CHAPTER 1 – CALCIUM CONCENTRATIONS IN MUSKOKA'S LAKES

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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*.

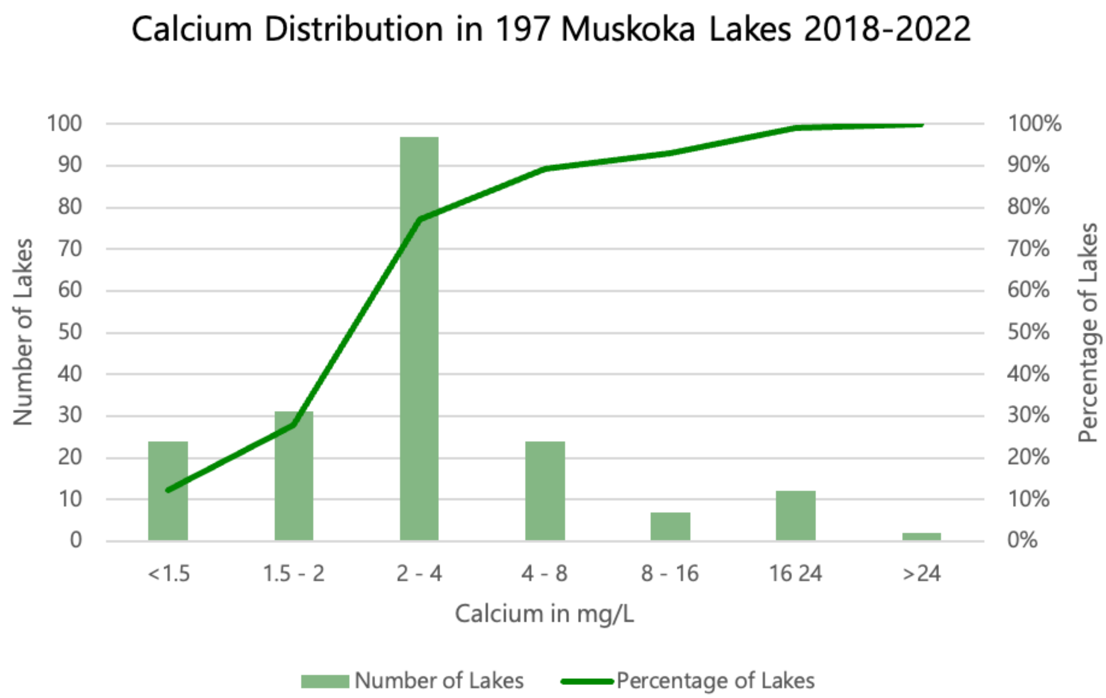

Figure 3. Mean calcium concentration in 197 Muskoka Lakes, 2018-2022.

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.