The Lake Partner Program

FOCA

Federation of Ontario Cottagers´ Associations

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1.0 Ontario's Lakes

1.5 billion years ago, the granite bedrock that makes up the Canadian Shield was formed through geological processes such as upheaval. Glacial movement across the shield left behind depressions in the bedrock, eventually filled with glacial meltwater from the Laurentide Ice Sheet (approximately 10,000 years ago). These depressions make up Ontario's more than 200,000 lakes. Lakes located on the Canadian Shield tend to be clear, and the soil on the Shield is typically acidic and low in nutrients. Lakes located off of the Canadian Shield tend to be shallower and more biologically productive than Shield lakes (*Minns et al., 2008*).

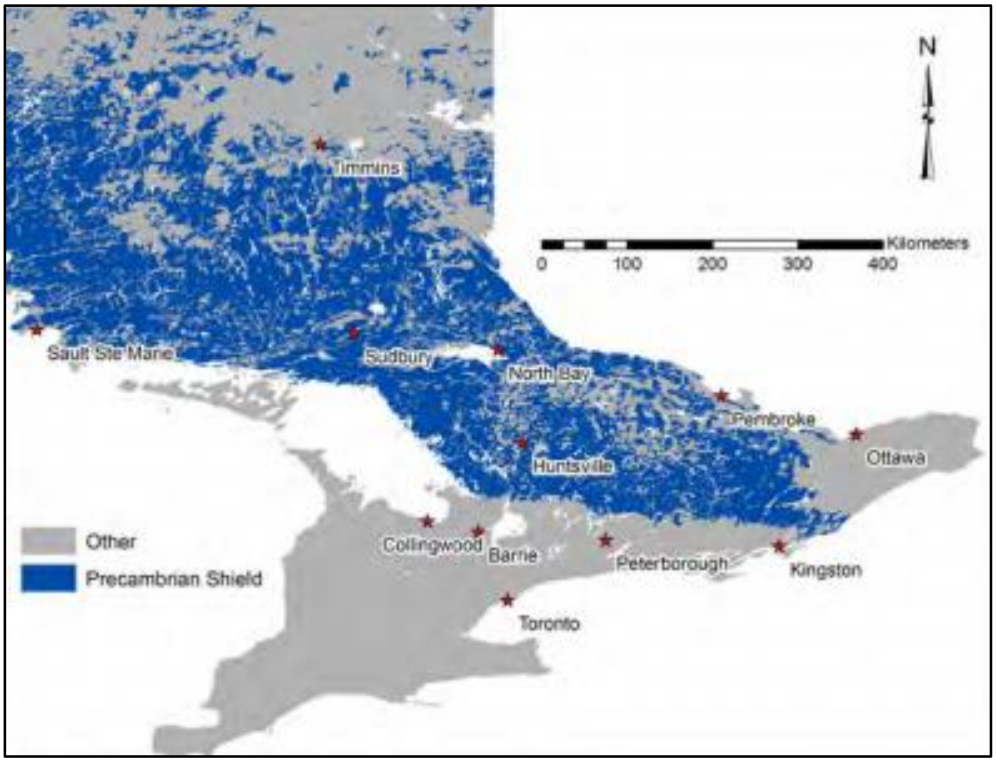


Figure 1: Boundaries of the Precambrian (Canadian) Shield in Ontario. (*Map credit: C. Hyatt)*

An estimated 17% of Canada's freshwater is located in Ontario (Natural Resources Canada, 2005), yet only an estimated 1-2% are monitored for water quality (Cox, 1978). The ecological health and water quality of Ontario's inland lakes is impacted by natural factors, such as watershed geology and vegetation; however, Ontario's lakes are also affected by anthropogenic forces such as building development, shoreline modification, deforestation, agricultural practices, climate change, and pollution. These human influences can magnify natural problems, as well as create new ones, by affecting the physical and chemical aspects of a lake ecosystem. Because of the many factors that can affect lake health, it is important that changes in water clarity trends are identified early, before they become problems to fish, wildlife, waterfront property owners, and other lake users. Ultimately, the health of the Province is linked to the health of our lakes and rivers.

Volunteers in their own words

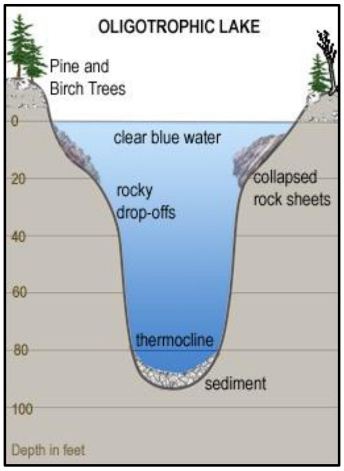
"Our Ontario Lakes are our crown and glory! There is nothing like looking out at our lake early in the morning when it is covered in mist and the fishing boats are out. There is a very real connection to nature all around - It can't be beat. Where will our wildlife go without the lakes - the loons, ducks, herons, and fish? The lakes need our voices to protect them!"

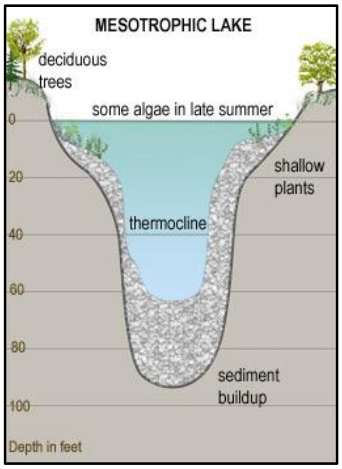
2.0 What is a Healthy Lake?

2.1 Lake Classification

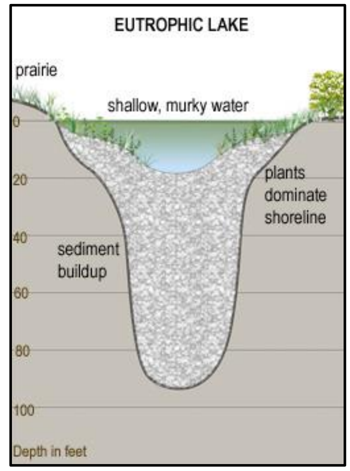
Trophic status is an indicator of how much growth or productivity occurs in a lake. Primary productivity is the process of plants incorporating sunlight energy, using carbon dioxide and water, to create organic matter in the form of plant tissue (*Whittaker et al., 1975*). The availability of nutrients is the limiting factor in determining trophic status and may be different between water bodies due to the geology, nutrients and surrounding land uses. Inland lakes scientists generally place lakes into three broad categories with respect to nutrient status: oligotrophic, mesotrophic, and eutrophic.

Oligotrophic: In general, oligotrophic lakes have low concentrations of limiting nutrients, including total phosphorus (less than 10 µg/L). This low nutrient content means that oligotrophic lakes have low primary productivity (and therefore low algal production). These deep lakes often have colder waters, which allow them to hold a considerable amount of dissolved oxygen throughout the water column (*Smol, 2008*). This is why oligotrophic lakes can provide suitable habitat for cold water fish species such as lake trout and lake whitefish (*photos' source, this page and next: RMB Environmental Laboratories Inc, 2019*).





Mesotrophic: Mesotrophic lakes display an intermediate level of nutrients (between 10 and 20 µg/L of total phosphorus) and mid-level primary productivity (*Smol, 2008*). These lakes can support some aquatic plants. Because of their range of nutrients levels, they can have an assortment of characteristics. Lakes with lower nutrients can be clear with low plant count, and lakes with higher nutrients can be susceptible to mild algal blooms (*Smol, 2008*). Mesotrophic lakes are able to support an abundance of fish – some of which include muskellunge, walleye, perch and smallmouth bass.



Eutrophic Lakes: Eutrophic lakes have high concentrations of limiting nutrients (over 20 µg/L of total phosphorus) (*Smol 2008*). Excess nutrients in these lakes leads to eutrophication, and can promote algal and aquatic plant growth. Extreme algal growth can lead to algal blooms. Plant biomass eventually dies and settles in the sediment; it is broken down by bacteria, depleting the dissolved oxygen in the lake. This may create conditions at the bed of a lake that result in fish die-offs (*Smol, 2008*). However, certain species of hardy fish are able to thrive in these lower dissolved oxygen levels; these species include fish such as carp and catfish.

