Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Jessop Lk	Huntsville	02EB-10	Little East River-Big East River
Jevins Lk	Gravenhurst	02EC-02	Sparrow Lake-Black River
Jill Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Joe Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Joseph River	Muskoka Lakes	02EB-09	Lake Rosseau
Jubilee Lake	Algonquin Park	02EB-10	Little East River-Big East River
Juniper Lk	Georgian Bay	02EB-01	Moon River Bay
Kagh Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Kahshe Lk	Gravenhurst	02EC-13	Kahshe River
Kahshe River	Gravenhurst	02EC-13	Kahshe River
Kahshe River	Gravenhurst	02EC-13	Kahshe River
Kapikog Lake	Archipelago	02EB-01	Moon River Bay
Kawagama Lake	Algonquin Highlands	02EB-13	Hollow River
Kawpakwakog River	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Kawpakwakog River	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Kawpakwakog River	Bracebridge	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Kawpakwakog River	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Kenney Lk	Georgian Bay	02EB-01	Moon River Bay
Ketch Lk	Bracebridge	02EC-09	Cache Creek-Black River
Keyhole Lk	Bracebridge	02EC-09	Cache Creek-Black River
Kimball Lake	Algonquin Highlands	02EB-13	Hollow River
Knife Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Krapek Lake	Seguin	02EB-09	Lake Rosseau
L Lk	Muskoka Lakes	02EB-03	Musquash River
La Force Lake	Archipelago	02EB-02	Blackstone Harbour
Lafarce Lk	Georgian Bay	02EB-03	Musquash River
Lake Couchiching	Severn	02EC-02	Sparrow Lake-Black River
Lake Joseph	Muskoka Lakes	02EB-09	Lake Rosseau
Lake Muskoka	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Lake of Bays	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Lake of Bays	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Lake Rosseau	Muskoka Lakes	02EB-09	Lake Rosseau
Lake St. George	Severn	02EC-02	Sparrow Lake-Black River
Lake St. John	Ramara	02EC-04	Lake St. John=Black River
Lake Vernon	Huntsville	02EB-08	Lake Vernon
Lalonde Lk	Georgian Bay	02EB-03	Musquash River
Lamberts Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Lamorie Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Lancelot Lk	Huntsville	02EB-06	North Branch Muskoka River
Langford Lake	Perry	02EB-10	Little East River-Big East River
Lassetter Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Lay Lake	Algonquin Park	02EB-10	Little East River-Big East River
Leclaric Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Lee Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Leech Lk	Muskoka Lakes	02EB-03	Musquash River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Leech Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Lena Lk	Huntsville	02EB-06	North Branch Muskoka River
Leonard Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Lily Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Linda Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Ling Lake	Algonquin Highlands	02EB-14	Tea Lake-Oxtongue River
Lioness Lake	Seguin	02EB-02	Blackstone Harbour
Little Arrowhead Lk	Huntsville	02EB-10	Little East River-Big East River
Little Blackstone Lake	Archipelago	02EB-02	Blackstone Harbour
Little Camp Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Little Clear Lk	Lake of Bays	02EB-10	Little East River-Big East River
Little Drummer Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Little East Lake	Minden Hills	02EC-09	Cache Creek-Black River
Little Eastend Lake	Algonquin Park	02EB-10	Little East River-Big East River
Little Go Home Bay	Georgian Bay	02EC-01	Little Lake-Severn River
Little Hardy Lake	Algonquin Park	02EB-10	Little East River-Big East River
Little Hellangone Lk	Georgian Bay	02EB-01	Moon River Bay
Little Hoover Lk	Lake of Bays	02EB-10	Little East River-Big East River
Little Jean Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Little Joe Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Little Lake Joseph	Muskoka Lakes	02EB-09	Lake Rosseau
Little Leech Lk	Bracebridge	02EC-09	Cache Creek-Black River
Little Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Little Lk	Georgian Bay	02EC-01	Little Lake-Severn River
