North Muldrew Lake

Muskoka District, Township of Gravenhurst

North Muldrew Lake has been sampled through the Lake Partner Program for total Phosphorus concentrations ([TP]) and water clarity readings (Secchi depth) at three locations. The sampling locations are at the deep spot in the middle of the lake (Site 1), the North end of the lake near Laurel Island (Site 2), and North/West of Kerr Island (Site 5). North Muldrew Lake (Station 4074) is located on the Canadian Shield.

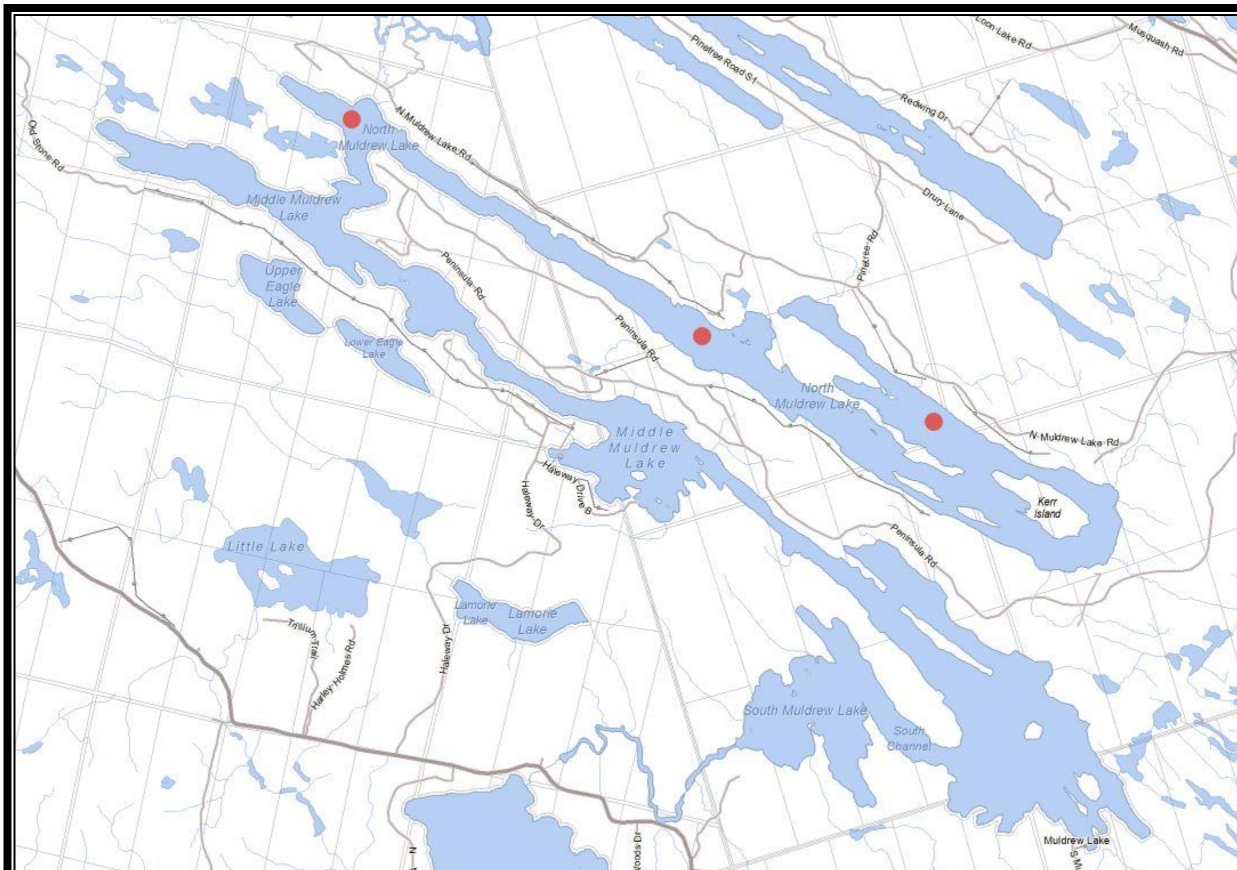


Figure 1. A map of North Muldrew Lake indicating the location of the Lake Partner Program sampling sites with red circles.