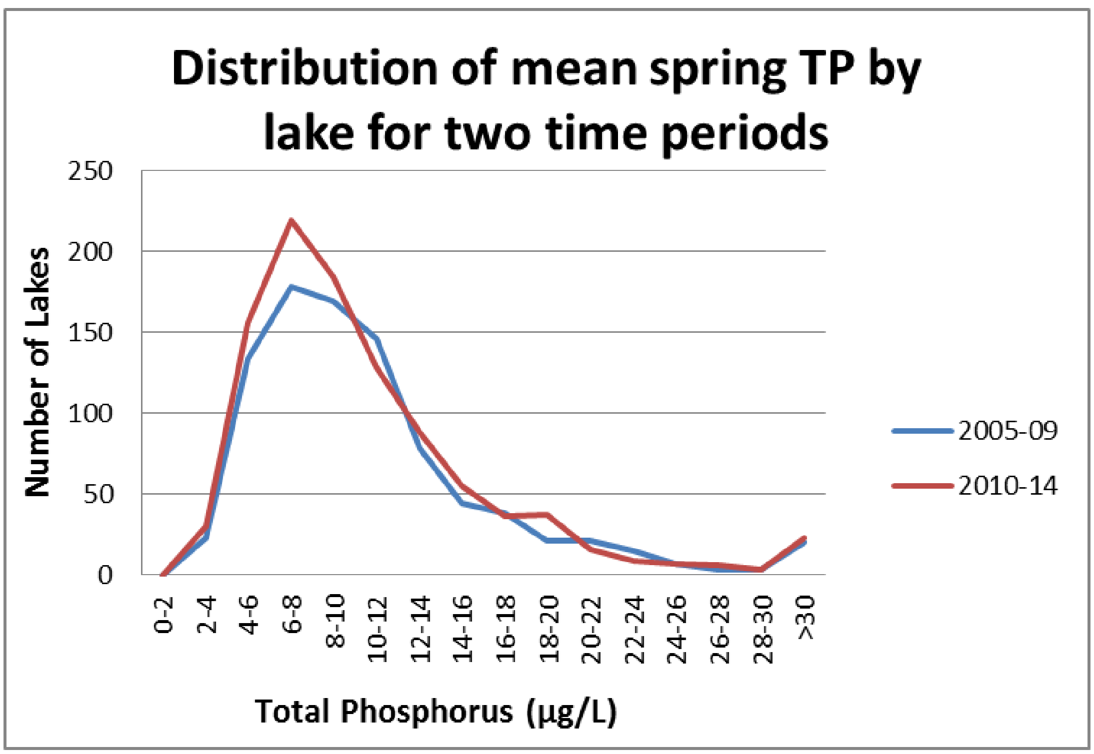


Figure 2: Distribution of mean total phosphorus concentrations for Lake Partner Program Lakes from two time periods, 2005-09 (n=900) and 2010-14 (n=997). Phosphorus is one of the key nutrients that determines a lake's trophic status (source: *Ministry of Environment, Conservation, and Parks*).

2.2 Water Chemistry

Inland lakes are affected by a variety of nutrients that can impact water quality, fish diversity, and algal blooms. In every lake there is a healthy background level; having too much or too little of a nutrient can have negative effects on the ecosystem, human health, and the economy. The Lake Partner Program monitors and analyzes four parameters: phosphorus, calcium, water clarity, and chloride.

Phosphorus: Phosphorus is an essential element for aquatic organisms and systems. It is the limiting nutrient that controls the growth of algae in most Ontario lakes (*Smol, 2008*). Increases in total phosphorus may cause extreme algal growth, known as algal blooms. In extreme cases, certain algal blooms can cause noxious odours, and produce toxins which impact human and animal health (*Winter et al., 2011*). In Ontario, the provincial government has recommended that "to avoid nuisance concentrations of algae in lakes, average total phosphorus concentrations for the ice-free period should not exceed 20 μg/L" (*Ontario Provincial Government, 1994*). Human impacts, such as septic systems, wastewater treatment plants, fertilizers and laundry detergents can affect phosphorus levels in a lake (*Minnesota Pollution Control Agency, 2008*).

Figure 3: In cases of very high levels of phosphorus, algal blooms can result (*photo source: Ministry of Environment, Conservation, and Parks)*

Calcium: Calcium is a nutrient that is required by all living organisms. For example, tiny organisms called *Daphnia* are a primary food for many fish, and are very sensitive to declining calcium levels. *Daphnia* use calcium in the water to form their calcium-rich body coverings. There are many other aquatic animals that need calcium such as mollusks, clams, amphipods, and crayfish (*Lake Partner Program Report Card, 2015*). Some Canadian Shield lakes are showing substantial decreases in calcium concentrations. Climate change, forest harvesting, and residual effects from acid rain have depleted watershed stores of calcium (*Keller et al., 2011*). Calcium loss can affect the growth, reproduction and survival of a variety of organisms including phytoplankton, fish, and birds (*Weyhenmeyer et al., 2019*).

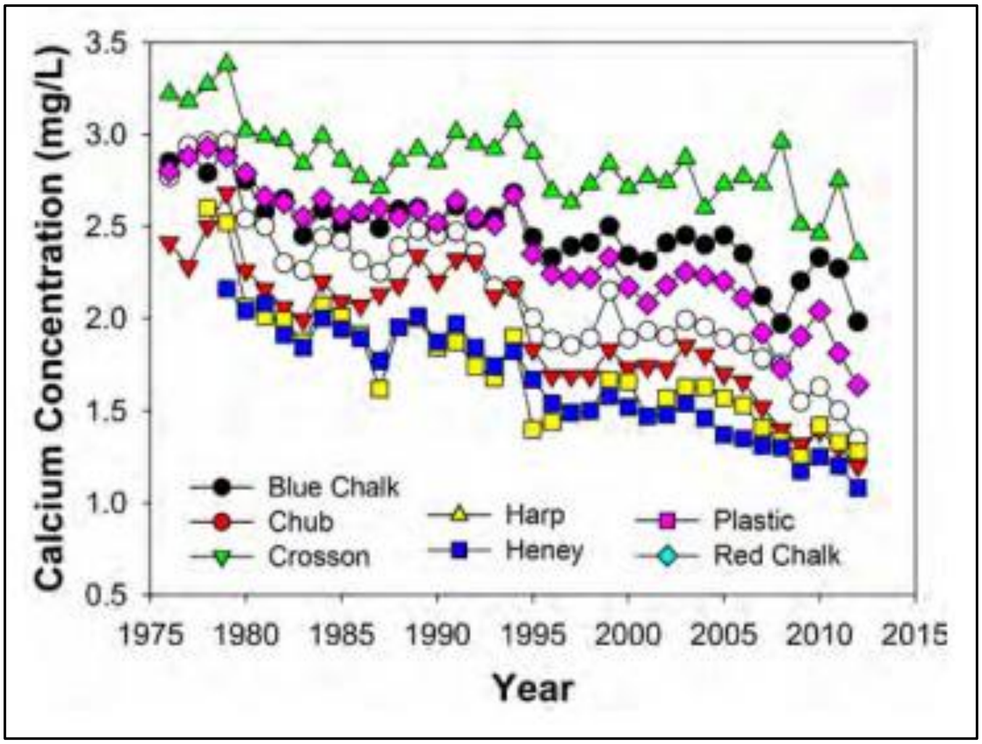


Figure 4: Declines in calcium concentrations over the last 35 years in 7 intensively-studied lakes in southcentral Ontario (*Ministry of Environment, Conservation, and Parks*).

Water Clarity: Water transparency, or water clarity, is measured by lake scientists with a piece of equipment called a Secchi disk. A Secchi disc is a round, plastic disc with white and black markings (see section 3.0 for pictures of Lake Partner Program volunteers using Secchi discs). The disc is attached to a rope pre-marked off in tenths of a metre, and lowered into the water. The point where the disc can no longer be seen is called the Secchi depth. Secchi depth (or water clarity) indicates the depth at which light can penetrate into the lake, and can relate to lake classification (see section 2.1 for more details). Light penetration in a lake can be affected by dissolved organic carbon (DOC), biological activity and growth such as from algae, and non-biological factors, such as sediment. Water clarity readings are used to track changes in the lake that might not be noticed by monitoring phosphorus alone, such as impacts from invading species (e.g., zebra mussels which might artificially increase water clarity), climate change effects, or other watershed disturbances (*Lake Partner Program Report Card, 2015*).

Secchi Depth Ranges

Oligotrophic (2-4m) **Mesotrophic (1-2m)** **Eutrophic (less than 1m)**

Figure 5: Relationship between Secchi depth (measured in metres), and lake classification.

Chloride: Chloride is an essential nutrient found in both fresh and salt water. However, elevated levels of chloride can have detrimental effects on lake ecosystems, as most organisms can only tolerate so much in a water body. With the widespread use of road salt across Ontario, studying the levels of chloride in Ontario's lakes is imperative. Urban areas with more surface area devoted to pavement often have higher chloride contractions. This is due to stormwater and snowmelt runoff having less chance to soak into the soil before entering waterbodies. The speed limit of a road can also affect how surface chloride impacts a waterway, and how far it can travel. When the speed limit is high, chloride has been observed traveling over 40m (130 ft) from the side of major highways (*Karraker, 2008*). In many parts of Ontario, this puts waterways at risk for excess chloride.

2.3 Biological Features

A key feature of inland lakes is the biological life they support. This life can be as small as zooplankton such as *Daphnia*, to increasingly complex species such as fish. Knowing the life that exists in Ontario's lakes, and how waterfront users interact with them is pivotal to maintaining a healthy ecosystem.

Algae: Algae are the foundation of aquatic ecosystems; without them, higher life such as fish, crabs, and mussels could not survive. They use nutrients to convert energy into organic matter through photosynthesis, and produce oxygen as a bio-product, which is essential for other organisms in the lake. Algae can become a problem when excess nutrients (particularly total phosphorus) and warmer lake temperature cause algal blooms.