Little Long Lk	Lake of Bays	02EB-10	Little East River-Big East River
Little Long Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Little Louie Lake	Algonquin Highlands	02EB-13	Hollow River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Little Margaret Lk	Lake of Bays		
Little McCraney Lake	Algonquin Park	02EB-10	Little East River-Big East River
Little Nelson Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Little Orillia Lk	Bracebridge	02EC-09	Cache Creek-Black River
Little Otter Lk	Muskoka Lakes	02EB-03	Musquash River
Little Oxbow Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Little Oxtongue River	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Little Pell Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Little Portage Lake	Seguin	02EB-02	Blackstone Harbour
Little Raccoon Lake	Algonquin Highlands	02EB-14	Tea Lake-Oxtongue River
Little Spaniel Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Little Sunny Lk	Gravenhurst	02EC-13	Kahshe River
Little Troutspawn Lake	Algonquin Highlands	02EB-13	Hollow River
Littledoe Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Livingstone Lake	Algonquin Highlands	02EB-13	Hollow River
Lk St. Patrick	Georgian Bay	023C	South Georgian Bay Shoreline
Loft Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Lone Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Long Lake	Kearney	02EB-10	Little East River-Big East River
Long Lake	Severn	02EC-01	Little Lake-Severn River
Long Lk	Muskoka Lakes	02EB-03	Musquash River
Longline Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Longs Lk	Huntsville	02EB-09	Lake Rosseau
Loon Lk	Lake of Bays	02EB-10	Little East River-Big East River
Loon Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Lost Channel	Georgian Bay	023C	South Georgian Bay Shoreline
Lost Channel	Georgian Bay	023C	South Georgian Bay Shoreline
Loucks Lake	Seguin	02EB-09	Lake Rosseau

Lake Name	Municipality	OWB Code	Quaternary Watershed
Loudon Lk	Georgian Bay		
Louie Lake	Algonquin Highlands	02EB-13	Hollow River
Lower Boleau Lk	Muskoka Lakes	02EB-03	Musquash River
Lower Eagle Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Lower Eastern Lake	Severn	02EC-01	Little Lake-Severn River
Lower Fletcher Lake	Algonquin Highlands	02EB-13	Hollow River
Lower Galla Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Lower Musquash River	Georgian Bay	02EB-03	Musquash River
Lower Pairo Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Lower Raft Lk	Lake of Bays	02EB-10	Little East River-Big East River
Lower Schufelt Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Lower Twin Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Luck Lake	Algonquin Highlands	02EB-13	Hollow River
Lulu Lake	Algonquin Park	02EB-10	Little East River-Big East River
Lunnen Lk	Georgian Bay	02EB-03	Musquash River
Lupus Lake	Algonquin Park	02EB-10	Little East River-Big East River
Lynch Lk	Huntsville	02EB-06	North Branch Muskoka River
Lynx Lk	Huntsville	02EB-06	North Branch Muskoka River
Mackinaw Lake	Algonquin Park	02EB-10	Little East River-Big East River
MacLean Lake	Severn	02EC-01	Little Lake-Severn River
MacLean Lake	Severn	02EC-01	Little Lake-Severn River
Maggie Lake	Algonquin Park	02EB-10	Little East River-Big East River
Magpie Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Mainhood Lk	Huntsville	02EB-09	Lake Rosseau
Mansell Lk	Lake of Bays	02EB-10	Little East River-Big East River
Maple Leaf Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
March Hare Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Margaret Lk	Lake of Bays		
Marion Lk	Lake of Bays	02EB-10	Little East River-Big East River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Marion Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Martencamp Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Martin Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Mary Jane Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Mary Lk	Huntsville	02EB-06	North Branch Muskoka River
Matthews Lk	Huntsville	02EB-09	Lake Rosseau
Mayflower Lk	Huntsville	02EB-10	Little East River-Big East River
McBrien Pond	Lake of Bays	02EB-10	Little East River-Big East River