Table 1. General Information pertaining to the monitoring locations on North Muldrew Lake

Lake Name	STN	Site ID	Latitude (DMS)	Longitude (DMS)	Site Description
North Muldrew Lake	4074	1	445418	792615	Mid Lake, deep spot
		2	445500	792748	N end, Laurel Is.
		5	445403	792514	N end-NW Kerr Island

Total Phosphorus

Based on the Lake Partner Program spring turnover total phosphorus concentrations ([TP]) for North Muldrew Lake the following observations can be made:

- The overall average [TP] for North Muldrew Lake is 9.2 µg/L (based on data from the last years 14 years, 2002-2015; Table 2.) The majority of Ontario lakes monitored by the Lake Partner Program have an average [TP] of 8-10 µg/L. Therefore, North Muldrew Lake has good water quality relative to other lakes in Ontario.
- There are two outlier data points that were be removed from analysis (Site 2 in 2008, 16.8 µg/L; Site 3 in 2012, 14 µg/L)

- We can see by looking at the spring [TP] data that North Muldrew Lake appears to have some inter-annual variability in total phosphorus concentrations. From (2002-2015), [TP] has been as low as 6.2 and as high as 10.5 µg/L (Table 2, Figure 2), with an overall average TP concentration of 8.5 µg/L.

- With respect to trophic status, North Muldrew Lake is an 'oligotrophic', low nutrient lake. "Oligotrophic" is a term used to describe lakes that have average TP concentrations of less than 10 µg/L.

- One common way of looking at long-term trends in water quality data is to use a statistical test called a Mann-Kendal Trend Test. The results of this statistical test show that there is no trend in the data (i.e., [TP] have not significantly increased over time at this site).

LAKE PARTNER PROGRAM RESULTS

Table 2. Total phosphorus (TP) concentrations for North Muldrew Lake, from 2002-2015. Note the data highlighted in yellow has been removed from the calculations.

STN	Site ID	Lat	Long	Site Description	Year	Sampling Date	Average
4074	1	445418	792615	Mid Lake, deep spot	2015	17-May-2015	9.3
	2	445500	792748	N end, Laurel Is.	2002	26-May-2002	7.8
					2003	25-May-2003	7.4
					2004	19-May-2004	7.2
					2005	03-Jun-2005	6.2
					2006	28-May-2006	8.7
					2007	21-May-2007	8.1
					2008	19-May-2008	16.84
					2009	19-May-2009	7.8
					2010	10-May-2010	8.6
					2011	21-May-2011	10.2
					2012	26-May-2012	9.8
					2013	19-May-2013	9.7
					2014	18-May-2014	10.0
					2015	17-May-2015	8.1
	5	445403	792514	N end-NW Kerr Island	2010	10-May-2010	9.2
					2011	21-May-2011	8.6
					2012	21-May-2012	14
					2013	19-May-2013	8.0
						Average Low:	6.2
						Average High:	10.2
						Overall Average:	8.5

Table 3. Monthly total phosphorus concentrations for North Muldrew Lake (Site 2, N end, Laurel Island) from 1994-2001. **Note that pre-2002 Lake Partner Program TP data are much less precise than TP data from 2002-15. Pre-2002 TP samples were not taken in duplicate, were not filtered to remove large zooplankton or other debris, and were analysed at a lab with low analytical precision (+/- 10-20 µg/L TP). Therefore, we recommend taking an overall average of the pre-2002 data and comparing this average to the precise, 2002-15 recent data.

Lake Name	STN	Site ID	Lat	Long	Site Description	Date	TP
NORTH MULDREW LAKE	4074	2	445500	792748	N end, Laurel Is.	02-Jul-94	8.0
						10-Jul-94	8.0
						17-Jul-94	8.0
						24-Jul-94	8.0
						01-Aug-94	10.0
						07-Aug-94	6.0
						14-Aug-94	12.0
						21-Aug-94	6.0
						28-Aug-94	6.0
						03-Sep-94	8.0
						03-Jul-95	14.0
						09-Jul-95	16.0
						23-Jul-95	14.0
						07-Aug-95	6.0
						13-Aug-95	26.0
						20-Aug-95	6.0
						27-Aug-95	6.0
						01-Jul-96	2.0
						07-Jul-96	12.0
						21-Jul-96	8.0
						28-Jul-96	6.0
						05-Aug-96	8.0
						11-Aug-96	6.0
						18-Aug-96	6.0
						25-Aug-96	6.0
						02-Sep-96	10.0
						08-Jun-97	8.0
						10-May-98	12.0
						30-May-99	10.0
						28-May-00	8.0
						14-May-01	12.0
						Overall Average TP	**9.1**