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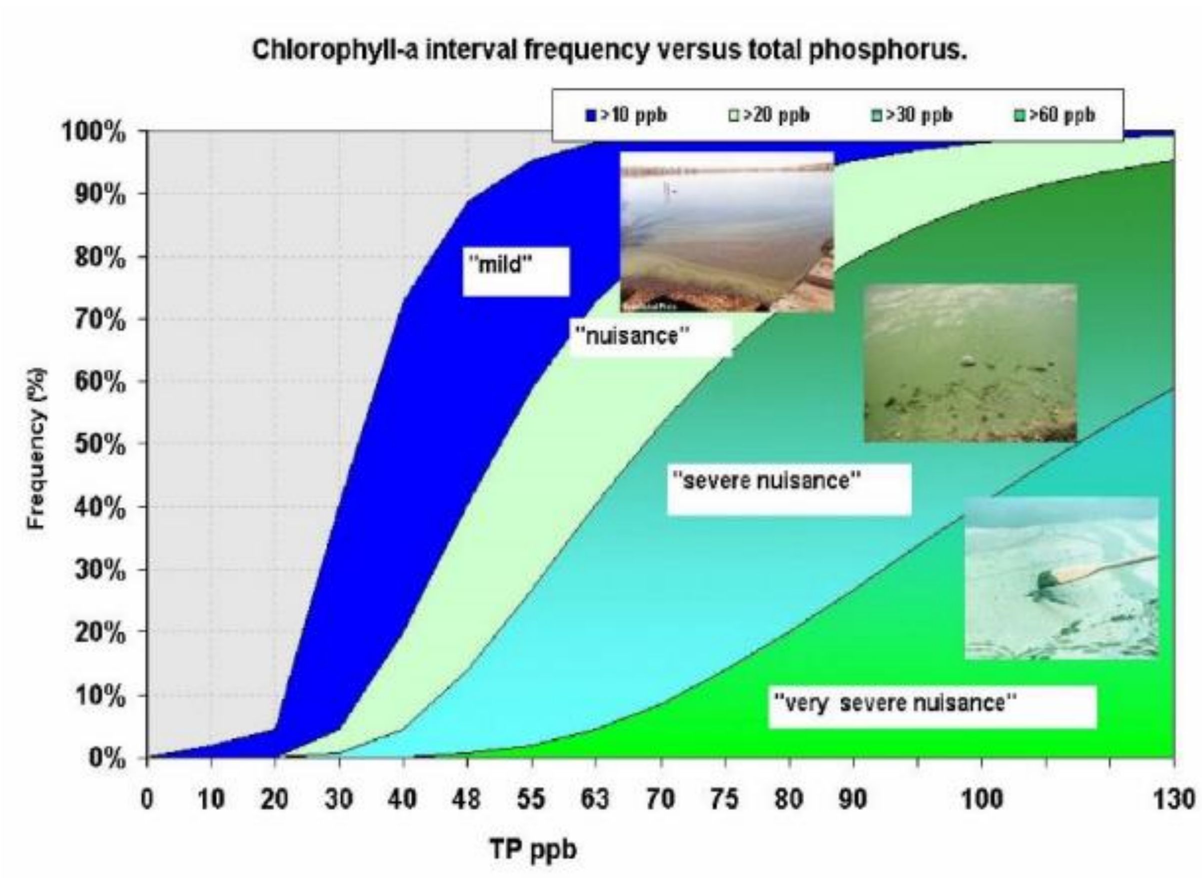


Figure 6: Frequency of blue-green algal blooms as total phosphorus concentration increases (*figure source: Minnesota Pollution Control Agency*)

Algal blooms are thick mats of algae which are found near the surface of the water. Algae have a short lifespan, so these blooms will eventually die and settle at the bottom of the lake. Bacteria break down the organic matter, using up dissolved oxygen in the water. Depleting this dissolved oxygen can affect aquatic plants and animals in the lake, even causing death as oxygen levels drop to those that cannot support higher life (*Federation of Ontario Cottagers' Associations, 2018*). These blooms can also affect recreational lake activities, at times emitting a strong odour, releasing harmful toxins, and clogging pipes and boat motors (*Minnesota Pollution Control Agency, 2005*).

Aquatic Macrophytes: Aquatic macrophytes are aquatic plant life more complex than algae, and are an important part of aquatic ecosystems. They grow best in a mixture of sand and muck, and can modify the zone they grow in by changing wave energy and temperature (*Peters and Lodge, 2009*). Smaller plants and animals can hang on to aquatic macrophytes. They also provide a hiding place for fish and other aquatic animals, and eventually decompose and become food for lake bed dwelling bacteria. Aquatic macrophytes respond to environmental stress, and can be a helpful indicator of pollution, climate change, or chemical changes in a waterbody (*Peters and Lodge, 2009*).

Fish Species: Fish are an important part of Ontario's lakes; they play a pivotal role in the ecosystem, and also are the driver behind a 2.2 billion dollars per year industry. 1.27 million anglers fish in Ontario each year *(Government of Ontario, 2019)*, and as such it is important to make sure our lakes are able to support a strong fish population. Fish are affected by many conditions in the lake including algae levels, nutrient levels, dissolved oxygen levels, and temperature.

Image source: Andy Metelka

Volunteers in their own words

"My great great grandfather started fishing the lake in 1872. I feel a responsibility to help ensure the lake is available for future generations and by monitoring the lake can see if there are any negative trends occurring."

3.0 What is the Lake Partner Program?

3.1 Background

In the 1960s-1970s, excess nutrients in a lake, which can lead to algal blooms, became an important water quality issue, as overall water quality was declining, and algal blooms were increasing. From this concern emerged the Ministry of Environment’s Self Help program in the 1970s-1980s, where volunteer lake stewards monitored for chlorophyll-a and Secchi depth measurements.

As the program gained in popularity, and the need for a long term inland lakes dataset became more prevalent, the program evolved into the Lake Partner Program (LPP) in 1996. Partnering with the Federation of Ontario Cottagers' Associations (FOCA), the District of Muskoka, and the Lake of the Woods District Stewardship Association, the LPP gained members steadily over the years. The program moved to the Dorset Environmental Science Centre (DESC) near Huntsville in 2001, permitting sample analysis in the state of the art Ministry of Environment lab on site (*Federation of Ontario Cottagers’ Association, 2016)*.

Figure 7: LPP volunteers, circa 2004, holding their Secchi discs.

Lake Partner Program Facts at a Glance

Over 600 volunteers

In over 500 lake associations

Sampling on over 550 inland lakes

At over 800 sample sites

Contributing over 2600 hours annually

To gather over 4,400 phosphorus samples

Contributing over half a million in in-kind field research every year

With over 20 years of data collected

The the LPP is Ontario's volunteer-based, water-quality monitoring program, and is the largest and longest standing program of its kind in North America. The Ontario Ministry of the Environment, Conservation and Parks (MECP) coordinates this program from DESC in partnership with FOCA.

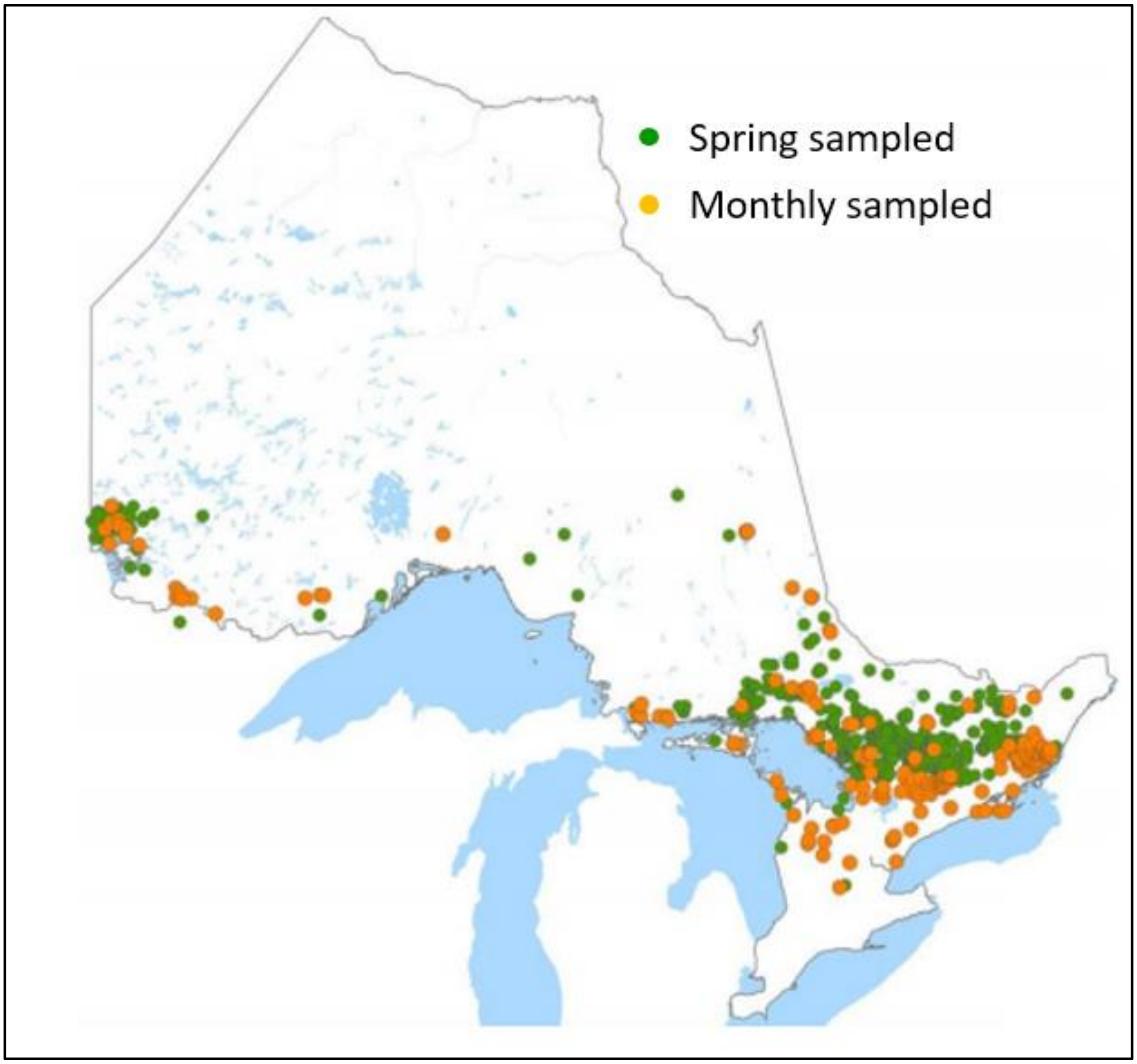


Figure 8: geographic extent of LPP sites sampled in Ontario. Generally, lakes on the Canadian Shield are sampled once in the spring, and lakes off the Shield are sampled monthly from May-October (*image source: Ministry of Environment, Conservation, and Parks)*.