McCrae Lk	Georgian Bay	023C	South Georgian Bay Shoreline
McCraney Lake	Algonquin Park	02EB-10	Little East River-Big East River
McDonald Lake	Minden Hills	02EC-09	Cache Creek-Black River
McDonald Lk	Georgian Bay	023C	South Georgian Bay Shoreline
McEachern Lake	Archipelago	02EB-02	Blackstone Harbour
McEwen Lk	Lake of Bays		
McFadden Lake	Algonquin Highlands	02EB-13	Hollow River
McGarvey Lake	Algonquin Highlands	02EB-13	Hollow River
McKay Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
McKechnie Lake	Seguin	02EB-02	Blackstone Harbour
McMaster Lk	Georgian Bay	02EB-01	Moon River Bay
McQuillan Lake	Archipelago	02EB-02	Blackstone Harbour
McRae Lk	Georgian Bay	02EB-01	Moon River Bay
McRey Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
McReynold Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
McTaggart Lake	Seguin	02EB-09	Lake Rosseau
Meadow Lk	Muskoka Lakes		
Medora Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Menominee Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Merdie Lake	Algonquin Highlands	02EB-13	Hollow River
Midget Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Mikado Lake	Algonquin Park	02EB-11	Oxtongue River Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Millichamp Lake	Algonquin Highlands	02EB-13	Hollow River
Mink Lk	Bracebridge	02EC-13	Kahshe River
Mink Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Minnow Lake	Algonquin Park	02EB-10	Little East River-Big East River
Minors Bay	Georgian Bay	02EB-03	Musquash River
Minto Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Mirage Lake	Perry	02EB-10	Little East River-Big East River
Mirror Lake	Seguin	02EB-09	Lake Rosseau
Mirror Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Mohawk Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Montgomery Lk	Huntsville	02EB-06	North Branch Muskoka River
Moon River	Georgian Bay	02EB-01	Moon River Bay
Moon River	Muskoka Lakes	02EB-03	Musquash River
Mooney Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Moose Lk	Gravenhurst	02EC-02	Sparrow Lake-Black River
Moot Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Morgan's Lake	Kearney	02EB-10	Little East River-Big East River
Morrison Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Mosquito Lk	Georgian Bay	02EB-09	Lake Rosseau
Mosquito Lk	Muskoka Lakes	02EC-01	Little Lake-Severn River
Mossy Lake	Algonquin Park	02EB-10	Little East River-Big East River
Motley Lake	Seguin	02EB-09	Lake Rosseau
Mouse Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Mud Lake	Ramara	02EC-04	Lake St. John-Black River
Mug Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Muskoka Bay	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Muskoka River	Bracebridge	02EB-04	Lake Muskoka-Muskoka River
Muskoka River	Bracebridge	02EB-06	North Branch Muskoka River
Muskoka River (north)	Huntsville	02EB-06	North Branch Muskoka River
Muskoka River (south)	Bracebridge	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Musquash River	Georgian Bay	02EB-03	Musquash River
Musquash River	Muskoka Lakes	02EB-03	Musquash River
Myers Lk	Georgian Bay	02EB-01	Moon River Bay
Nadjiwan Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Namakootchie Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Narrow Lk	Muskoka Lakes	02EB-03	Musquash River
Neilson Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Neipage Lk	Muskoka Lakes	02EC-01	Little Lake-Severn River
Nelson Lk	Lake of Bays	02EB-10	Little East River-Big East River
Niger Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Nightfall Lake	Kearney	02EB-10	Little East River-Big East River
Nine Mile Lk	Muskoka Lakes	02EB-03	Musquash River
Norah Lake	Algonquin Park	02EB-10	Little East River-Big East River
Norman Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
North Bay	Georgian Bay	023C	South Georgian Bay Shoreline
North Dotty Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
North Healey Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
North Longford Lk	Gravenhurst	02EC-04	Lake St. John-Black River
North Muldrew Lk	Gravenhurst	02EC-01	Little Lake-Severn River
North Oak Lake	Algonquin Park	02EB-10	Little East River-Big East River
