WHITE LAKE Property Owners Association Environment Volunteers

REPORT

Water Quality Monitoring Program and Research Activities 2022

Quiet Morning, Western Shore - C. Grégoire

Water Quality Monitoring Program
And Research Activities
2022

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WHITE LAKE PROPERTY OWNERS ASSOCIATION ENVIRONMENT VOLUNTEERS

2022 Water Quality Monitoring Program and Research Activities

Summary and Highlights

Conrad Grégoire PhD and David Overholt BA

1.1 Introduction

2022 marked the 9^{th} year that we have been monitoring water quality in White Lake. In our work, we keep track of changes in phosphorus concentrations, water clarity, algal blooms and much more in order to accurately asses water quality. The interpretation of this data is validated by research reports in the scientific literature. This approach forms the basis of annual water quality reports. Data obtained over a period of years is valuable in detecting long and short-term trends. The more data we have the more realistic is our assessment of the changing state of White Lake.

Water quality is a term which can mean different things to different people. Depending on your interest, it could refer to clear water, good fishing, or water suitable for drinking free of toxic chemicals or pathogens. In fact, it is all of these and more. Wikipedia defines it as “the chemical, physical, and biological characteristics of water based on the standards of its usage. The most common standards used to monitor and assess water quality convey the health of ecosystems, safety of human contact, and condition of drinking water”.

In this Summary Report we provide highlights of our findings for 2022. For a complete referenced account of our work, we ask that you access the White Lake Science and Information Website for full-length Water Quality Monitoring Reports as well as Special Reports on individual topics.

1.2 The State of White Lake Report

In 2022, we published The State of the Lake Report; White Lake and the Environment. The state of White Lake is constantly changing over time. However, over the years since the arrival of settlers, certain events have made dramatic changes to lake water quality over just a few years. Among these are logging operations during the 1800s, the construction of the dam at Waba Creek in 1845 (reconstructed 1948 and 1968), and the arrival of invasive species such as the Zebra Mussel in 2015.

This State of the Lake report is a snapshot of the condition of the lake today. It explains why and how the lake is changing and what we can do to help preserve the lake.

This report along with the extensive information available on the White Lake Science and Information website (www.wlpp.ca) provides the reader with a comprehensive source of virtually all available data collected and reports written on the lake by government and independent sources.

The annual collection of chemical and biological data allows us to detect when significant changes to the lake occur, and guides us in our research on White Lake water quality. More changes are coming with possible invasions of more aquatic invasive species, and the increasing effects of climate change and lake overuse. At some point, a new State of the Lake report may then have to be written.

1.3 Algal Blooms - 2022

The first algal bloom of the year was a green algal bloom which started in mid-June and continued until the end of summer. This bloom was green filamentous algae, which grew in large patches along the shoreline. Nutrients, such as phosphorus, supporting this alga comes from sediments, shoreline runoff where shorelines are disturbed, as well as nutrients dissolved in lake water from sources like septic systems and zebra mussels.

Blue-green algal blooms are not benign and so warrant our special attention. When these blooms occur, they can create a public health hazard and anyone using the lake should be apprised of the seriousness of this issue. In 2022, there was one blue-green algal bloom located partly in Three Mile Bay and extending into the main water body northwards past Pickerel Bay. This bloom of Anabaena blue-green algae was relatively mild and dissipated over a period of 5 days.

1.4 Total Phosphorus, Water Clarity, Water Levels and Temperature

Total Phosphorus

Total phosphorus levels in White Lake changed dramatically when zebra mussels infested White Lake. Prior to this event, total phosphorus concentrations reached levels of about 22 parts per billion. These concentrations were above the Provincial Water Quality Objective. Once zebra mussels were established, total phosphorus levels decreased by about 50% and have not changed greatly since that time.

Since 2018, total phosphorus levels have remained low and virtually constant

Unfortunately, lower total phosphorus levels were not achieved by any improvement in lake usage, but rather because of a side effect of the presence of zebra mussels. Now, algal blooms occur annually when the total phosphorus level is about 10 parts per billion, which is below the Provincial Objective. The MOECP is now using a different measure in setting its new objective, which for White Lake is now 11 parts per billion. Total phosphorus levels in White Lake currently peak at about 14 parts per billion. It may be that the measured levels of total phosphorus are more of an indicator of the impact zebra mussels are having on the measurement of lake water quality parameters.

Water Clarity

Water clarity, as expressed as the Secchi depth, doubled after zebra mussels arrived in 2015. Since that time, water clarity has remained relatively stable from year to year. Any variations are likely due to weather conditions and changes in the number and size of active zebra mussels in the lake. One of the reasons why there has been an increase in aquatic plant growth and spread to deeper waters, is the greater intensity of sunlight now available at any given depth.

Water clarity for 2022 increased by 0.5 metres over values recorded in 2021 reversing a downward trend lasting 3 years.

Temperature

For most of the summer, water temperatures in 2022 were lower than last year and lower than for most of the previous nine years. Air temperatures were relatively cool and rainfall high which may have contributed to lower lake water temperatures.

Water Levels

Contrasting with 2021 when water levels were lower than the regulated planned levels for the summer months, 2022 water levels were high. Water levels were generally higher than planned by about 5 to 10 cm, mainly due to the heavier rainfall during summer.

1.5 Loon and Cormorant Counts

In 2022, there were a total of 10 confirmed loon nests, each with two adults. These nests produced a total of 15 chicks. These results are very encouraging and signal a turnaround for Common Loon populations on White Lake. In 2021 and 2022 only 5 chicks were produced. Prior to these years, on average about 18 chicks were hatched annually. Typically, only about 50% of chicks survive to join their parents on the annual migration south.

For the past four years, we have been observing the number of double-crested cormorants using White Lake. So far, our observations indicate that the population is growing but at a very small rate. In 2021, we estimated that there are about 4 to 5 nesting pairs on the lake. The 2022 data suggests that there are about 10 to 12 cormorants making White Lake their home. This translates to a minimum of 5 to 6 nesting pairs producing less than 10 offspring, as reflected in the total cormorant count taken in mid-August.

1.6 White Lake Water Quality is in Decline: What can we do?

Over the last nine years, we have completed many studies on White Lake in addition to monitoring changes in water quality. During this time, we have published over 1300 pages of annual and special reports. All of these are available on the White Lake Science and Information Website. We have also co-authored an academic research paper in collaboration with Carleton University, published in an international journal, which supports all of our findings with more hard evidence.

Our special reports on the History of White Lake Water Quality and on White Lake Algal Blooms: 1860 to 2021 unambiguously demonstrate that White Lake water quality is in decline. A cursory reading of personal accounts on White Lake water quality in *White Lake, The Early Years*[1] (available on the members only section of the White Lake Property Owners Association website) reinforce our findings.

Our goal is to collect and interpret data and to persuade property owners around White Lake to act responsibly. At times, this may require a change in mindset and a re-evaluation of how we are treating the lake.

Many people are not aware that septic systems do not prevent nutrients from entering the lake. The purpose of septic systems is to render human waste free of dangerous pathogens. In fact, the Ontario Ministry of the Environment clearly states that all nutrients, such as phosphorus, entering a septic system located within 300m of the lakeshore, will eventually reach and be discharged into the lake environment. The same assertion also applies to any fertilizers, pesticides, and herbicides.

White Lake water quality is being affected by climate change, invasive species, and lake overuse. We can make a difference by following the well-developed guidelines for reducing our impact on the lake.

One of the most important actions a property owner can take is to restore their shoreline to a natural state using native plants. Maintaining fully-treed lots as much as possible interrupts and/or delays movement of nutrients from septic systems to the lake. Using native plants will improve water quality, reduce shoreline erosion, enhance wildlife habitat and increase resilience to the effects of climate change and severe weather events.