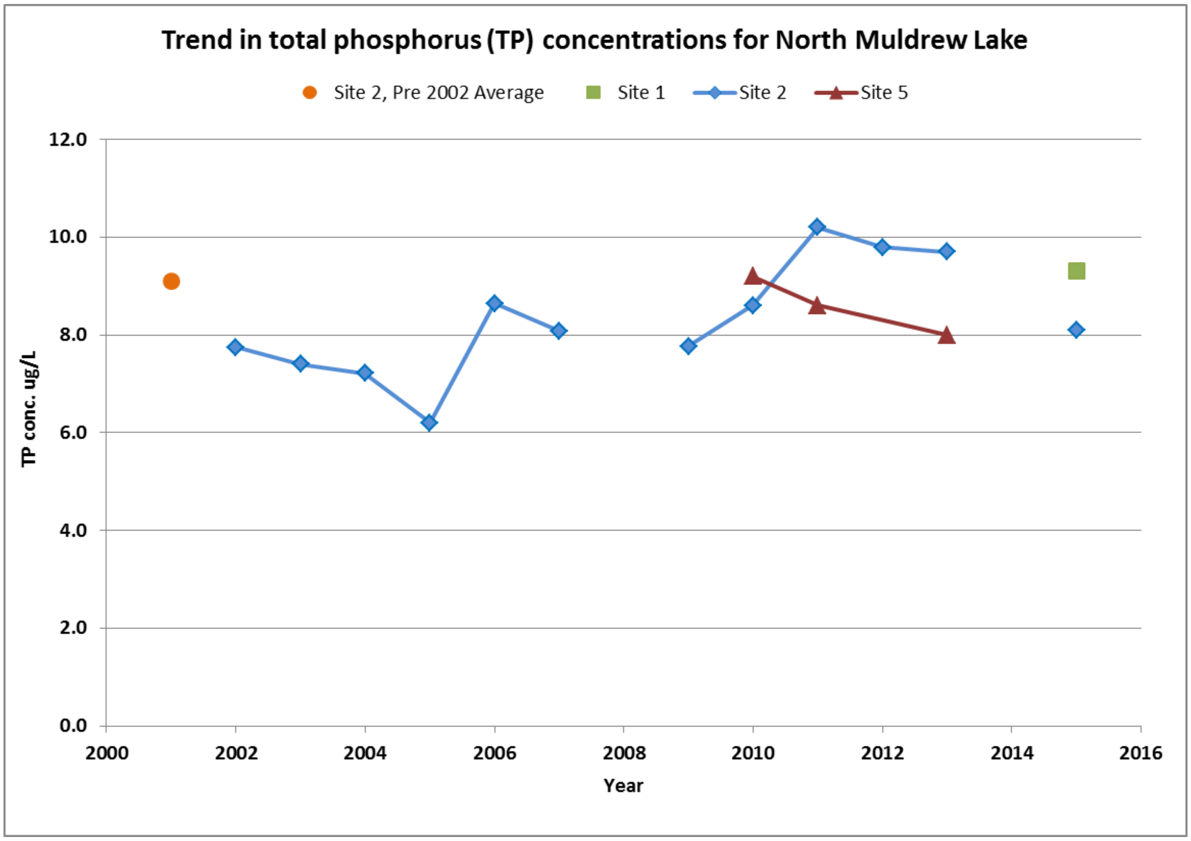


Figure 2. Between-year variation in spring total phosphorus concentrations ([TP]) for North Muldrew Lake from 2002-2015. Orange circle represents the 1994-2001 monthly average of site 2 [TP] of 9.1 µg/L.