Notsobig Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Nutt Lk	Muskoka Lakes	02EB-09	Lake Rosseau
O'Connor Lk	Georgian Bay	02EB-03	Musquash River
O'Gorman Lake	Algonquin Park	02EB-10	Little East River-Big East River
Oak Lake	Algonquin Park	02EB-10	Little East River-Big East River
Oak Lake	Seguin	02EB-02	Blackstone Harbour
Oldfield Lake	Archipelago	02EB-02	Blackstone Harbour
Onawaw Lk	Huntsville	02EB-08	Lake Vernon
One Island Lake	Seguin	02EB-02	Blackstone Harbour
Otter Lake	Algonquin Highlands	02EB-07	Baysville Narrows-S Branch Muskoka R
Otter Lake	Severn	02EC-01	Little Lake-Severn River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Otter Lk	Huntsville	02EB-06	North Branch Muskoka River
Oudaze Lk	Huntsville	02EB-10	Little East River-Big East River
Oxbow Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Oxtongue Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Oxtongue River	Lake of Bays	02EB-11	Oxtongue River Outlet
Oxtongue River	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Paddy Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Paint Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Palette Lk	Huntsville	02EB-10	Little East River-Big East River
Palmer Lk	Huntsville	02EB-06	North Branch Muskoka River
Panther Lake	Algonquin Park	02EB-10	Little East River-Big East River
Park Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Park Lk	Georgian Bay	02EB-01	Moon River Bay
Pathfinder Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Paul's Lk	Bracebridge	02EB-04	Lake Muskoka-Muskoka River
Pauls Lake	Archipelago	02EB-02	Blackstone Harbour
Pauper Lake	Minden Hills		
Payne Lake	Seguin	02EB-02	Blackstone Harbour
Peanut Lake	Archipelago	02EB-02	Blackstone Harbour
Peeler Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Pell Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Pence Lk	Gravenhurst	02EB-03	Musquash River
Penfold Lk	Huntsville	02EB-06	North Branch Muskoka River
Peninsula Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Pennsylvania Lk	Muskoka Lakes	02EB-03	Musquash River
Perch Lk	Huntsville	02EB-10	Little East River-Big East River
Pickering Lake	Seguin	02EB-09	Lake Rosseau
Pigeon Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Pincher Lake	Algonquin Park	02EB-10	Little East River-Big East River
Pine Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Pine Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet

Lake Name	Municipality	OWB Code	Quaternary Watershed
Pipio Lake	Algonquin Highlands	02EB-13	Hollow River
Plough Lake	Algonquin Highlands	02EB-14	Tea Lake-Oxtongue River
Poker Lake	Minden Hills	02EC-09	Cache Creek-Black River
Poorhouse Lake	Algonquin Highlands	02EB-13	Hollow River
Porcupine Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Portage Lake	Seguin	02EB-09	Lake Rosseau
Potter Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Powderhorn Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Pretty Channel	Georgian Bay	023C	South Georgian Bay Shoreline
Pretzel Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Prospect Lk	Bracebridge	02EC-13	Kahshe River
Pup Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Quiver Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Ragged Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Rain Lake	Algonquin Park	02EB-10	Little East River-Big East River
Rainbow Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Rat Lk	Gravenhurst	02EB-03	Musquash River
Raven Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Rebecca Lk	Lake of Bays	02EB-10	Little East River-Big East River
Red Chalk Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Red Lake	Algonquin Park	02EB-10	Little East River-Big East River
Red Wing Lake	Algonquin Park	02EB-10	Little East River-Big East River
Ricketts Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Ridge Lake	Kearney	02EB-10	Little East River-Big East River
Ridout Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Ril Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Riley Lk	Gravenhurst	02EC-04	Lake St. John-Black River
Ripple Lk	Huntsville	02EB-10	Little East River-Big East River
Roberts Lake	Seguin	02EB-09	Lake Rosseau