About 85% of the volunteers sample lakes on the Canadian Shield and these volunteers collect one water sample in the spring each year. The remaining volunteers sample once a month during the ice-free season for lakes that are predominantly off the Canadian Shield. These water samples are used to measure nutrient concentrations (total phosphorus, calcium, and chloride) for Ontario's inland lakes. Volunteers are also asked to make a minimum of six (roughly monthly) water clarity observations using a Secchi disk.

Supporting the Made in Ontario Environmental Plan

The Made in Ontario Environmental Plan (MOEP), produced in 2018, is Ontario's plan for protecting Ontario's environmental heritage. Protection of waterbodies will be key in a changing climate, and the LPP supports many aspects of the MOEP through monitoring water quality across the province. The MOEP highlights the importance of citizen science and stewardship early in the report: "True environmentalism begins with a sense of civic responsibility that we foster through meaningful action close to home." *(Made in Ontario Environmental Plan, 2018, page 6*)"

"…excess road salt can damage roads, cause vehicle corrosion and be harmful to fish in our waterways" (*Made in Ontario Plan, 2018 page 12*), which is why the LPP added chloride as a monitored parameter in 2015.

"Declining ice cover is causing shoreline erosion, warmer water is creating conditions for blooms of harmful algae, and shifting water conditions are changing when and where fish spawn." (*Made in Ontario Plan, 2018, page 12*), which is why the LPP monitors for ice on and off date, and nutrients that impact algal bloom growth.

"Continue to protect and identify vulnerable waterways and inland waters." (*Made in Ontario Plan, 2018, page 13*); vulnerable waterways will be identified in the future following stringent water quality monitoring.

"Protect the quality of the Lake of the Woods by continuing to work with partners on reducing phosphorus that, in excessive quantities, can cause toxic blue-green algae." (*Made in Ontario Plan, 2018, page 13*); the Lake of the Woods is monitored at multiple sites through the LPP in order to learn more about how their phosphorus levels are changing over time

3.2 Water Stewardship Through Citizen Science

Citizen scientists are interested in volunteering their time for a variety of reasons. They might have a keen interest in the natural world and wish to learn more; they may want to ensure that the experiences and places they love are preserved for future generations; they may wish to be better stewards to their environment. Regardless of their motives, citizen scientists provide an incredibly valuable service. Generally, they allow for a larger scope of research and data collection than any team of researchers could accomplish on their own.

Citizen scientists and lake stewards are essential in helping to monitor and maintain the quality of Ontario's lakes. These dedicated people volunteer their own time to measure physical and chemical characteristics of their lake. This is essential to understand changes in Ontario's lakes, and to provide a historical data record against which to benchmark the health of Ontario's lakes.

Long-term data is incredibly valuable as it allows a baseline condition of a waterbody to be recorded (*Federation of Ontario Cottagers' Associations, 2018*). This baseline allows policy makers and researchers to watch for trends and changes. Citizen science can provide benefits beyond the data as well. Long-term monitoring creates a connection to one of Ontario's most valuable resources. When volunteers discuss sampling and results with their neighbours or a local lake association, a community can grow that is collectively concerned about the health of their watershed. Water quality monitoring provides scientific information that allows for better informed decisions from lake associations and waterfront property owners (*Federation of Ontario Cottagers' Associations, 2018*).

LPP volunteers are trained to take accurate water samples. Each sampling kit comes with thorough instructions on how to take Secchi depth readings and water samples. In addition, FOCA provides a training video for volunteers to review the steps. Most volunteers stay with the program year after year, and many train new volunteers to increase the sampling done on their lake.

Why Do You Participate in the Lake Partner Program?

"Our lakes are a valuable heritage that need to be protected."

"The LPP allows for you to learn more about your natural environment by engaging with it directly."

"The LPP provides great opportunities to educate children (and adults too!) with real world examples."

"Contributing to the LPP ensures a long term water quality data-set that will be vital in our changing climate."

"Sampling with the LPP helps engage the local lake community and bring folks together over a common goal."

3.3 Lake Partner Program Survey Results

The LPP is run by one full time MECP Inland Lakes Monitoring Scientist, and one FOCA Assistant Lake Stewardship Coordinator. With over 2000 water kits to send out, 4,400 phosphorus and 900 calcium and chloride samples to process, 3500 Secchi disc readings to input, and 600 volunteers to coordinate each and every year, it is a busy year! While FOCA aids in promoting the program and providing lake stewardship education and resources, the LPP is always seeking to improve, especially in ways that can most benefit the volunteers (for more on the annual LPP logistics, see *Federation of Ontario Cottagers' Association, 2016)*.

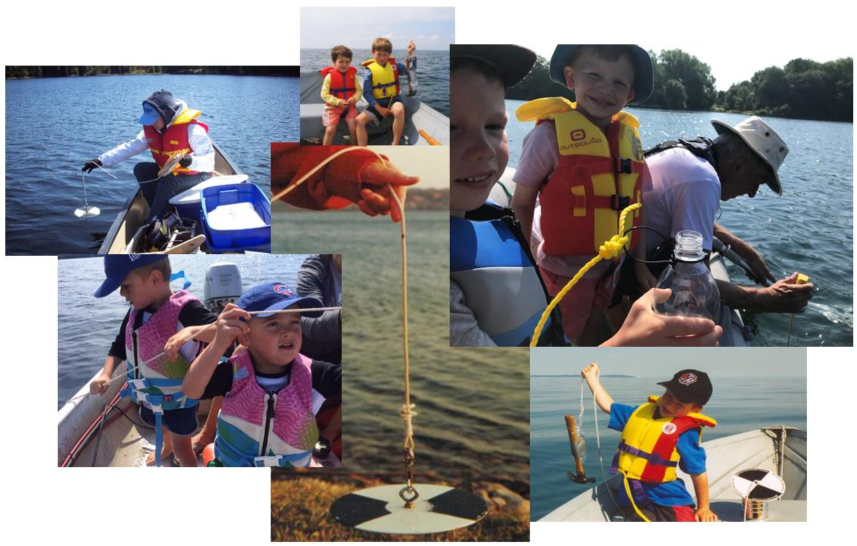


Figure 9: images of the next generation of samplers, courtesy of LPP's volunteers.

In 2016, the LPP team, together with FOCA, asked volunteers to participate in a survey. This survey was developed in order to collect some demographics (age of volunteer, how long volunteers have been sampling with the LPP, how many lakes they sample, etc.), and to gain volunteer insight into what the program means to those who volunteer their time for water sampling. With an amazing response rate of 70%, some key insights were gained from this survey. Some highlights include:

- Almost 90% of the respondents were part of their local lake association
- Over half of the volunteer respondents were 65 or older (and almost 90% were 51 or older). FOCA is currently working to engage younger volunteers.

- Over 70% of respondents were very satisfied about the amount of time they had donated to collect samples
- Over half of the volunteers who took the survey had been sampling more than 6 years (and a third of them for over 10!)
- One third of respondents also participated in another volunteer environmental group / endeavour other than the LPP.

Some of the most common questions and concerns expressed by survey respondents were a desire for increased communication from the LPP. FOCA is the LPP's primary source of environmental communication. Each year, FOCA produces publications on a variety of topics, including citizen science monitoring, climate change in Ontario, and invasive species. LPP volunteers have access to FOCA's rich array of literature, fact sheets, and infographics, which can aid them in understanding their sampling results.

The LPP volunteers come from all walks of life; some have a background in scientific research, some are waterfront property owners, and some are merely curious about the state of Ontario's lakes. Regardless of a volunteer's background, education, or economic status, each one contributes towards better understanding one of Ontario's most valuable resources: our inland lakes. Each one contributes with passion, dedication, and a desire to protect the waterbodies that they love. The LPP could not be run without them, and volunteers should be aware that the work they do is incredibly valued by the LPP and FOCA team.

Volunteers in their own words

"This program has helped me get involved in our community, as it has provided me with the resources and information I needed to get started. I felt helpless as one waterfront property owner but being involved in the Lake Partner Program, I feel empowered and not alone in monitoring the health of lakes in Ontario."

4.0 Lake Partner Program Data

4.1 LPP Data Usage

The LPP database contains data from the 1990s, to the current year. This database of more than 20 years is tremendously helpful in understanding lake health and trends. Lakes that have been sampled for long periods of time have strong benchmark information which can aid in lake management. The LPP database is used by a variety of citizens, government and non-government organizations, community associations, and institutional researchers.

Who Uses the Data?

- Individuals who are curious about the health of their lake, and may be seeking to make informed property decisions, such as naturalizing their shoreline.
- Lake associations who seek to best manage their lake and be lake stewards; many monitor for trends, and use the LPP data to engage their lake community.
- Private organizations or companies who focus in environmental work and use LPP data as a baseline on potential projects or proposals.
- Researchers studying topics such as lake health, aquatic species, waterfront property economics, cumulative effects on lake ecosystems, and human impacts on lakes.
- Government staff and scientists who incorporate LPP data into government-funded research such as studying the effects of road salt on inland lakes, and government policies and tools, such as the Lakeshore Capacity Assessment Guidebook.