Two recently published reports from Watersheds Canada both explain the importance of vegetated shoreline buffers and offer a guide to preparing a shoreline naturalization planting plan. We recommend that you access and read these documents if you want to know more about how to best preserve and improve White Lake water quality.

[1] White Lake, The early Years, White Lake Property Owners Association, 2000, 64 pages.

As in any society, there is always a fraction of property owners who will not fully understand the impact that they are having on the lake. It could also be that they are not interested in knowing, and/or just want to enjoy the lake.

This is when governments can intervene and take action to preserve White Lake. The people who are charged with managing the lake (with the assistance of the Ministry of the Environment Conservation and Parks), are the Councils of the four municipalities sharing White Lake. It is difficult to find evidence that White Lake is being effectively managed by any level of government.

Since the Township of Lanark Highlands has both the greatest number of taxpayers of any municipality and a large percentage of its own taxpayers located on White Lake, it has both the most to lose as well as the most to gain when it comes to the health of White Lake.

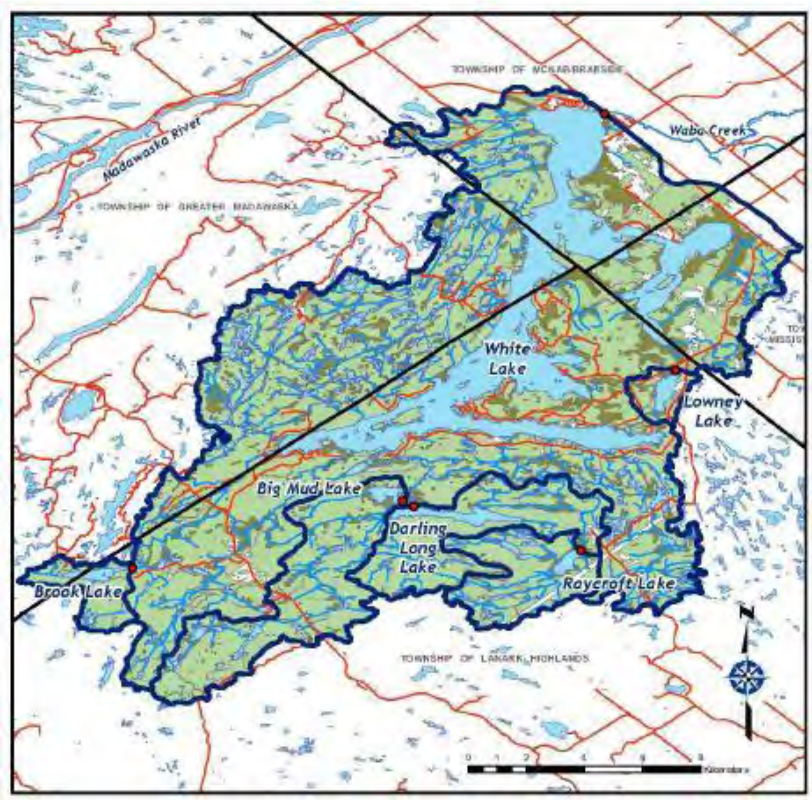
One suggestion is for LH to take the lead and establish a 4-municipalty committee which could effectively manage White Lake. This committee would provide a forum for local taxpayers to bring forward concerns related to the management of the lake.

Individually and as a group, we should be contacting our Councillors (Wards 1 & 2) and urging them to bring to Council our concerns and request the formulation of an action plan to preserve White Lake for future generations.

PART II
Water Quality Parameters

2.0 2022 Water Quality Monitoring Program

Introduction and Summary



Introduction: White Lake is characterized as a shallow warm water lake. The watershed or drainage basin (pictured on the map) is relatively small compared with the total area of the lake. Most of the water entering the lake is from natural springs.

The western part of the lake shore is comprised mainly of pre-Cambrian (acidic) rocks whereas the remainder of the shoreline and the rocks under the lake are calcium rich in nature (basic). It is the calcium rich rocks that give the lake its chemical signature with a basic pH and high calcium content. Both of these factors strongly favour the growth of zebra mussels, an invasive species which has now been observed in great numbers in all parts of White Lake since 2016.

An examination of the watershed map (above) in concert with topographical maps reveals that the parts of the lake which abut pre-Cambrian rocks are fed by surface and ground waters emerging from heavily forested and hilly terrain. In previous studies reported by the authors, it has been shown that that this terrain does not contribute significantly to the chemical character of White Lake. The remainder of the lake, including areas starting at Hayes Bay and stretching through The Canal, the Narrows and finally the White Lake Village Basin, is surrounded by deforested landscape including some farms.

The forested areas, which include numerous beaver dams and ponds, serve as a buffer storing much of the water falling as rain or melting from snow. Trees also have a significant uptake of water during the growing season. On the other hand, the remainder of the drainage basin comprising deforested landscape offers little or no storage of water above the natural water table. In parts of the lake which are surrounded by dense forest, and which also contain the deepest waters, rain and runoff reach the lake at a slower pace relative to the deforested areas. As a consequence of this, the shallowest parts of the lake (including parts of The Canal and areas leading to and including parts of the White Lake Village Basin) receive rain and snow melt surface waters as well as ground water infiltration from the bottom of the lake at a much higher rate, especially after a weather event such as a heavy rain.

Water Quality Monitoring: The quality of the water in White Lake is of great importance to anyone wishing to use the lake for recreational purposes and also for the maintenance of a healthy ecosystem including fisheries. The long-term monitoring of water quality will provide a record of how the lake is changing with time. The effects of climate change, increasing use by humans and the influence of invading species on White Lake need to be recorded so that we can take whatever actions are required to ensure the long-term health of the lake.

Many people ask us to describe the condition of White Lake in a word. They ask if it is in good condition or in only fair condition. Although it would be expedient to do so, these terms are subjective, have little meaning, and cannot be used to paint a complete picture which is in reality much more complex. Our objective is to collect valid data in a systematic and scientific manner, to interpret these data taking into consideration the significant body of knowledge available in the published scientific literature, and in turn inform you of changes taking place in White Lake over time. We publish all of our raw data and invite anyone to suggest alternate interpretations. The only requirement is that adherence to scientific principles is respected. This is how science works. The word '*Preservation*' looms large in our work because one of our main objectives is to keep the lake from further degradation and if possible, improve its current condition.

In 2016, White Lake experienced an explosion in populations of zebra mussels, with numbers estimated to be up to one billion individuals. Zebra mussels have been found in every part of White Lake and are especially prevalent attached to aquatic plants. In 2018, the extent of the infestation continued to increase, but in 2019 and especially 2020 it was clear that zebra mussel populations were decreasing somewhat. This was largely due to natural die-off due to age and the growth of calcareous algae. In 2021 and 2022, zebra mussel populations have rebounded. It will likely take a number of years before an equilibrium is reached and zebra mussels numbers, or more accurately zebra mussel biomass, becomes stable.

The most obvious effect of the presence of zebra mussels is the greatly increased clarity of the lake. Looking back at 2015 and years previous, such a finding would have been welcomed as an improvement in water quality. However, attendant effects of zebra mussels are serious and transformative. Zebra mussels are filter feeders and can lead to the wholesale (~90%) transfer of nutrients from lake waters to waters and sediments, especially near the shoreline. White Lake is only 9.1 m deep at the deepest location and has an average depth of 3.0 m. Secchi depth readings which measure water clarity reached over 9 m in 2018. This means that virtually the entire floor of the lake was and continues to be illuminated with sunlight during most the ice-free season.

Since 2015, the concentration of measured total phosphorus in the lake has declined by about 50%. The general reduction in total phosphorus levels in no way indicates that there is less phosphorus entering the lake. There is, in fact, no evidence of any changes in human activity or other factors which would result in lower total phosphorus levels in all parts of the lake other than those resulting from zebra mussels infesting the lake.