Lake Name	Municipality	OWB Code	Quaternary Watershed
Robinson Lk	Gravenhurst	02EC-04	Lake St. John-Black River
Robinson Lk	Huntsville	02EB-08	Lake Vernon
Rockaway Lake	Algonquin Highlands	02EB-13	Hollow River
Roderick Lk	Muskoka Lakes	02EB-01	Moon River Bay
Roger Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Ronald Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Rose Lk	Huntsville	02EB-06	North Branch Muskoka River
Rosswood Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Round Lake	Kearney	02EB-10	Little East River-Big East River
Round Lake	McMurrich-Monteith	02EB-08	Lake Vernon
Round Lake	Severn	02EC-01	Little Lake-Severn River
Roundabout Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Ryde Lk	Gravenhurst	02EC-13	Kahshe River
Sage Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Sahanatien Lk	Georgian Bay	02EB-03	Musquash River
Sam Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Samlet Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Sand Lk	Lake of Bays		
Saucer Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Saw Lk	Bracebridge	02EC-09	Cache Creek-Black River
Sawyer Lake	Algonquin Park	02EB-10	Little East River-Big East River
Sawyer Lk	Muskoka Lakes	02EB-01	Moon River Bay
Schufelt Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Scott Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Second Lake	Seguin	02EB-02	Blackstone Harbour
Seventeen Mile Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Severn River	Georgian Bay	02EC-01	Little Lake-Severn River
Severn River	Muskoka Lakes	02EC-01	Little Lake-Severn River
Severn River	Gravenhurst	02EC-02	Sparrow Lake-Black River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Severn River	Georgian Bay	02EC-01	Little Lake-Severn River
Shack Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Shapter Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Shaw Lk	Muskoka Lakes	02EB-03	Musquash River
Shawandasee Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
Shier Lake	Algonquin Highlands	02EB-13	Hollow River
Shoe Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Sickle Lake	Kawartha Lakes	02EC-09	Cache Creek-Black River
Siding Lk	Huntsville	02EB-06	North Branch Muskoka River
Silver Lake	Seguin	02EB-09	Lake Rosseau
Silver Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Silver Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Silver Sand Lk	Georgian Bay	02EB-01	Moon River Bay
Simpson Lake	Kearney	02EB-10	Little East River-Big East River
Sims Lk	Huntsville	02EB-08	Lake Vernon
Six Mile Channel	Georgian Bay	02EC-01	Little Lake-Severn River
Six Mile Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Sixteen Mile Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Skeleton Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Skidway Lake	Archipelago	02EB-01	Moon River Bay
Slim Lk	Lake of Bays	02EB-10	Little East River-Big East River
Slipper Lake	Dysart et al	02EB-13	Hollow River
Slocombe Lk	Huntsville	02EB-06	North Branch Muskoka River
Sly Lk	Lake of Bays	02EB-10	Little East River-Big East River
Smoke Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Snow Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Snowshoe Lake	Kearney	02EB-10	Little East River-Big East River
Solitaire Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
South Bay	Georgian Bay	023C	South Georgian Bay Shoreline

Lake Name	Municipality	OWB Code	Quaternary Watershed
South Jean Lake	Minden Hills	02EC-09	Cache Creek-Black River
South Longford Lk	Gravenhurst	02EC-04	Lake St. John-Black River
South McDonald Lake	Minden Hills	02EC-09	Cache Creek-Black River
South Muldrew Lk	Gravenhurst	02EC-01	Little Lake-Severn River
South Nelson Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
South Tasso Lk	Lake of Bays	02EB-10	Little East River-Big East River
South Wildcat Lake	Dysart et al	02EB-13	Hollow River
Southworth Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Spaniel Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Sparrow Lk	Gravenhurst	02EC-02	Sparrow Lake-Black River
Spectacle Lake	Seguin	02EB-02	Blackstone Harbour