4.2 Case Study: Water Clarity Impacts on Waterfront Property Prices

Ontario's lakes are a major portion of Ontario's economy, drawing in tourists and cottagers. These lakes provide a relaxing getaway for many, with approximately 250,000 families owning waterfront property across Ontario. This booming sector of Ontario's economy was investigated by Clapper and Caudill in 2014, who sought to see if there was a relationship between water quality and cottage sales prices. Data on water quality (via Secchi depth measurements) and lake size for 74 lakes were taken from the LPP database. Waterfront property price data was used from the Huntsville North area, the Almaguin Highlands and the Parry Sound districts. Cottages in these areas were selected to compare between a similar market base; the researchers avoided comparisons with extremely large lake houses and cottages in areas to the south of the study area. The data was modeled to look for a relationship between the Secchi depth and property values.

The results of the study indicated that water quality / clearness of the lake does indeed correlate to waterfront property prices. Models showed that a one-foot increase in water clarity (as measured by Secchi depth) is associated with about a 2% increase in waterfront property value. This study indicates that prospective cottage buyers are willing to pay more for a cottage on a clearer lake; and conversely that poor water quality can reduce waterfront property values.

4.3 Case Study: Lake Capacity Assessment in the Tay Valley Township

What is the Lakeshore Capacity Assessment?

Lakeshore Capacity Assessment (LCA) is a planning tool that was developed by the Ontario Ministry of the Environment, Conservation, and Parks to predict the impacts of shoreline development on water quality of inland lakes on the Canadian Shield. The LCM, or Lakeshore Capacity Model, is one component of the LCA approach. The model is used to determine the maximum amount of development that can occur on the shorelines of a lake without negatively impacting water quality (Federation of Ontario Cottagers' Associations, 2014). The LCA was designed for use on the Canadian Shield.

The LCM allows municipalities and community partners to determine the carrying capacity of a lake in terms of the maximum allowable total phosphorus (TP) concentration (i.e., 'predevelopment'). This P limit can be translated into a development capacity, which states the number of future shoreline developments (e.g., residential, cottage lots) permitted on the lake before water quality is impaired (Federation of Ontario Cottagers' Associations, 2014).

Lakeshore Capacity Model Example:

Maximum allowable total phosphorus = [TP] + 50%

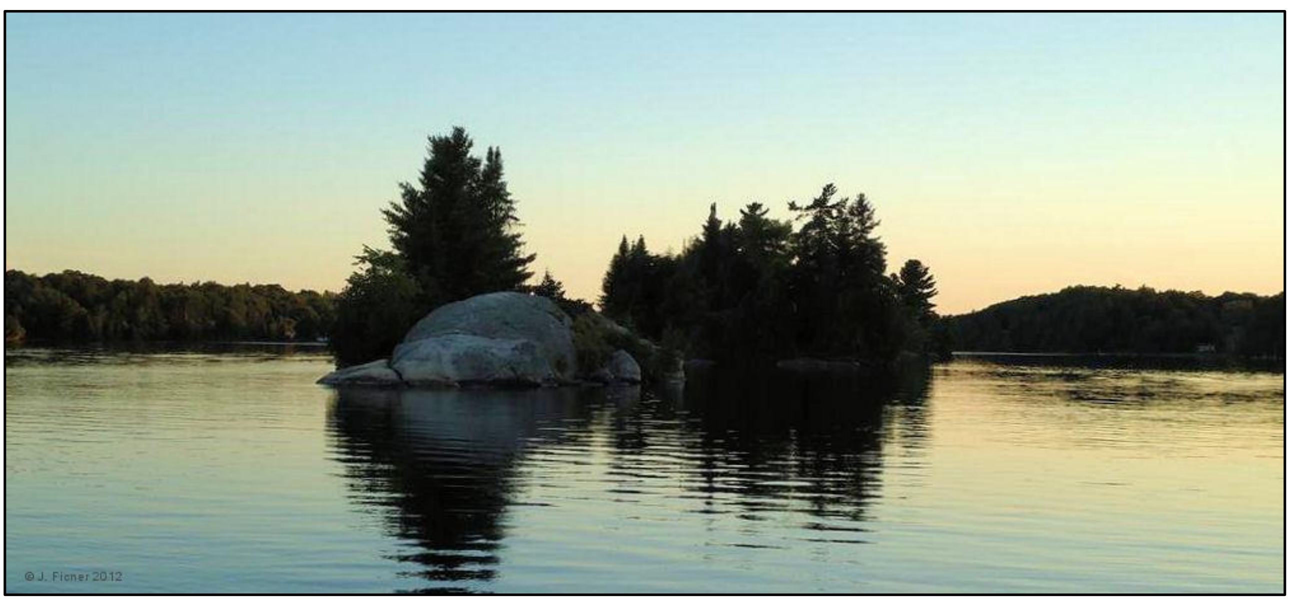
A lake with a modeled background TP of 10 µg/L would have a development capacity limited to TP 15 µg/L (i.e., 10 µg/L + 50%).

A LCA relies largely on total phosphorus data. In order for a LCA to be successful, it is highly recommended that extended monitoring on the lake be conducted. This allows for a better calculation of the background phosphorus amount. For this reason, the LPP can be invaluable, as it provides resources, knowledge, and data to conduct these samples and interpret them. Use of the LPP in gathering phosphorus data is recommended in the official LCA handbook under the "Monitoring water quality" section.

LCA in Use: Tay Valley Township

In 2011, at the request of local lake associations, the MECP conducted a LCA on various lakes throughout the Township of Tay Valley. In response to the Ministry's findings, the Township passed an Interim Control By-law in 2012, for a period of one year, on all properties bordering the shorelines of Farren and Adam Lake, which both showed high total phosphorus results. This effectively froze development for a year so that the Township could conduct further research. A planning study was carried out to investigate the problem of overloading of phosphorus into Farren (pictured below) and Adam Lakes. The end goal of the study was to determine planning mechanisms to improve the current condition of the lakeshore; in addition, the study sought to find tools and methods to prevent any further deterioration from future building and development or over over-development.

A working group in the Township of Tay Valley collected data on the shoreline of the lakes and the lots and buildings on them. From this, it was recommended the Township continue the Site Plan Control Agreement requirements; continue the mandatory septic re-inspection program; and, continue to educate waterfront property owners about reducing phosphorus, and the benefits of natural shorelines and shoreline buffers.



In 2014, the issue of excess phosphorus in Farren and Adam Lakes was brought again to the attention of the Township of Tay Valley. Both Farren and

Adam Lakes had been sampling for the LPP for over a dozen years, which supplied important total phosphorus information, in addition to the MECP test results. As the Township wrote its new official plan, they included a section requiring planning staff to have regard for Lake Association Management Plans listed in a new Appendix to the Official Plan. By 2016, the official plan for the Township was approved, and now referred to lake management plans, and the LCA. Consultations with the MECP continue, and they have suggested that Farren and Adam Lakes could be “at capacity” for development. The Township requested other options besides declaring the lakes at capacity; in 2017, ideas brought forward included increasing lot frontages, increasing lot area, and adding a phosphorus removal adjunct to new or replacement septic systems for consultation with residents of Farren and Adam Lakes. Since then, the three suggestions have been accepted and passed as the Official Plan Amendment (*Farren Lake Property Owners Association, 2019*). Farren and Adam Lake still continue to monitor their total phosphorus levels through the LPP.

4.4 Case Study: District Municipality of Muskoka's Lake System Health

While some volunteers sample because of their individual interest in the health of their lake, many LPP volunteers sample to contribute to a larger, long-term picture. One such example is the District Municipality of Muskoka (DMM), which publishes an annual Lake System Health Water Quality Monitoring Program report. The DMM, located in the heart of cottage country, recognizes that its lakes are an important part of ecosystem health, economic prosperity, and recreational enjoyment. Because of this, the DMM has developed a Muskoka Water Strategy; a key portion of this strategy is water quality monitoring. Water quality monitoring is done at 193 sites on 164 lakes on a rotational basis (below, taken from 2018 Lake System Health Annual Report). The DMM includes many LPP volunteers, all working to create a long-term dataset on lakes in the Muskoka region (*District Municipality of Muskoka, 2018*).

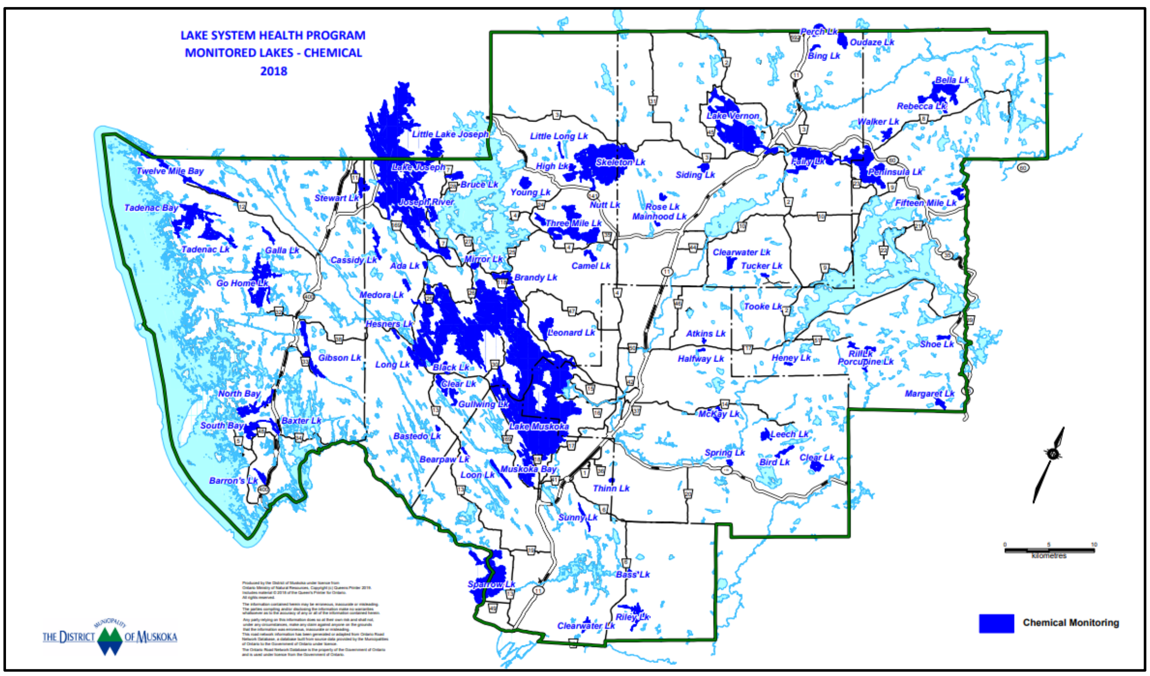


Figure 10: Lake system health program monitored lakes in the District Municipality of Muskoka in 2018.