Water Clarity

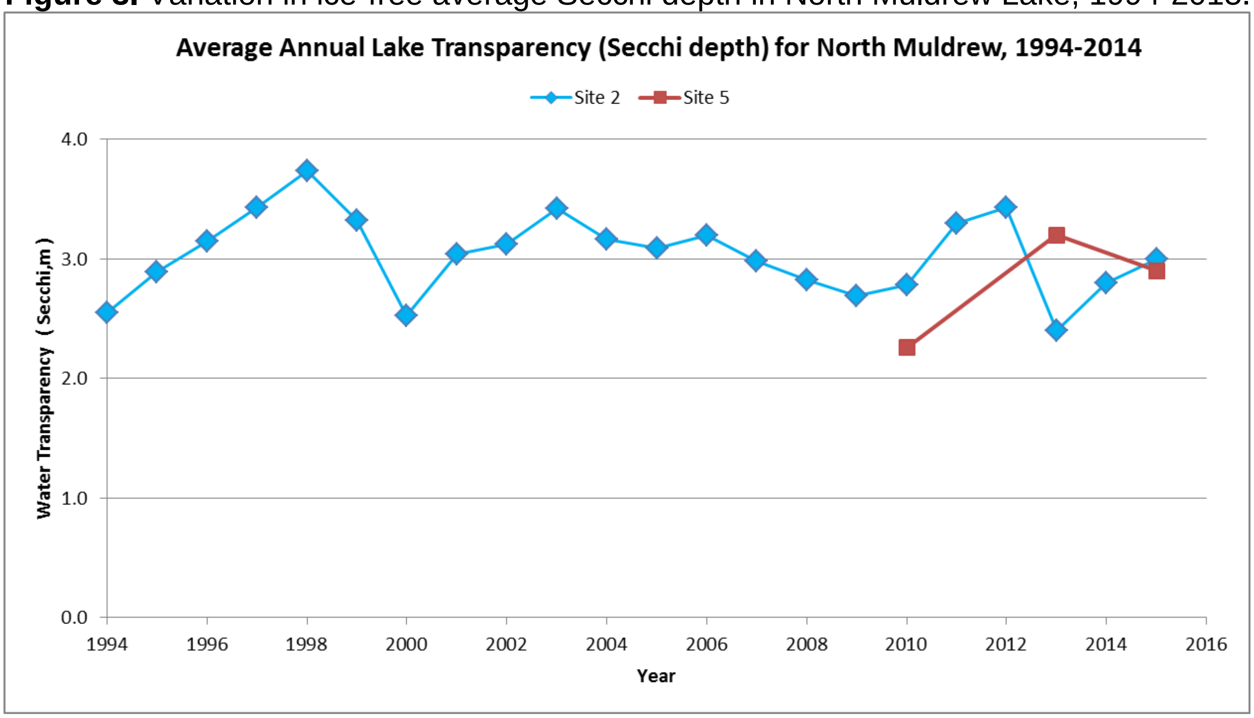
Changes in water clarity may indicate that changes are occurring in the algal biomass of the lake, although this relationship is more apparent in lakes with high [TP]. In lakes with low concentrations of TP, such as North Muldrew, changes in water clarity may reflect variation in lake colour, concentrations of dissolved organic matter or other watershed changes.

A Secchi disc is lowered into the water to take water clarity measurements. The average Secchi disk transparencies for each year are presented in Table 4 and displayed graphically in Figure 3. The overall average water clarity from 1994-2015 is 3.0 m. Between-year variation in water clarity in North Muldrew Lake is minimal.

Table 4. Annual ice-free average Secchi depth readings for North Muldrew Lake from 1994-2015.

STN	Site ID	Site Description	Lat	Long	Year	Average Secchi
4074	2	N end, Laurel Is.	445500	792748	1994	2.6
					1995	2.9
					1996	3.1
					1997	3.4
					1998	3.7
					1999	3.3
					2000	2.5
					2001	3.0
					2002	3.1
					2003	3.4
					2004	3.2
					2005	3.1
					2006	3.2
					2007	3.0
					2008	2.8
					2009	2.7
					2010	2.8
					2011	3.3
					2012	3.4
					2013	2.4
					2014	2.8
					2015	3.0
	5	N end-NW Kerr Island	445403	792514	2010	2.3
					2013	3.2
					2015	2.9
					Overall Average:	3.0

Figure 3. Variation in ice-free average Secchi depth in North Muldrew Lake, 1994-2015.