Speiran Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Spence Crk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Spence Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Spider Lk	Huntsville	02EB-06	North Branch Muskoka River
Splash Lake	Algonquin Park	02EB-10	Little East River-Big East River
Splatter Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Sprat Lake	Minden Hills	02EC-09	Cache Creek-Black River
Spring Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Spry Lake	Kearney	02EB-10	Little East River-Big East River
St Germaine Lk	Muskoka Lakes	02EB-09	Lake Rosseau
St. John Creek	Ramara	02EC-04	Lake St. John-Black River
Steeple Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Steveson Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Stewart Lk	Georgian Bay	02EB-09	Lake Rosseau
Stinking Lk	Huntsville	02EB-06	North Branch Muskoka River
Stocking Lake	Dysart et al	02EB-13	Hollow River
Stonehouse Lake	Archipelago	02EB-02	Blackstone Harbour
Stoneleigh Lk	Bracebridge	02EB-06	North Branch Muskoka River
Straight Shore Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Stuart Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Sucker Lake	Seguin	02EB-09	Lake Rosseau
Sugarbowl Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Sullivan Lk	Georgian Bay	02EB-01	Moon River Bay
Sunbeam Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Sunken Lake	Algonquin Highlands	02EC-09	Cache Creek-Black River
Sunny Lk	Gravenhurst	02EC-13	Kahshe River
Sunrise Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Sunset Lake	Algonquin Park	02EB-10	Little East River-Big East River
Surerus Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Surprise Lk	Lake of Bays	02EB-10	Little East River-Big East River
Swallow Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Swamp Lk	Bracebridge	02EC-04	Lake St. John-Black River
Swan Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Swan Lk	Georgian Bay	02EB-03	Musquash River
Sward Lake	Algonquin Highlands	02EB-13	Hollow River
Tabor Lake	McMurrich-Monteith	02EB-08	Lake Vernon
Tackaberry Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Tadenac Bay	Georgian Bay	023C	South Georgian Bay Shoreline
Tadenac Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Tamarack Lk	Bracebridge	02EC-09	Cache Creek-Black River
Tank Lk	Muskoka Lakes	02EC-01	Little Lake-Severn River
Tar Lk	Muskoka Lakes	02EB-03	Musquash River
Tasso Crk	Lake of Bays	02EB-10	Little East River-Big East River
Tasso Lk	Lake of Bays	02EB-12	Distress Pond-Big East River
Tate Lk	Georgian Bay	023C	South Georgian Bay Shoreline
Tea Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Tea Lake	Severn	02EC-01	Little Lake-Severn River
Teapot Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Tee Lk	Bracebridge	02EC-09	Cache Creek-Black River
Tepee Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River

Lake Name	Municipality	OWB Code	Quaternary Watershed
Tern Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Thinn Lk	Bracebridge	02EB-04	Lake Muskoka-Muskoka River
Third Lake	Seguin	02EB-02	Blackstone Harbour
Thirty Lake	Kearney	02EB-10	Little East River-Big East River
Thompson Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Thorne Lk	Muskoka Lakes	02EB-04	Lake Muskoka-Muskoka River
Three Brothers Lakes	Minden Hills	02EC-09	Cache Creek-Black River
Three Island Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Three Mile Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Three Mile Lk	Gravenhurst	02EC-13	Kahshe River
Thumb Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Thunder Lake	Algonquin Park	02EB-10	Little East River-Big East River
Tingey Lake	Minden Hills	02EC-09	Cache Creek-Black River
Toad Lk	Lake of Bays	02EB-10	Little East River-Big East River
Tom Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Tom Thomson Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Toms Lk	Huntsville	02EB-06	North Branch Muskoka River
Tonakela Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Tonawanda Crk	Lake of Bays	02EB-10	Little East River-Big East River
Tongua Lk	Huntsville	02EB-06	North Branch Muskoka River
Tooke Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Toronto Lk	Georgian Bay	02EB-01	Moon River Bay