The LPP provides data to organizations such as the DMM to make informed decisions. Maintaining a historical database allows organizations to observe trends over time, and to create science-based policy to protect the health of our inland lakes

4.5 Case Study - Modeling the Effects of Multiple Stressors

Understanding the effects of multiple stressors on Ontario`s lakes is imperative; by understanding how these factors interact, responses to climate change and other environmental challenges can be better planned. In 2016, a program to build a geospatial database for assessing the effects of multiple stressors on inland lakes was instigated, with partnership between FOCA, MECP, and Ryerson University. This project was intended to aid multi-scale examinations of watersheds, which would aid in analysis of lake ecosystem characteristics. This database would provide researchers and policy makers with insight about the stressors affecting inland lake water quality.

Total phosphorus (TP) can be used to model lake health, especially in regards to algal blooms. The project used LPP data to model and predict where TP hotspots are likely to occur. This was done using interpolation – a technique to predict lake characteristics in systems where measurements are not made. Interpolation assumes lakes in the region of interest have the same ecological forces affecting them.

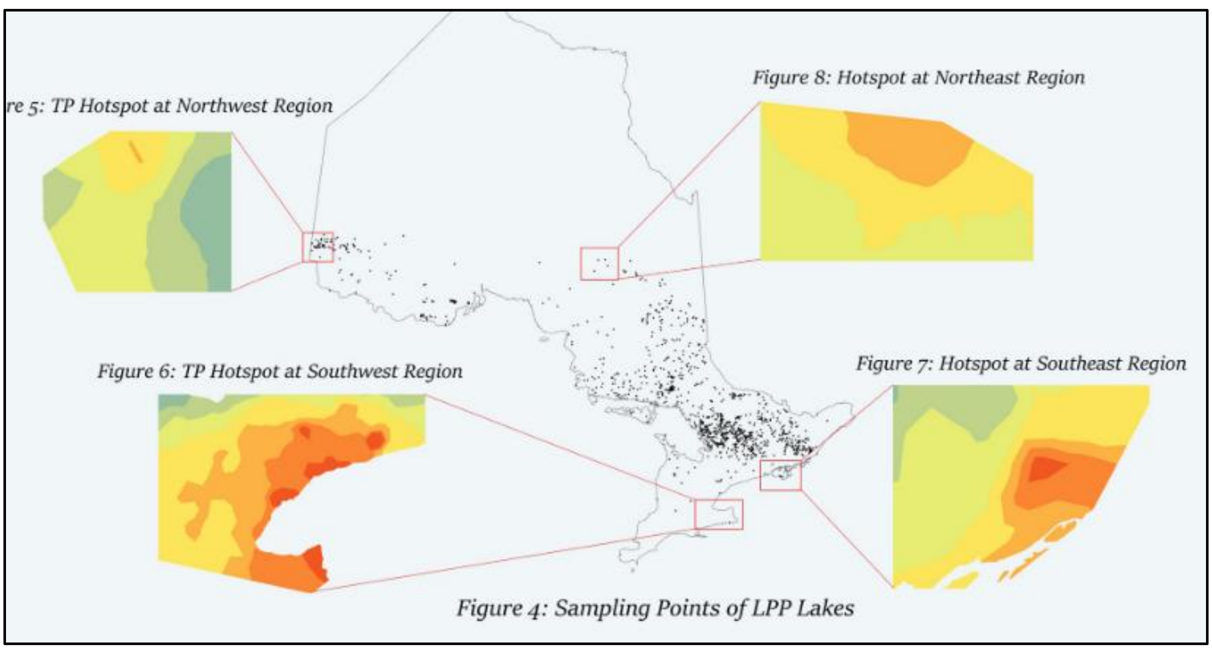


Figure 11: image taken from project report, indicating four TP hotspots in Ontario based on predictive modeling (*image source: Alam et al., 2016*).

Using data like the LPP database, researchers, policy makers, and organizations can predict which areas of the province will be most affected by environmental stressors, and how different factors will interact. This is crucial in order to make effective policy and business decisions that protect Ontario`s inland waterbodies.

Volunteers in their own words

“The Lake Partner Program data can be used by the scientific community to determine lake trends over time, which can be very important for driving policy changes and the way we manage our environment.”

5.0 What Does the Data Tell Us?

5.1 Interpreting the Data: What to Consider

Comparing water quality data between lakes can be a challenging, since individual lakes can be so different from their neighbours as to make comparison impossible. The best use of LPP data is to see trends on one lake over time. If data does not exist for your lake, you might look for the lakes of similar size, depth, classification, and development. When interpreting LPP data, you should ask yourself a few questions, including:

How Big is Your Lake? Is your lake large (example, Kennisis Lake has a surface area of over 1,640 hectares) or small (Little Lake, aptly named, has a surface area of 64 hectares in comparison)? Lake size can impact lake health and water data in many ways. For example, on large surface area lakes, wind blows across a greater distance, creating larger wave energy, which can mix sediments into the water column, reducing water clarity readings.

How Deep is Your Lake? Is your lake deep (for example, Lake Timiskaming is more than 700m deep at some points), or shallow (Lake Couchiching in comparison has a maximum depth of only 12 metres). Shallow lakes have faster fall and spring water column turnovers (where the lake water mixes), which can affect TP readings (*image source: Andy Metelka*).

How is Your Lake Classified? As discussed in section 2.1, lakes can be described as oligotrophic (clear, low nutrient content, low primary productivity), mesotrophic (commonly clear, submerged aquatic plants, medium level of nutrients), or eutrophic (high nutrient content, high primary productivity, more susceptible to algal blooms). If your lake is eutrophic, don't expect your Secchi disc readings or TP levels to resemble another, very clear lake.

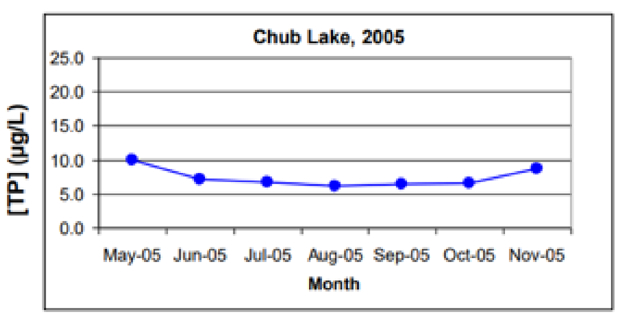
Is Your Lake Heavily Populated? Ontario's lakes are enjoyed by year-round waterfront property owners, as well as seasonal cottagers and tourists. How many homes there are on the shore can impact a lake. Heavily developed lakes might have less wildlife due to noise and light pollution, more nutrient input into the lake from leaky septic systems or excess fertilizers, and more hardened shorelines due to boathouses and cottages. All of these factors affect water quality.

What's Nearby Your Lake? The nearby surroundings of a lake play an important role in the health of the lake. Lakes located near urban centres will be different from lakes located near agricultural fields, which will be different again from lakes in remote forests. Surface water runoff feeds into lakes, and where it is coming from can affect what nutrients enters a waterbody; this can include increased levels of TP and chloride.

What Does the Shoreline Look Like? Waterfront shorelines plays a vital role in the health of a lake. Highly developed shorelines can lead to erosion of sediment into the lake, impacting Secchi depth readings. Lack of trees can increase water temperature, and removal of shoreline plants can reduce animal habitat. For more information, consult FOCA's *Shoreline Owner's Guide to Healthy Waters, 2016*.

Figure 12: a natural shoreline with plentiful native plants can lead to a strong root system, which aids in erosion prevention, reducing sediment loading into the lake.

Is Your Lake On the Canadian Shield, or Off? Lakes on the Canadian Shield are generally lower in nutrients, and as such are chemically less susceptible to algal blooms. Lakes off the Shield are sampled monthly in the LPP, as their nutrient content can vary more considerably throughout the summer.



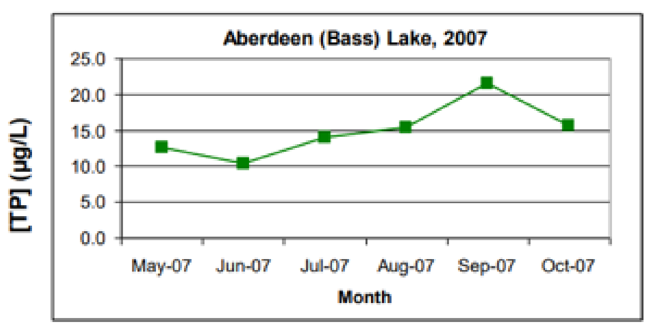


Figure 13: Lakes on the Canadian Shield (example Chub Lake, left) have less variety in their total phosphorus over a summer than those off the Shield (example Aberdeen (Bass) Lake right).