The *Summary and Highlights* section of this report summarizes the current status of White Lake based on our observations and the best available science published in the open literature. Reported is the influence of zebra mussels in transferring particulate phosphorus from the deeper parts of the lake to near shoreline environments while leaving behind that fraction of total phosphorus responsible for algae propagation. This means that we can no longer point to lower total phosphorus levels as a positive indicator of lake health.

We now can show[2] that White Lake is at capacity meaning that the lake cannot tolerate additional nutrient inputs such as phosphorus. We also know that the lake is experiencing annual green and blue-green algal blooms. These two issues taken together present us with our greatest challenge in preserving White Lake and should be the driving force motivating us to take action!

> *The effects of zebra mussels as well as climate change are only two of the multiple stressors affecting White Lake which, taken together, make the lake more susceptible to algal blooms and other undesirable consequences due to human activity. The results contained in this report highlight the importance that we, the caretakers of White Lake, do whatever we can to minimize our impact on White Lake ecosystems.*

In the meantime, we have to become more vigilant and press our politicians to work with our lake association. Also, the Ministry of the Environment, Conservation and Parks, and other interested parties must help to ensure that existing bylaws are used properly in planning decisions and enforced, and that we take measures to protect and preserve the lake. These measures could include septic inspections, shoreline rehabilitation, limits on boat sizes and the control of damaging wakes. There are many things we can do to mitigate the effects of other stressors we cannot control, notably the care, restoration and preservation of the 15 metre 'ribbon of life' along the water's edge.

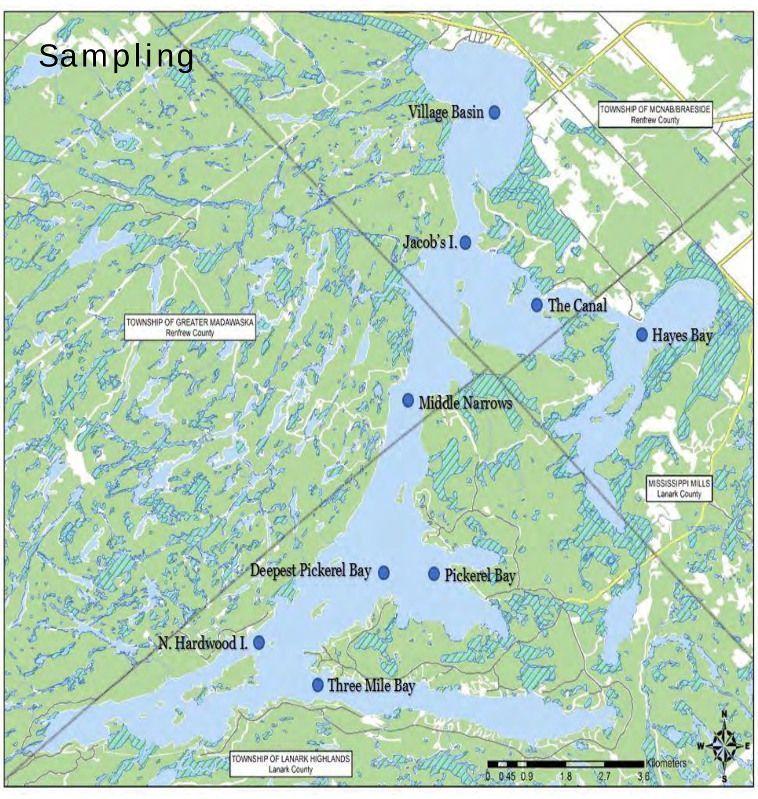
We should also become organized as a society to pro-actively work to prevent the infestation of White Lake with other invasive species some of which have effects far worse than zebra mussels. They are just around the corner. We should also be pro-active in preventing the spread of zebra mussels from White Lake to other local non-affected water bodies.

[2] State of the Lake Report, White Lake Property Owners Association, 2022, 117 pages.

White Lake Water Quality Monitoring Program

The water quality monitoring program for 2022 was carried out by volunteers and involved the collection of water samples mid-month for 6 months starting in May. Duplicate water samples were collected for phosphorus analysis and a single separate sample was collected for calcium and chloride measurements Water samples were filtered through an 80-micron mesh filter to remove any large biota such as daphnia which would skew analytical results. Note that the total phosphorus data obtained is for both phosphorus available as free phosphorus (there are many phases or chemical species of phosphorus suspended and in solution) as well as phosphorous contained in small phytoplankton and zooplankton. Secchi depth (water clarity) readings as well as temperature at the Secchi depth were recorded at the same time. Additionally, Secchi depth and temperature readings were taken every two weeks during the summer season providing additional data. Throughout the summer we monitored biota populations in the lake and monitored the lake for algal blooms.

All water samples collected for the determination of total phosphorus content were shipped to the Dorset Environmental Science Centre (Ontario Ministry of the Environment Conservation and Parks) for analysis under the auspices of the Lake Partner Program. The method used for the determination of phosphorus is described in the publication: B.J. Clark et al, *Assessing variability in total phosphorus measurements in Ontario lakes*, Lake and Reservoir Management, 26:63-72, 2010. The limit of detection for phosphorus using this method is 0.2 parts per billion (ppb).



3.0 Algal Blooms – 2022

During 2022 two algal blooms were recorded. The first type of algal bloom which occurred was from filamentous green algae. This bloom lasted, as in previous years, from mid-June until mid-September.

The second type of bloom was from blue-green algae which covered parts of the lake including Three Mile and Pickerel Bays and extending into the main water body (See Appendix 1). Note that the Ministry of the Environment policy towards blue-green algal blooms is: "MOE regards any cyanobacterial (blue-green algae) bloom as potentially toxic, whether or not toxins are detected in the water upon testing"[3]

> The authors emphasize that the algal blooms observed by our team are the minimum number for White Lake, and there may very well have been others on the lake which went undetected or unreported. No Provincial or local authority monitors water bodies for algal blooms. The Ministry of the Environment and local health units respond only to reports from the public at large. Currently only two volunteers are monitoring the 22 Km^2 of White Lake, which has a shoreline stretching nearly 100 km!

3.1 Green Algal Blooms

The first algal bloom of the year started in mid-June and continued until the end of summer. This bloom was of a filamentous green alga, which grew in patches along the shoreline.

In 2022, the filamentous green algal bloom was less extensive than in precious years with fewer occurrences than in 2021. The most serious and largest blooms were found immediately adjacent to newly de-treed and landscaped cottage lots, and areas of severely altered shorelines.

Algae bloom when conditions are right for its rapid and uncontrolled growth. These conditions include the presence of excess nutrients (phosphorus), favourable water temperature and clarity, sunlight, and the action of wind and waves. For White Lake, the presence of zebra mussels is an additional factor promoting the growth of filamentous green algae. These mussels tend to concentrate nutrients from open waters to the shoreline area where filamentous algal blooms occur. The severity of the algal bloom resulting from the sum of the above factors can be intensified by the runoff of nutrients from areas of shoreline which have been de-treed or altered in such a way that nutrients

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[3] Algal Blooms in Ontario, Canada: Increase in reports since 1994; J.G. Winter, A.M. DeSellas, R. Fletcher, L. Heintsch, A. Morley, L. Nakamoto, and K. Utsumi (all Ontario Ministry of the Environment scientists); *Lake and Reservoir Management*, 27:107-114, 2011.

can enter the lake unmoderated by the presence of trees and other natural shoreline vegetation which prevents or slows entry nutrients into the lake.

Viewed from underwater, the algae mass forms very large volumes extending from just below the surface of the lake all the way down to the lake floor. Other aquatic plants become enveloped within the growing mass. Over time, the algae die, collapses into itself and sinks to the bottom of the lake.