Trackler Lk	Huntsville	02EB-08	Lake Vernon
Traves Lake	Archipelago	02EB-02	Blackstone Harbour
Treefrog Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Troutspawn Lake	Algonquin Highlands	02EB-13	Hollow River
Tucker Lake	Seguin	02EB-09	Lake Rosseau
Tucker Lk	Huntsville	02EB-06	North Branch Muskoka River
Tug Channel	Georgian Bay		

Lake Name	Municipality	OWB Code	Quaternary Watershed
Turtle Lake	Severn	02EC-01	Little Lake-Severn River
Turtle Lk	Muskoka Lakes	02EB-03	Musquash River
Turtle Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Twelve Mile Bay	Georgian Bay	023C	South Georgian Bay Shoreline
Upper Andrews Lake	Kawartha Lakes	02EC-04	Lake St. John-Black River
Upper Boleau Lk	Muskoka Lakes	02EB-03	Musquash River
Upper Crane Lake	Minden Hills	02EC-09	Cache Creek-Black River
Upper Eagle Lk	Gravenhurst	02EC-01	Little Lake-Severn River
Upper Gibson River	Georgian Bay	02EB-03	Musquash River
Upper Oxbow Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Upper Pairo Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Upper Raft Lk	Lake of Bays	02EB-10	Little East River-Big East River
Upper Twin Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Vanishing Pond	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Vaughan Lk	Georgian Bay	02EB-01	Moon River Bay
Verner Lk	Lake of Bays	02EB-10	Little East River-Big East River
Victory Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Virtue Lake	Seguin	02EB-02	Blackstone Harbour
Walker Lk	Lake of Bays	02EB-06	North Branch Muskoka River
Waseosa Lk	Huntsville	02EB-10	Little East River-Big East River
Washa Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Watson Lake	Seguin	02EB-09	Lake Rosseau
Webster Lk	Georgian Bay	02EB-03	Musquash River
Weed Lake	Algonquin Park	02EB-10	Little East River-Big East River
Weeduck Lk	Huntsville	02EB-06	North Branch Muskoka River
Weirs Marsh	Gravenhurst	02EC-01	Little Lake-Severn River
Weismuller Lk	Bracebridge	02EC-13	Kahshe River
Wells Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
West Boot Lk	Georgian Bay	02EB-03	Musquash River
West Buck Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
West Dolly Lake	Algonquin Park	02EB-10	Little East River-Big East River

Lake Name	Municipality	OWB Code	Quaternary Watershed
West Duffy Lk	Muskoka Lakes	02EB-01	Moon River Bay
West Ermine Lk	Lake of Bays	02EB-10	Little East River-Big East River
West Harry Lake	Algonquin Park	02EB-10	Little East River-Big East River
West Maggie Lk	Lake of Bays	02EB-10	Little East River-Big East River
West Otterpaw Lake	Algonquin Park	02EB-10	Little East River-Big East River
Westward Lake	Algonquin Park	02EB-11	Oxtongue River Outlet
White Lk	Georgian Bay	02EB-01	Moon River Bay
Whitehouse Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Whites Lk	Huntsville	02EB-10	Little East River-Big East River
Whitespruce Lake	Algonquin Park	02EB-10	Little East River-Big East River
Wier Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Wilbur Lake	Algonquin Highlands	02EB-11	Oxtongue River Outlet
Wilcox Lake	Archipelago	02EB-02	Blackstone Harbour
Wildcat Lake	Dysart et al	02EB-13	Hollow River
Wildcat Lk	Lake of Bays	02EB-05	South Branch Muskoka R Outlet
Wileys Lake	Seguin	02EB-09	Lake Rosseau
Willie Lake	Kearney	02EB-10	Little East River-Big East River
Willow Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Wilson Lk	Lake of Bays	02EB-11	Oxtongue River Outlet
Windfall Lake	Seguin	02EB-02	Blackstone Harbour
Wisp Lake	Algonquin Park	02EB-14	Tea Lake-Oxtongue River
Wolf Lake	Algonquin Highlands	02EB-13	Hollow River
Wolfish Lake	Algonquin Highlands	02EB-13	Hollow River
Wolfkin Lk	Lake of Bays	02EB-07	Baysville Narrows-S Branch Muskoka R
Wolfsbane Lake	Algonquin Highlands	02EB-13	Hollow River
Wood Lk	Bracebridge	02EB-05	South Branch Muskoka R Outlet
Woodbine Lk	Huntsville	02EB-06	North Branch Muskoka River
Woodland Lk	Muskoka Lakes	02EB-03	Musquash River
Woodroffe Lk	Georgian Bay	02EB-01	Moon River Bay

Lake Name	Municipality	OWB Code	Quaternary Watershed
Woods Lk	Muskoka Lakes	02EB-09	Lake Rosseau
Wren Lk	Lake of Bays	02EC-09	Cache Creek-Black River