5.2 Long-term Data Trends from the LPP

Through the hard work of citizen science volunteers over more than two decades, a strong water quality database has been produced. In 2015, the some of the most recent LPP data (2010-2014) was analyzed to search for trends in LPP monitored lakes for phosphorus, calcium, and water clarity across Ontario. Chloride trends have not yet been identified, as a large enough database has not been developed (chloride was only added to tested parameters in 2015).

Phosphorus: Most of the lakes in Ontario's LPP are oligotrophic (62%), and tend to be located on the Canadian Shield. 31% are mesotrophic, and the remaining 7% are eutrophic, and tend to be located off the Canadian Shield bedrock. In general, almost three-quarters of LPP lakes have TP concentrations between 4-12 µg/L. Therefore, 93% of inland lakes in the Lake Partner Program meet the Provincial Water Quality Objectives of being under 20 µg/L (PWQO).

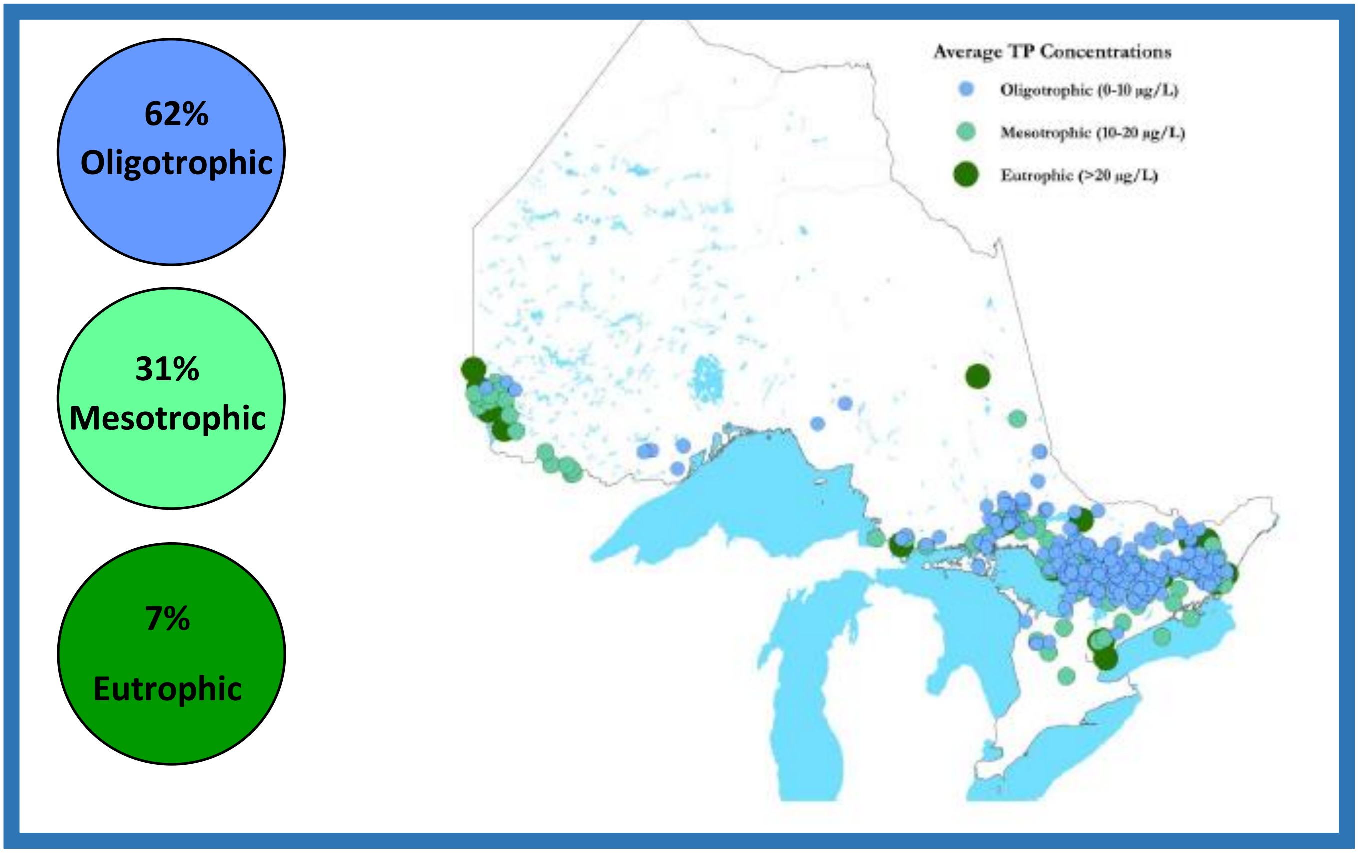


Figure 14: Distribution of lake trophic status based on total phosphorus (TP) concentrations, across Ontario, and by percentage. Data represent 466 Ontario lakes monitored for spring TP concentrations for at least 3 years between 2010-14 (*Lake Partner Program Report Card, 2015)*.

Calcium: The LPP began monitoring calcium concentrations in 2008. The majority (74%) of lakes monitored through the LPP have moderate-to-high levels of calcium, and 97% are above the 1.5 mg/L threshold considered to limit reproduction of large zooplankton. This means that 3% of lakes have very low calcium. The lakes with low-moderate calcium concentrations tend to be located on the hard, poorly-weathered, granitic bedrock of the Canadian Shield.

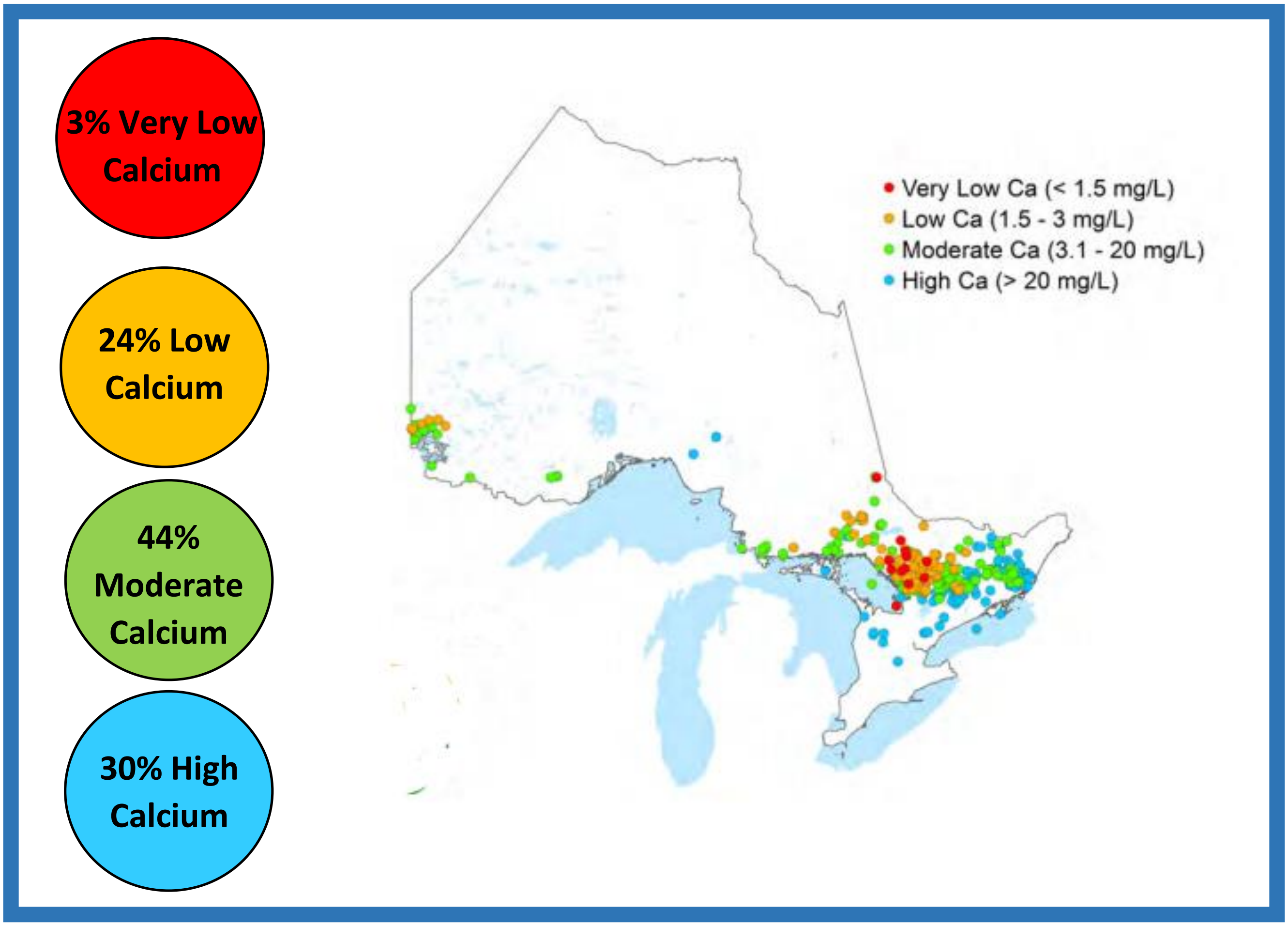


Figure 15: Distribution of lake calcium (Ca) concentrations based on four categories of concentration across Ontario, and by percentage. Data represents 506 Ontario lakes monitored for spring Ca for at least 3 years during 2010-14 (*Lake Partner Program Report Card, 2015*).