Calcium

The average [Ca] for North Muldrew Lake is 3.3 mg/L based on these seven years of data (Table 5). This value is above the 2.5 mg/L concentration that has found through laboratory experiments to be critical for crayfish and *Daphnia* (a zooplankton) survival. See attached information sheet on calcium decline in Ontario's inland lakes for more information.

Table 5. Spring calcium concentrations for North Muldrew Lake.

STN	Site ID	Lat	Long	Site Description	Date	Ca
4074	1	445418	792615	Mid Lake, deep spot	17-May-15	3.1
	2	445500	792748	N end, Laurel Is.	19-May-08	3.4
					19-May-09	3.0
					10-May-10	3.3
					26-May-12	3.5
					19-May-13	3.0
					18-May-14	3.7
					17-May-15	3.2
	5	445403	792514	N end-NW Kerr Island	10-May-10	3.2
					21-May-12	3.5
					19-May-13	3.1
					Ovrall Average:	3.3

Information on the Lake Partner Program

Information on the Lake Partner Program can be found at:
http://desc.ca/programs/LPP

There is now an interactive map of the Lake Partner Program sampling sites and results on Ministry of the Environment's Lake Partner Program website:

http://www.ontario.ca/environment-and-energy/map-lake-partner

Calcium in Ontario's Inland Lakes

Calcium is a nutrient that is required by all living organisms. For example, water fleas (*Daphnia*, Figure 1), which are tiny organisms called zooplankton, are very sensitive to declining calcium levels. *Daphnia* use calcium in the water to form their calcium-rich body coverings when they moult.

Figure 1. Image of a calcium-rich Daphnia (Photo credit: Dr. Derek J. Taylor)

Recent experiments have shown that the reproduction of most *Daphnia* species is jeopardized at lake calcium concentrations below 1.5 mg/L. There are many other aquatic animals that need calcium, such as mollusks, clams, amphipods, and crayfish. Calcium concentrations of 0.5 mg/L and between 1-2.5 mg/L are the survival thresholds for daphniids and crayfish, respectively. However, these results are based on laboratory experiments; in nature, where organisms must cope with multiple stressors, limiting calcium concentrations could be higher.

Based on a dataset of 770 lakes in Ontario, approximately 35% currently have calcium levels below 1.5 mg/L. Many lakes on the Precambrian Shield in Ontario are nearing or have recently crossed this important threshold.

Ecosystem Disturbances & Lake Calcium Decline

Under natural conditions (i.e., without human influence), calcium levels in soils are governed by inputs from mineral weathering of rocks and atmospheric deposition of calcium-rich dust, and losses through uptake by growing forests, and leaching to lakes and rivers (Figure 2a).

The two main human causes of calcium decline in soils, and thus in lakes, are acidic deposition ("acid rain") and forest harvesting, which are described on page 2.

Acid Rain

The majority of Ontario's lakes are located in the Precambrian Shield region where the bedrock is very hard and resistant to weathering. This is why most Ontario lakes have soft waters that are low in calcium. These low calcium concentrations can make lakes vulnerable to acid rain because they are less able to neutralize or 'buffer' incoming acids.

In the early days of acid rain (early to mid-1900s), calcium was leached from watershed soils into lakes faster than it could be replenished through weathering or deposition from the atmosphere (e.g., dust). This accelerated leaching of calcium from watershed soils likely led to a period of increased calcium levels in some lakes (Figure 2b).

In recent years, acid deposition rates have fallen, and rain is 50% less acidic now than it was in the 1980s. This means that less calcium is being leached from watershed soils into lakes. In addition, with no or very slow replenishment of calcium to watershed soils, the available pool of calcium has slowly decreased in size. This has resulted in noticeable declines in calcium concentrations in lakes and streams (Figure 2c).

Forest Harvesting

Acid rain is not the only stressor affecting calcium levels in Ontario's Precambrian Shield lakes. As mentioned previously, forest growth is one way in which calcium is removed from watershed soils. The removal of timber, and the re-growth of forests following timber harvesting, can further diminish the supply of calcium in soils that is available for export to lakes (Figure 2c).