Appearance of Filamentous Green Algal Bloom from Lake Surface

This alga does not produce toxins in the water and so the bloom is considered a nuisance bloom. However, when large mats of algae die and decompose, the water column can become anoxic (no oxygen) causing the release of phosphorus trapped in sediments. Sediments contain about 200,000 times the concentration of phosphorus found in lake water. The released phosphorus can trigger a secondary bloom which could be larger and last longer than the original event.

3.2 Blue-Green Algal Blooms

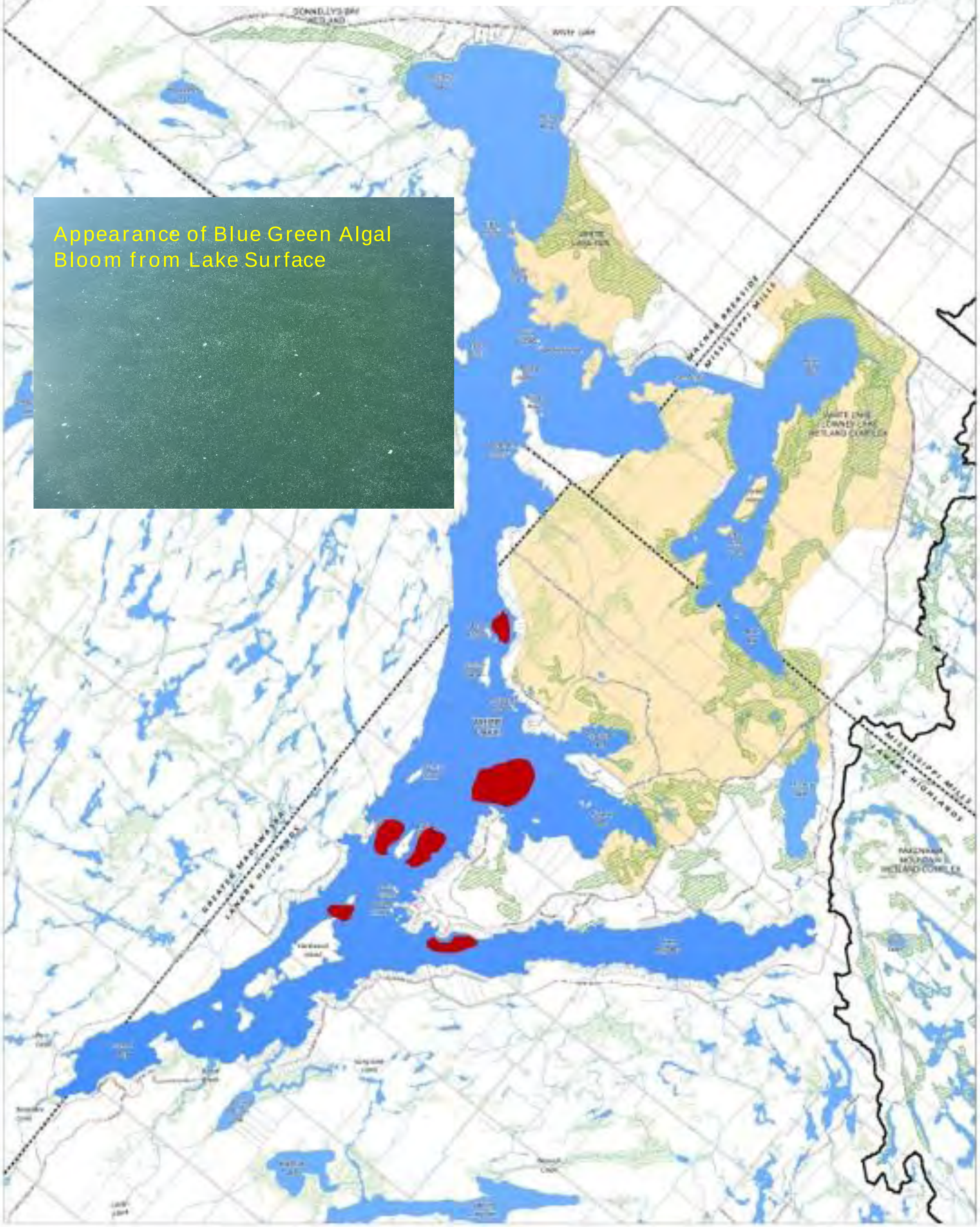
Blue-green algal blooms are not benign and so warrant special attention. When these blooms occur, they can create a public health hazard and anyone using the lake should be apprised of the seriousness of this issue.

In 2022, White Lake hosted one blue-green algal blooms detected on September 12,2022. The bloom was confined to about 6 patches located in the main water body of White Lake, as shown on the map below. The bloom was identified as anabaena and dissipated within a week. It should be noted that both anabaena and microcystis are present in all parts of the lake. During most of the water sampling season, it is possible to observe specimens of both of these algae in the water column, usually at very low concentrations

We know from the scientific literature that the presence of zebra mussels favours the propagation of microcystis over anabaena blue-green algae. However, in deeper waters, it may be possible that anabaena could have the advantage over microcystis for two reasons: 1) there are fewer or no zebra mussels present in deeper waters where the lake bottom is muddy; 2) anabaena has the ability to fix nitrogen from the atmosphere; microcystis does not. Both are capable of moving up and down the water column during the day using gas vacuoles, which are like air bubbles held within the algae.

The occurrence of algal blooms is complicated and dependent on a number of factors including wind, temperature, sunlight, water depth, the presence of different phosphorus and sulphur containing compounds, as well as nitrate and nitrite concentrations, to name just a few.

Anabaena Blue-Green Algal Bloom: September 12, 2022



3.3 Lake Scum

On May 31, 2022 large areas of the main water body of White Lake were covered with lake scum. At first glance the scum appeared to be an algal bloom, but on closer examination turned out to be a combination of flotsam from three sources brought together by a gentle wind on the lake surface.

The scum was composed of floating tree pollen grains intermixed with the white, fluffy down released by three in the *Salicaceae* family which includes willow, aspen, cottonwood and poplar trees. The down contains seeds. The third component was discarded exoskeletons (called *an exuviae*) left behind by billions of flies and other insects hatching into adulthood from the lake surface.

It took several days for the action of wind and waves to clear the surface of the lake sending the lake scum to downwind shorelines or sinking to the lake bed.

4.0 Water Clarity – Secchi Depth

One of the most dramatic changes in White Lake water quality which we have observed since the arrival of zebra mussels in 2016 is the increase in water clarity. So how much clearer is the water now compared to 2015 when the lake was in its natural state?

It turns out that the water clarity has changed differently in different parts of the lake. In areas close to shorelines (where most zebra mussels are found) like Three Mile Bay, water clarity has increased up to 138%! At locations further away from shorelines, the Secchi depth has increased up to 109%. In the middle of the lake, the increase is about 95%.

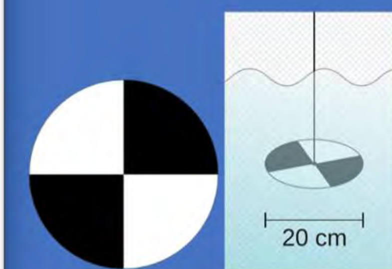
In July of 2015, the Secchi depth in Three Mile Bay was 2.1 metres and by July 2018, the Secchi depth had increased to 5.0 metres. We are now measuring Secchi depths of over 9 metres at some locations. So what?