Water Clarity: Water clarity data from LPP lakes across the province show that more than half of the lakes (55%) have high transparency (Secchi depth >4 m), while approximately 39% are moderately transparent (Secchi depth 2-4 m), and 6% have low transparency (Secchi depth 0-2 m).

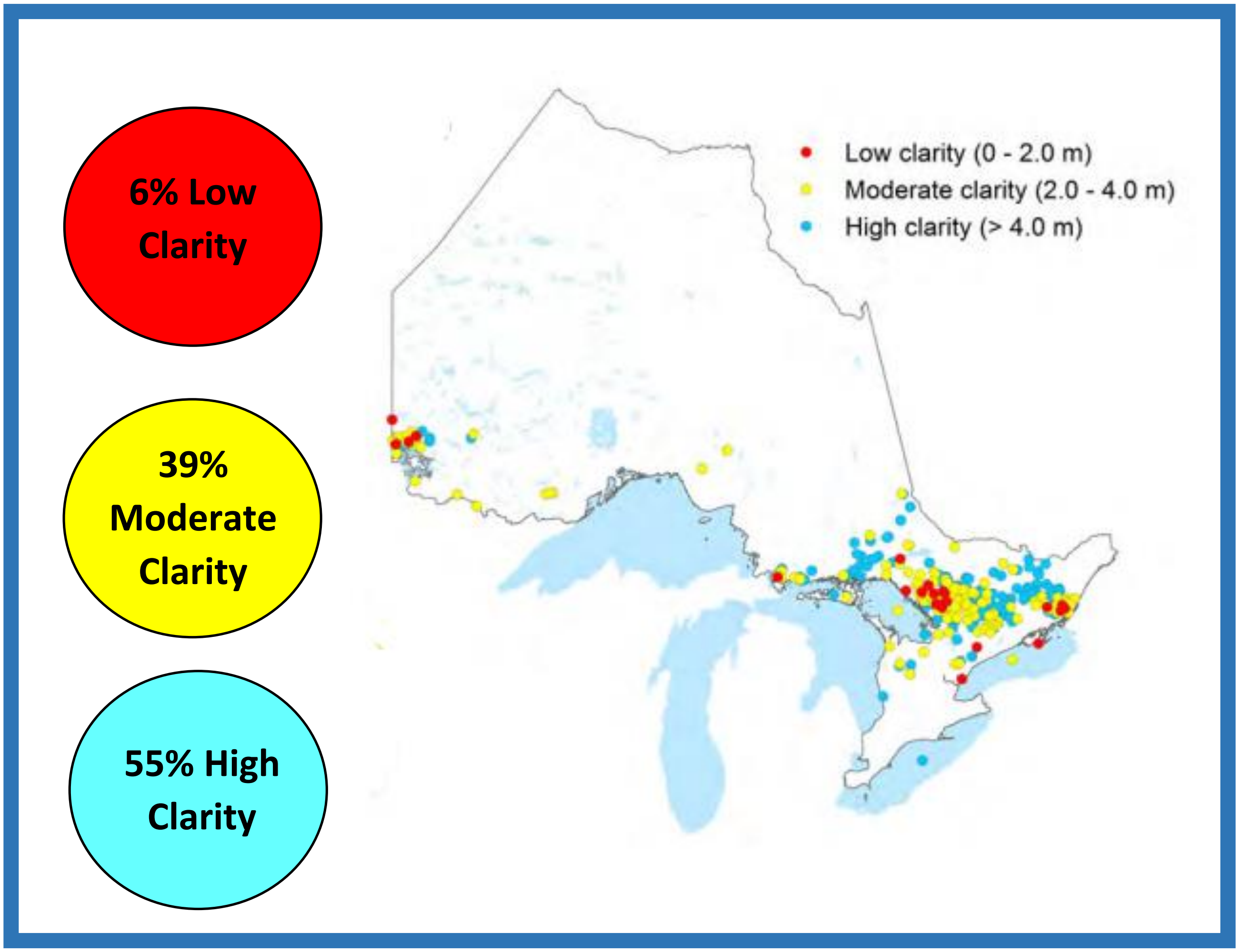


Figure 16: Distribution of average summer (July-September) lake Secchi depth (water clarity) for three levels of water clarity across Ontario, and by percentage. Data represents 376 Ontario lakes monitored for summer water clarity for at least 3 years between the years 2010-14 (*Lake Partner Program Report Card, 2015*).

5.3 Concerns for the Future

The success of the LPP is relies upon a large community of volunteers who are able to sample water across a widespread area. With thousands of data points coming in every year, the LPP has accrued a substantial database that has aided researchers, lake associations, and policy makers. This data source will be crucial as we face changes due to climate change, invasive species, and algal blooms.

Climate Change

The changing climate is an issue presently being felt by Ontarians. Within the last 40 years, Ontario has experienced changes in temperature, rainfall patterns, and extreme weather events (Federation of Ontario Cottagers' Associations, 2016). These changes in climate will affect Ontario's waterbodies both environmentally and economically. As our climate changes, so too will our lakes.

Invasive Species

Invasive plant and fish species can negatively affect lake health in Ontario as they compete with native species for space, light, and food. Invasive species are generally introduced from other regions or countries, and as such have few or no natural competitors. This allows them to out compete with native species. Once established in an aquatic ecosystem, an invasive species is almost impossible to eliminate and control measures can be costly. Monitoring the water chemistry of our inland lakes will be essential to understanding how these invasives are impacting Ontario's lakes (*Federation of Ontario Cottagers' Associations, 2016*). LPP volunteers are the "eyes on the ground" across Ontario, and will be among the first to spot new invaders.

Algal Blooms

Algal blooms are an increasingly prevalent issue in Ontario. Warmer water due to climate change might favor harmful algae for a variety of reasons. Harmful algae usually bloom during the warm weather of the summer months when the water temperature rises; therefore, an increase in temperature could increase bloom frequency. In addition, warmer temperatures prevent water from mixing, allowing algae to grow thicker and faster (*Environmental Protection Agency, 2019*). Changing temperatures affect the ice-on and ice-off dates on lakes, potentially adding additional factors into the mix. Algae use phosphorus as a key nutrient; controlling phosphorus can help control algae. Therefore, monitoring phosphorus levels is essential as we cannot protect what isn't monitored.

Volunteers in their own words

"The Otter Lake Ratepayers' Association (OLRA) has been participating in the LPP for many years and highly values the data. Promoting and preserving our lake's water quality and health is our top priority. OLRA uses LPP data to educate our members on good lake stewardship and in particular on how to help avoid a blue-green algae bloom. Maintaining a healthy watershed system is of the utmost importance. If the water quality of our lakes drop so will the enjoyment of our properties, the value of our properties and the viability of the economy of our entire township."

6.0 Lake Science in Ontario

6.1 The Dorset Environmental Science Centre

Lake stewards who participate in the LPP receive their annual sampling kits and return their water samples and observations to the Dorset Environmental Science Centre (DESC). Located in the heart of Ontario's cottage-country, roughly 200 km north of Toronto, DESC conducts cutting edge inland lake science with its top notch staff of MECP scientists, lab tech, and partners. DESC serves as a centre of scientific expertise, and a place to research environmental issues affecting Ontario's inland lakes. The LPP is coordinated out of DESC, with the state-of-the-art lab analyzing the LPP samples, and sampling kits being coordinated and assembled out of DESC.

Figure 17: The lab at DESC is highly efficient, analyzing samples for government researchers, LPP volunteers, and external partners. In 2016, the DESC Water Chemistry Lab

produced 100,000 data points representing water chemistry from streams and lakes across the entire province.

In the early 1970s, several Ontario ministries worked to research and understand the science on water quality in Ontario's lakes. This would go on to support policy to minimize the impacts of land-use change on the water quality of Ontario's inland lakes. DESC began a variety of monitoring programs and research on climate, benthic invertebrates, aquatic species, and water quality. This research focused on the impacts of land-use change also provided data that contributed to the discovery of acid rain impacts in Ontario. This discovery led to environmental regulations for reducing sulphur emissions across North America (*Federation of Ontario Cottagers' Associations, 2015*).

> *"These data sets are a provincial treasure, in my opinion." – Dr. Norman Yan, York University, speaking about DESC's calcium database.*

Beginning in the mid-1990s, research at DESC evolved to focus on environmental stressors affecting inland lakes, and their interactions. This allowed DESC scientists to better understand how lakes respond to human development and activities. DESC uses a variety of means to gather data, using including man power, citizen science, and technology. DESC led sampling includes:

- A raft deployed near the centre of Harp Lake records a variety of water-quality parameters at different depths every 10 minutes, all day, and all year.
- Three of the 8 DESC intensive lakes are sampled every two weeks throughout the ice-free season from April to December; the remaining 5 lakes are sampled once a month during the same ice-free period
- The 26 extensive DESC lakes are sampled once in the spring and once in the fall.

- Another 20 lakes are sampled once each year for benthos, crayfish and associated water chemistry.
- Over 850 sites are sampled by LPP volunteers, contributing to a growing water quality database.

Figure 18: Long term ecosystem science conducted at DESC: 1. Hydrology instruments which gather information on rainfall, snow fall, and wind speed. 2. One of DESC's monitoring buoys, which records a variety of water-quality parameters at different depths every 10 minutes all year. 3. A float plane ready to be packed with gear for sampling remote lakes. 4. A MECP scientist sampling one of the regularly sampled Dorset lakes. 5. Winter stream hydrology sampling in the Dorset area (*photo source: Ministry of Environment, Conservation, and Parks*).

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