Climate Change

Calcium decline is likely exacerbated by climate change. A recent study examined 29 years of calcium data from three intensively-studied lakes in south-central Ontario and found that calcium decline has worsened with recent warming. Climate change in this region has led to decreased water flow, resulting in less calcium being exported from watersheds to lakes.

How is the Ministry of the Environment and Climate Change monitoring calcium in Ontario?

Scientists at the Ministry of the Environment and Climate Change's Dorset Environmental Science Centre (DESC) have been monitoring calcium levels in south-central Ontario lakes and streams since 1976. They have found that calcium concentrations have declined significantly over the period of record in their long-term study lakes.

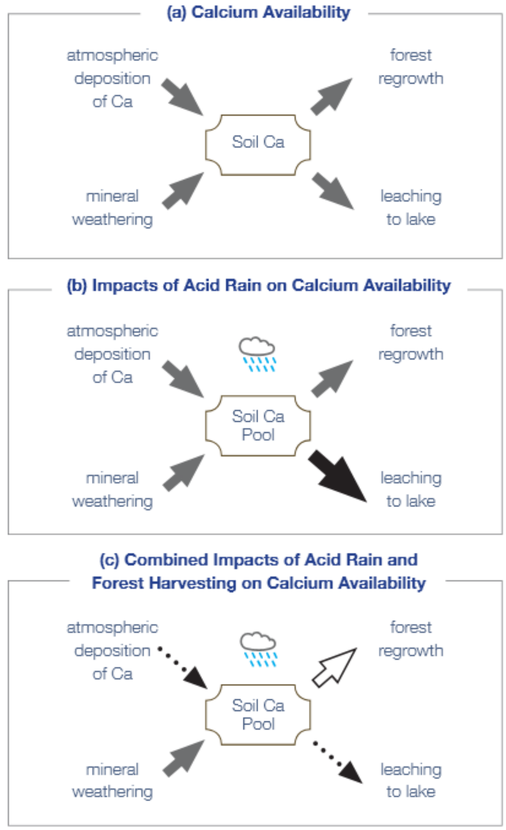
Calcium concentrations have been measured from water samples collected by the Ministry's Lake Partner Program volunteers since 2008.

The DESC is also involved with monitoring lakes for water chemistry (including calcium) throughout the province as part of the Broad-scale Monitoring Program, a collaborative monitoring program with the Ministry of Natural Resources and Forestry.

What can we do to reduce the potential impacts of calcium decline?

Calcium in soils is normally replaced by the weathering of bedrock, which is a slow process. Long-term, sustainable solutions to address calcium decline have yet to be developed. Here are some examples of what we can do to reduce the potential impacts of calcium decline:

1. Support the government's efforts to reduce SO2 and NOX emissions to reduce acid deposition rates;
2. Work with the Ministry of Natural Resources and Forestry to consider soil nutrients, especially calcium status, when they set logging quotas;
3. Join Ontario's Lake Partner Program to help monitor Ontario's lakes. You can visit **www.ontario.ca/lakepartner** or **www.desc.ca** for more information.



Modified from Smol J.P., 2010. Freshwater Biology 55:43-59

Figure 2. (a) Ca availability prior to human influence. In this undisturbed ecosystem, calcium concentrations remained relatively stable because calcium outputs were balanced by inputs. Specifically, mineral weathering of rocks and atmospheric deposition of calcium-rich dust were the main sources of calcium to soils. The major outputs were forest re-growth and the leaching of calcium to lakes and rivers;

(b) The impacts of acid rain on calcium availability. During the early stages of acidic rain (early to mid-twentieth century), the leaching of calcium from watershed soils was accelerated, and the calcium available in soils decreased over time; and

(c) The combined effects of acid rain and forest harvesting on calcium availability. Eventually, with continued acid rain, the pool of available calcium in watershed soils was diminished to the point that calcium leaching was greatly reduced. In addition, other disturbances, such as forest harvesting, caused additional loss of calcium from the ecosystem. Following harvesting, forest regrowth removed more calcium from the soil.

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