Water clarity on the surface appears to be a good thing. However, there are some important consequences to consider, especially since the increased clarity is due to the presence of zebra mussels in White Lake:

- Aquatic plants will propagate in deeper parts of the lake.
- Aquatic weed beds will thicken in shallow areas where weeds currently exist.
- More zebra mussel habitat will be created on new plant beds.
- Enhanced water clarity means less food for small creatures, including fish.
- The presence of filamentous green algae along shorelines will become more prominent. This 'green angel hair' was visible in nearly all parts of the lake this year.
- Fish will have a harder time hiding from predators in clear water.
- Currently, there are no approved ways of reversing any of the changes noted above.
- We must now prevent the spread of zebra mussels from White Lake to other water bodies.

WHAT IS SECCHI DEPTH AND HOW IS IT MEASURED?

The Secchi depth is a measure of the clarity or transparency of the water. The Secchi disk, named after an Italian scientist, is used to make the measurement. The disk is segmented black and white and 20 cm in diameter:



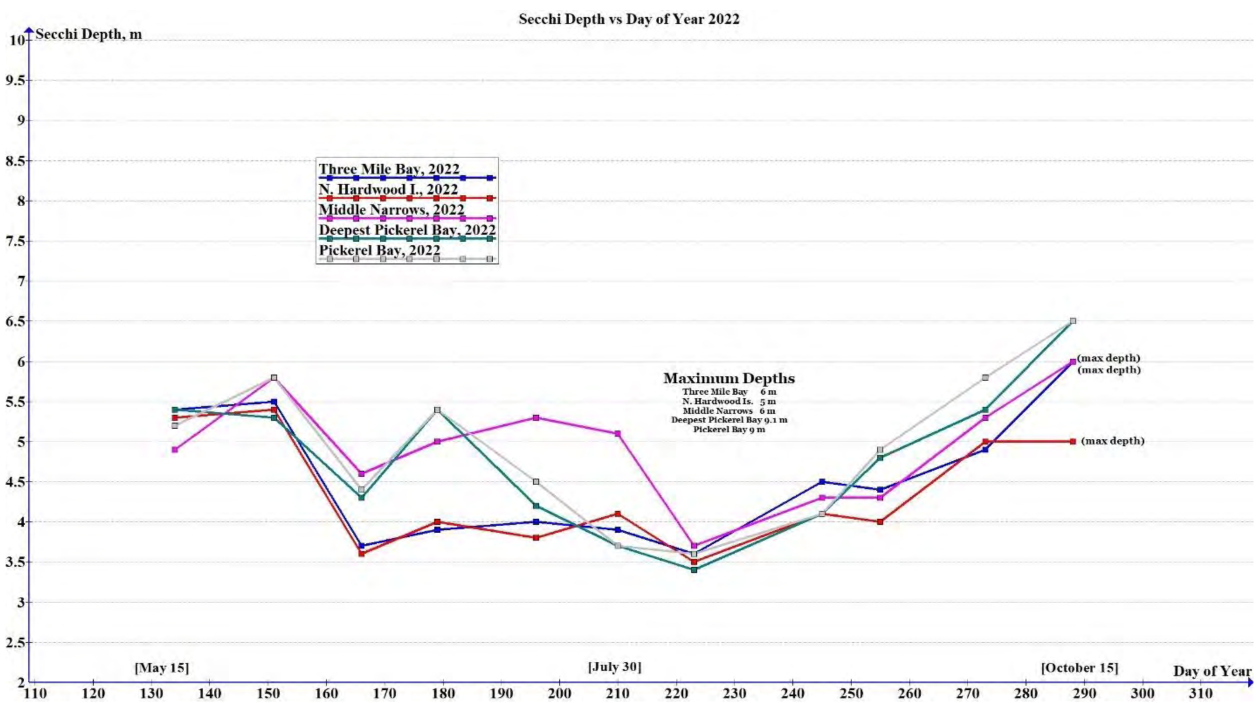
The disk is lowered into the water until it is no longer visible. The recorded depth, in metres, is one half of the distance that light can travel through the body of water being measured. A Secchi depth of 6 metres, for example, means that light can travel through 12 metres of water. White Lake is a maximum of 9.1 metres in depth.

4.1 <u>Secchi Depth Data:</u>

Below is a graph containing the Secchi depth readings for White Lake taken during the 2022 ice-free season.

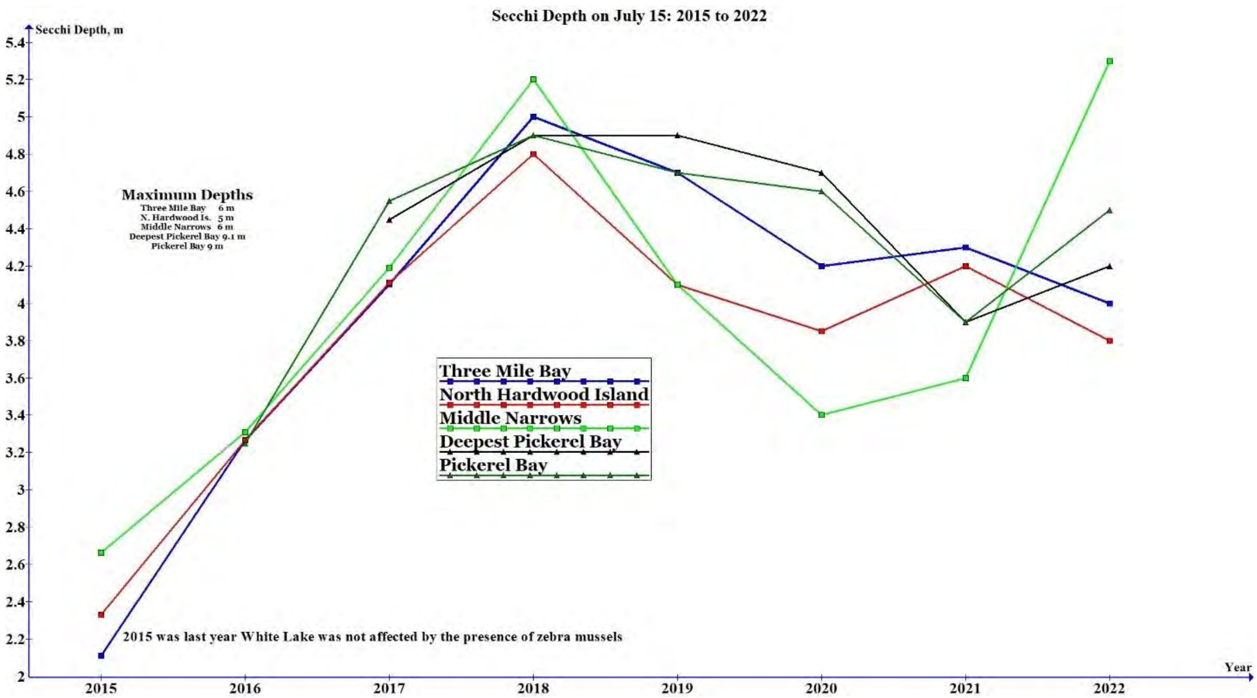
Of the nine sites we sampled, there were only five that had measurable Secchi depths. The remainder of sites were too shallow or the water was too clear at all times. The pattern of Secchi depth readings in 2022 is similar to that of previous years. Secchi depths increase as the lake water column becomes uniform in temperature in the spring and then decreases as the temperature of the lake increases. At higher temperatures there is more biological activity as well as supply of nutrients. Minimum Secchi depths of about 3.4 m (lowest water clarity) were recorded in mid-August with a maximum of 6.5 m recorded in mid-October.

The highest value for Secchi depth (~9m) was recorded in 2017. Since that time, water clarity has decreased somewhat, but is still much higher than it was prior to the invasion of zebra mussels. One can speculate that this pattern may be related to weather conditions



since it is doubtful that nutrient levels in the lake have changed appreciably in recent years. Alternatively, the presence of reduced numbers of zebra mussels may also have had an effect in decreasing water clarity.