Wrights Lk	Gravenhurst	02EB-04	Lake Muskoka-Muskoka River
Wrist Lk	Bracebridge	02EC-09	Cache Creek-Black River
Young Lk	Muskoka Lakes	02EB-09	Lake Rosseau

APPENDIX C – TABLE OF LAKES FOR LAKE TROUT MANAGEMENT

Table 23. Lakes designated by the MNRF for the management of lake trout in tertiary watershed 02EB and the District of Muskoka (2015).

Lake	Area (ha)	Municipality	Quaternary Watershed	Management Designation
Bear Lake	95	Algonquin Highlands	2EB-13	Natural
Bella Lake	328	Lake of Bays	2EB-10	Natural
Big Porcupine Lake	250	Algonquin Park	2EB-14	Natural
Bigwind Lake	107	Bracebridge	2EB-05	Put-Grow-Take
Blackstone Lake	532	Archipelago	2EB-02	Put-Grow-Take
Blue Chalk Lake	50	Lake of Bays	2EC-09	Natural
Bonnie Lake	42	Bracebridge	2EB-06	Natural
Brûlé Lake	86	Algonquin Park	2EB-14	Natural
Buck Lake	40	Lake of Bays	2EB-07	Natural
Burnt Island Lake	987	Algonquin Park	2EB-14	Natural
Camp Lake	189	Lake of Bays	2EB-12	Natural
Canoe Lake	367	Algonquin Park	2EB-14	Natural
Clear Lake	100	Bracebridge	2EC-09	Natural
Clearwater Lake	72	Gravenhurst	2EC-02	Natural
Clinto Lake	142	Algonquin Highlands	2EB-07	Natural
Crane Lake	515	Archipelago	2EB-02	Put-Grow-Take
Dotty Lake	153	Lake of Bays	2EB-11	Put-Grow-Take
Eighteen Mile Lake	36	Algonquin Highlands	2EB-07	Natural
Emsdale Lake	61	Kearney	2EB-10	Natural
Fairy Lake	712	Huntsville	2EB-06	Put-Grow-Take
Fifteen Mile Lake	86	Lake of Bays	2EB-07	Natural
Flaxman Lake	63	Seguin	2EB-02	Natural
Fletcher Lake	256	Algonquin Highlands	2EB-13	Put-Grow-Take
Forget Lake	27	Seguin, Archipelago	2EB-02	Put-Grow-Take
Fox Lake	63	Kearney	2EB-12	Natural
Harp Lake	72	Huntsville	2EB-16	Put-Grow-Take
Jerry Lake	57	Lake of Bays	2EB-06	Natural

Lake	Area (ha)	Municipality	Quaternary Watershed	Management Designation
Joe Lake	139	Algonquin Park	2EB-14	Natural
Lake Joseph	5156	Muskoka Lakes	2EB-09	Natural
Kawagama Lake	2819	Algonquin Highlands	2EB-13	Natural
Kimball Lake	213	Algonquin Highlands	2EB-13	Natural
Lake of Bays	6904	Lake of Bays, Huntsville	2EB-07	Natural
Linda Lake	100	Algonquin Park	2EB-14	Natural
Little Joe Lake	50	Algonquin Park	2EB-14	Natural
Little Raccoon Lake	38	Algonquin Park	2EB-14	Natural
Littledoe Lake	121	Algonquin Park	2EB-14	Natural
Livingstone Lake	189	Algonquin Highlands	2EB-13	Natural
Louie Lake	31	Algonquin Highlands	2EB-13	Natural
Lower Fletcher Lake	61	Algonquin Highlands	2EB-13	Put-Grow-Take
Maggie Lake	138	Algonquin Park	2EB-12	Natural
Margaret Lake	58	Lake of Bays	2HF-05	Natural
Mary Lake	1065	Huntsville	2EB-06	Put-Grow-Take
McCraney Lake	392	Algonquin Park	2EB-12	Natural
McFadden Lake	54	Algonquin Highlands	2EB-13	Natural
McGarvey Lake	68	Algonquin Park	2EB-13	Natural
Lake Muskoka	12206	Muskoka Lakes, Bracebridge, Gravenhurst	2EB-04	Natural
Namakootchie Lake	19	Algonquin Park	2EB-14	Natural
Oxbow Lake	169	Lake of Bays	2EB-11	Put-Grow-Take
Oxtongue Lake	249	Algonquin Highlands	2EB-11	Natural
Peninsula Lake	865	Lake of Bays, Huntsville	2EB-06	Put-Grow-Take
Pine Lake	77	Bracebridge	2EB-05	Natural
Portage Lake	98	Seguin	2EB-09	Put-Grow-Take
Potter Lake	94	Algonquin Park	2EB-14	Natural
Ragged Lake	602	Algonquin Park	2EB-14	Natural
Rain Lake	167	Algonquin Park	2EB-12	Natural
Rebecca Lake	211	Lake of Bays	2EB-10	Put-Grow-Take
Red Chalk Lake	58	Lake of Bays	2EC-09	Natural
Lake Rosseau	6374	Muskoka Lakes	2EB-09	Natural

Lake	Area (ha)	Municipality	Quaternary Watershed	Management Designation
Sawyer Lake	48	Algonquin Park	2EB-12	Natural
Shoe Lake	39	Lake of Bays	2EB-07	Put-Grow-Take
Silver Lake	55	Seguin	2EB-09	Put-Grow-Take
Skeleton Lake	2156	Muskoka Lakes, Huntsville	2EB-09	Natural
Smoke Lake	661	Algonquin Park	2EB-14	Natural
Solitaire Lake	122	Lake of Bays	2EB-07	Natural
South Tasso Lake	18	Lake of Bays	2EB-12	Natural
Sucker Lake	104	Seguin	2EB-09	Put-Grow-Take
Sunbeam Lake	82	Algonquin Park	2EB-14	Natural
Swan Lake	89	Algonquin Park	2EB-14	Natural
Tasso Lake	170	Lake of Bays	2EB-12	Natural
Tea Lake	149	Algonquin Park	2EB-14	Natural
Tepee Lake	77	Algonquin Park	2EB-14	Natural
Tom Thomson Lake	149	Algonquin Park	2EB-14	Natural
Lake Vernon	1505	Huntsville	2EB-08	Put-Grow-Take
Young Lake	109	Muskoka Lakes	2EB-09	Put-Grow-Take