The graph below shows that the water clarity, expressed as Secchi depth, increased significantly during the years 2015 to 2022. The reason for the increased water clarity has been attributed to the growing presence of zebra mussels in White Lake. The slope of the lines in the graph below were positive during these years as water clarity continued to increase every year. The Secchi depth values obtained in 2015 are typical of those measured in previous years prior to 2015, when no zebra mussel were present in the lake.

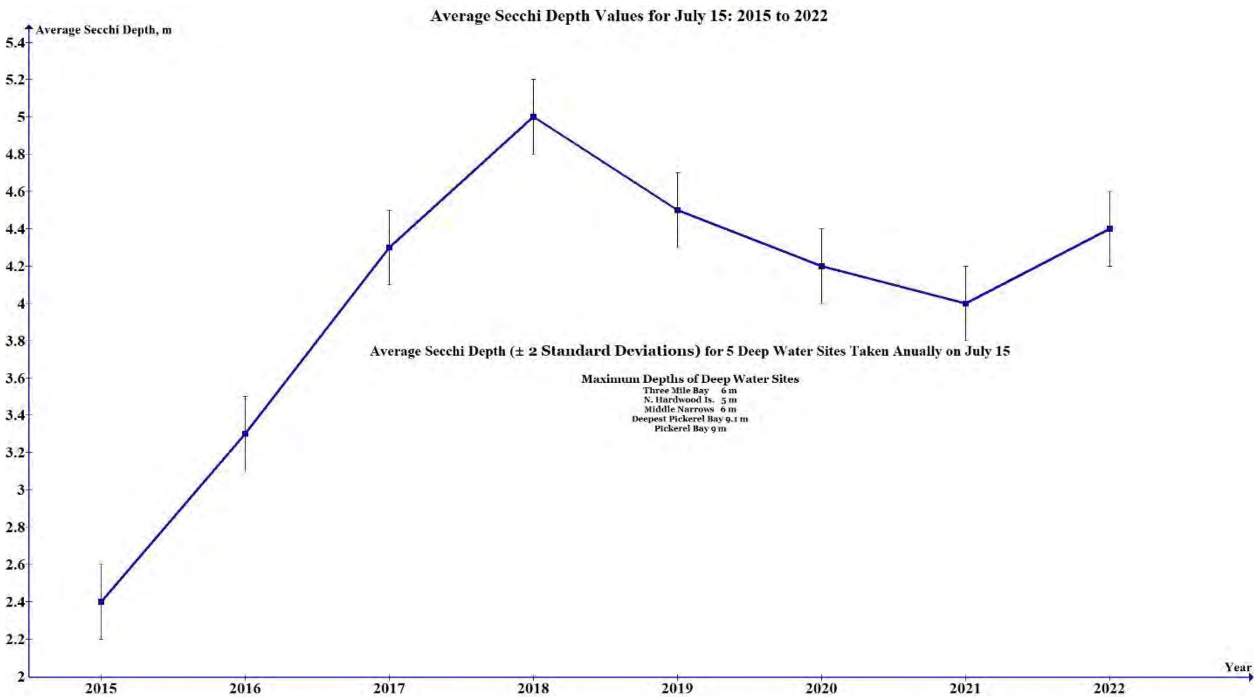


In 2019, this trend was suddenly reversed with Secchi depths decreasing from values obtained in 2018. This trend continued into 2020 with even lower values recorded. During 2021 and 2022, water clarity began to again increase, probably due to fluctuating zebra mussel numbers. To put this in perspective, the Secchi depth for Three Mile Bay in 2022 is still twice the Secchi depth obtained in 2015, and only reduced by 20% from the maximum value obtained in 2018.

A clearer illustration of year over year changes in Secchi depths can be obtained by plotting the average Secchi depth obtained annually on July 15th for all deep-water sampling sites (Zone 1).

The graph below shows that after 2018, when Secchi depths reached a maximum, water clarity decreased moderately each year thereafter and then increased in 2022.

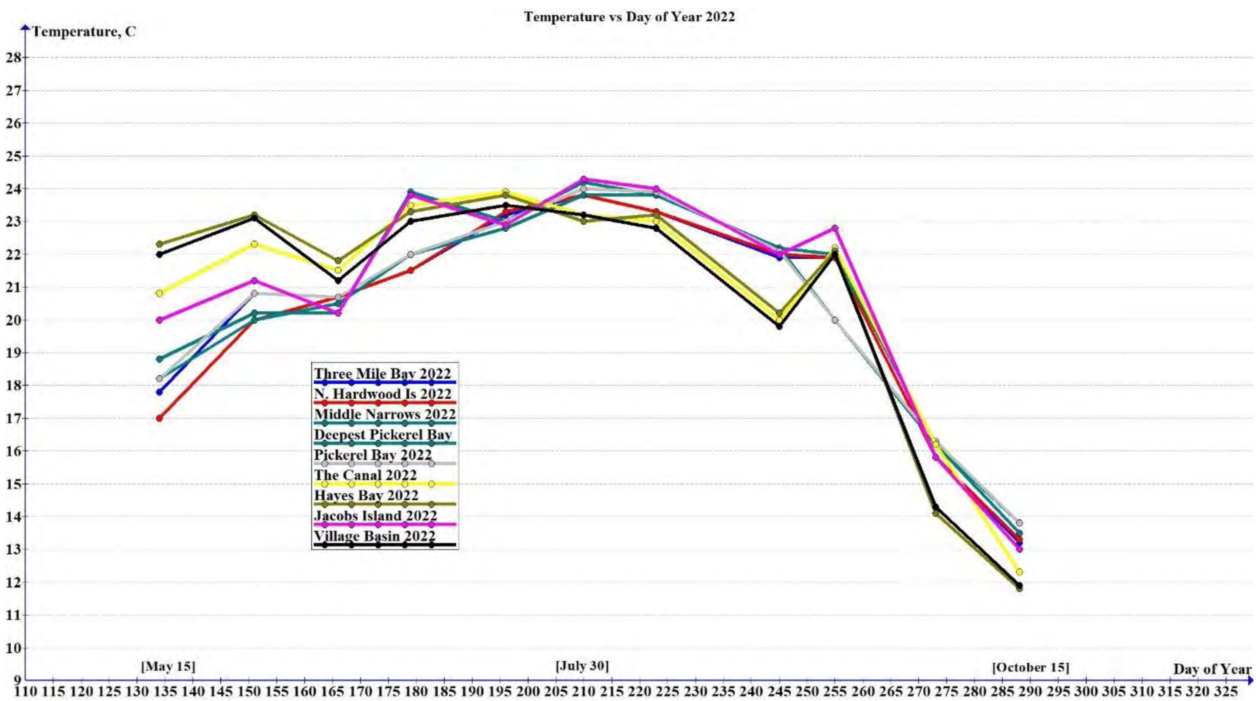
We believe these trends are significant and show that water clarity is now annually changing by no more than about 0.5 metres. Continued monitoring of water clarity in future years will reveal if trends are again changing significantly or only marginally year over year.


Average Secchi Depth Values for July 15: 2015 to 2022
Average Secchi Depth, m
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
Year
2015
2016
2017
2018
2019
2020
2021
2022
Average Secchi Depth (± 2 Standard Deviations) for 5 Deep Water Sites Taken Anually on July 15
Maximum Depths of Deep Water Sites
Three Mile Bay 6 m
N. Hardwood Is. 5 m
Middle Narrows 6 m
Deepest Pickerel Bay 9.1 m
Pickerel Bay 9 m


Eagle one; Lake Gull zero
Photo Credit: Jim Austin

5.0 <u>Water Temperature</u>

Temperature is one of the most important factors when discussing water quality parameters. Changes in temperature affect the rates of chemical reactions, pH, and also the equilibrium concentrations of dissolved gases in the water column such as oxygen and carbon dioxide. Temperature also affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. For White Lake, increased water temperatures would also increase the release of phosphorus by internal loading from sediments into the water column. All temperatures reported in this study were taken at the Secchi depth using a thermometer calibrated against a secondary standard mercury glass thermometer.



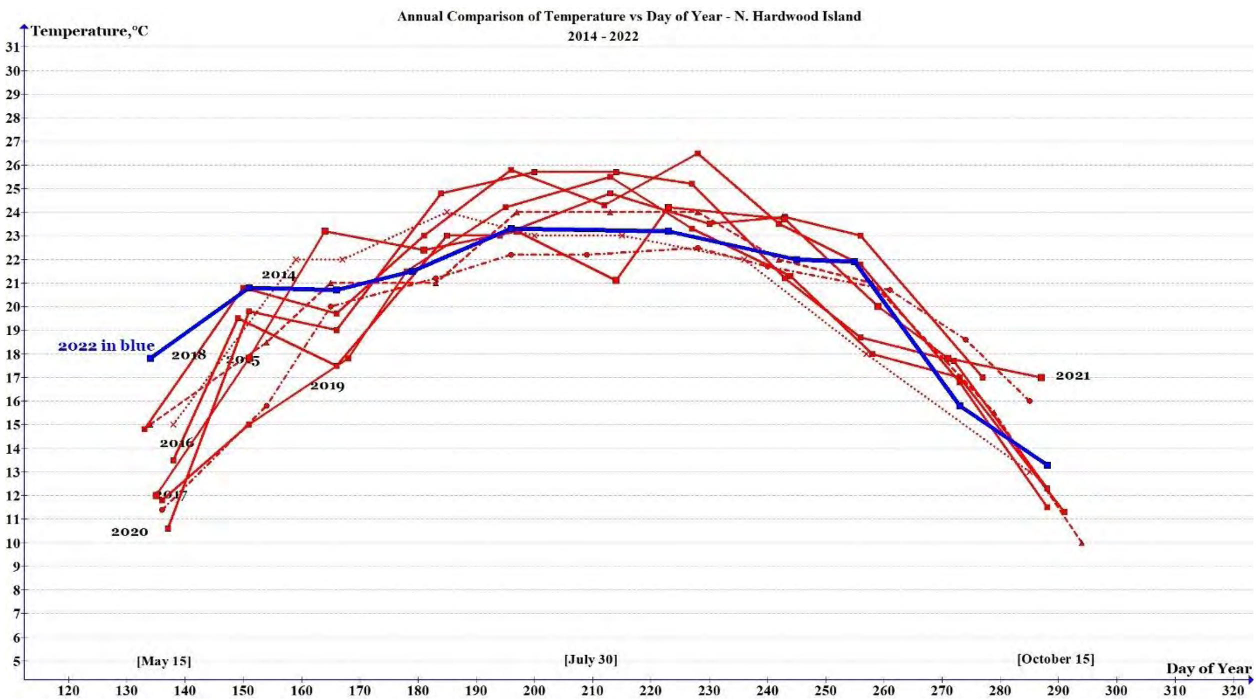
The graph above shows the temperature of White Lake water over the course of the 2022 ice-free season.

Although there is clearly some variation in measured temperatures depending on the location of the sampling site, the temperature curves follow a trajectory very similar to those observed in previous years. The noticeable 'dips' in temperature which occur from time to time are usually correlated with significant rain events one to three days prior to sampling. Cooler waters resulting from rain enters the lake via springs in the floor or the lake as well as from surface runoff. Because White Lake has such varied bathymetry, there are differences in temperatures at different sampling sites. For the most part, water temperatures for all of the deeper sites were almost the same differing by no more than 0.5 °C. However, temperatures for the shallow sites were at times quite different from those of the deeper sites because they are more susceptible to recent or current weather conditions. A full explanation of this topic can be found in the 2016 and 2019 Water Quality Monitoring Program Reports available on the White Lake Science and Information website.

5.1 Annual Trends in Lake Water Temperatures

Although there are some year-to-year differences for temperatures recorded on a given date, the same general pattern in water temperatures with day of year is observed (see previous reports). This indicates, along with the other data in this section, that the temperature regime of the lake is quite regular from year to year, but may be subject to change due to local climatic conditions.

For example, the 2019 data presented in the graph below shows that lake water temperatures were several degrees cooler at the beginning and end of summer when compared to previous years. The very significant rains experienced in the spring and cooler temperatures during the same time period explain this observation.



We now have 9 consecutive years of water temperature measurements for the deeper sites (Zone 1: Main Water Body) on White Lake. The figure above gives temperature measurements obtained at the North Hardwood Island site for the years 2014 to 2022. The thick blue line is 2022 data.

The 2022 data (thick blue line) shows that temperatures were generally higher during the Spring and comparable in the Fall as compared to previous years. However, from about June 15 to early September, water temperatures were relatively low compared to previous years. Depending on weather conditions, the data contained in the above graph shows that temperatures can vary by about 5 degrees over most of the summer from year to year.

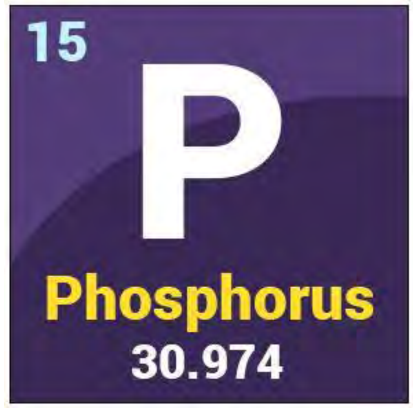
The table below gives maximum temperatures recorded for White Lake during the past 9 years. 2018 had the highest water temperature recorded to date was 4.1 ◦C higher than the lowest temperature recorded during 2017.

Year	Day of Year	Maximum Temperature, °C
2014	199	24.1
2015	217	24.0
2016	223	24.7
2017	216	22.9
2018	196	27.0
2019	213	25.6
2020	214 and 227	26.0
2021	181	25.2
2022	210	24.3

Note that temperatures cited in these pages are for sampling sites located in open water away from the shoreline. During the day, higher temperatures than open water temperatures are expected which could result in more prolific aquatic plant growth and also encourage propagation of algae, including blue-green algae.

6.0 Phosphorus

What is Total Phosphorus?



Phosphorus is element 15 of the Periodic Table. It is so important because life cannot exist without it. Phosphorus is one of the building blocks of DNA and hence proteins, and is integral to any ecosystem including lakes like White Lake. However, if there is too much of it, then we can have problems such as dangerous or nuisance algal blooms. For this reason, we monitor the levels of phosphorus in the water so that we can assess the health of the lake and hopefully modify our behaviour to prevent excess quantities of phosphorus from entering the lake.

But what are we measuring anyway? We report our results for phosphorus as 'Total Phosphorus' which implies that total phosphorus is not just one thing but the sum of many things. This is the case!

Phosphorus is a very reactive element and can exist in many oxidation states, which is to say that it likes (as much as an element can 'like') to combine with other elements in many different ways.

But where does it come from? Phosphorus occurs in nature mostly as the mineral apatite which is also called calcium phosphate $Ca_5(PO_4)^+$. It can enter lake water by a number of ways including: rain which contains atmospheric dust; pollen which is high in proteins; fertilizers, detergents, septic systems, etc.; surface soil runoff, and ground water containing dissolved phosphorus compounds. It has been estimated[4] that the concentration of total phosphorus in White Lake waters prior to the arrival of Europeans was about 7.5 parts per billion or nanograms/ml.

When it comes to lakes, we are not really interested in ALL forms of phosphorus, but only the forms which can affect living creatures including fish, plankton (including certain algae, bacteria, protozoans, crustaceans, mollusks) and us!

In lake water, the term 'Total Phosphorus' includes all of the phosphorus that can be measured in water which has passed through an 80-micron (micro or millionth of a metre) filter. The 80-micron filter is used only to remove large zooplankton and, for example, colonies of chrysophyte algae which can form into relatively large 'clumps. Everything else including phytoplankton, small zooplankton, particles containing phosphorus, dissolved inorganic and organic phosphorus compounds pass through the filter and are measured together as total phosphorus. These are true total phosphorus

[4] J.P. Ferris, White Lake Integrated Resources Management Plan, Part I, Ministry of Natural Resources, Lanark and Renfrew Counties, December, 1985.

samples and are not in any way described as filtered and only containing dissolved phosphorus. If you place one 1 mm-sized daphnia in a phosphorus sample tube and analyze it in distilled water, one can get a result of 35 µg/L (ppb)[5]. For this reason, these larger organisms must be filtered out prior to analysis.

The dissolved phosphorus-containing fraction is sometimes called the bioavailable phosphorus. This definition is great for most people, but chemists and biologists will want to tell you that the term' Total Phosphorus' includes all forms of organic phosphates, inorganic phosphates and also organic and inorganic soluble reactive phosphates as well as small particulate phosphate-containing materials.

Since zebra mussels have established themselves in White Lake, the total phosphorus concentrations measured in the lake have decreased by about 50%. This is because zebra mussels are filter feeders and they very efficiently remove all particulate material (down to 1 micron) containing phosphorus. The phosphorus which remains in solution is not filtered out by mussels, but remains available for algal growth. In effect, even though overall phosphorus concentrations have diminished, the amount of phosphorus which algae feed on has not changed at all. Therefore, the total phosphorus concentrations we are now obtaining (much lower than before) do not reflect a reduced risk for algal blooms!

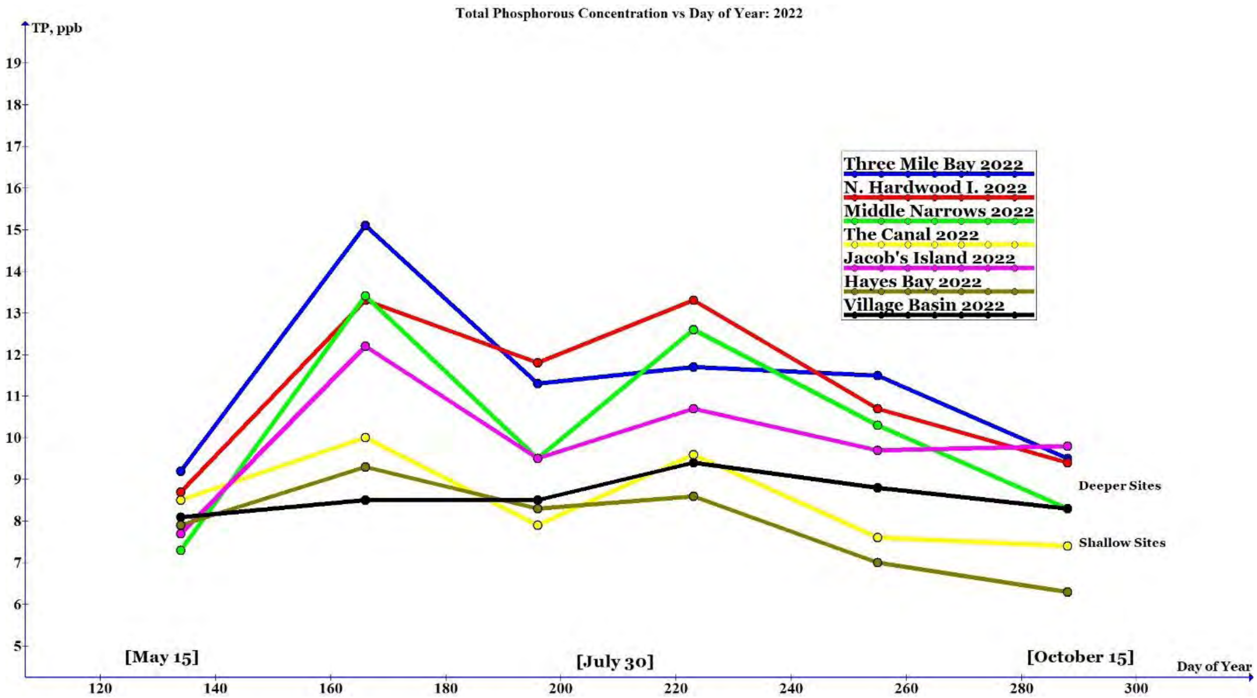
The phosphorus contained in sediments is just as complex if not more so. It is easy to realize that the study of lakes as well as other bodies of water is very challenging and requires the highest levels of science and ingenuity to completely describe the complexity of an aquatic system.

One final note: It is important to realize that the 'Total Phosphorus' we are measuring in White Lake waters only accounts for a small portion of the total amount of phosphorus which enters the lake. Most of the phosphorus entering the lake falls to the bottom of the lake (such as pollen) and once there, eventually decomposes and becomes available to animals and plants. This is why the concentration of phosphorus in lake sediments is literally hundreds of thousands of times greater than in the water just above it!

Now we can discuss the total phosphorus results for White Lake for 2022.

[5] B.J. Clark et al, *Assessing variability in total phosphorus measurements in Ontario lakes*; Lake and Reservoir Management, 26:63-72, 2010.

The graph below shows the change in total phosphorus concentrations during the 2022 ice-free season.



The data for 2022 (above) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in mid-June. After this date, the total phosphorus concentration decreases, the increases in mid-July and deceases towards the end of summer and into the fall. These data also show that the highest total phosphorus values were obtained at the southern part of the lake nearest the N. Hardwood Island and Three Mile Bay sampling sites. These results and trends are in agreement with measurements recorded during the last ten years by government agencies and lake association volunteers. Over the years we have observed that the highest TP values for these two sites sometimes are the same or they could alternate with one site being higher than the other depending on the year. In 2022, the maximum TP for the Three Mil Bay site was significantly higher than the maximum TP concentration for Three Mile Bay.

The total phosphorus curves in the figure above can be separated into two groups. The first group are those representing the deeper sampling sites, which have higher concentrations. The second group of curves are those representing the shallow sampling sites, located in the northern part of the lake. These sites uniformly have significantly lower total phosphorus concentrations.

There are two main reasons for which shallower locations have lower total phosphorus concentrations. The first is because of more effective mixing of the water column all the way to lake sediments. More oxygen-rich conditions reduce the amount of phosphorus released from sediments.

The second reason contributing to lower total phosphorus values in shallow areas is the nature of the sediments themselves and their ability to sequester (physically entrap) phosphorus contained in waters entering the lake through sediments.

Marl sediments are formed when waters rich in bicarbonate enter from the floor of the lake and upon reaching the surface encounter higher temperatures and lower pressures. Under these conditions, bicarbonate can spontaneously decompose releasing carbon dioxide and leaving behind finely divided (small particle size) insoluble calcium carbonate (marble). When this process occurs, phosphorus can be trapped in the calcium carbonate matrix resulting in lower total phosphorus concentrations.

Parts of the lake such as the Village Basin, The Canal and Hayes Bay are all shallow areas underlain by these marl deposits, a process which is still unfolding today. If one takes a sample of these sediments and adds droplets of 10% hydrochloric acid, the mixture fizzes releasing carbon dioxide while forming calcium chloride. This test is a positive for marl. Sediments devoid of calcium carbonate will show no reaction when this test is applied.

The table below gives the concentration of calcium carbonate in sediments from four shallow areas of White Lake[6].

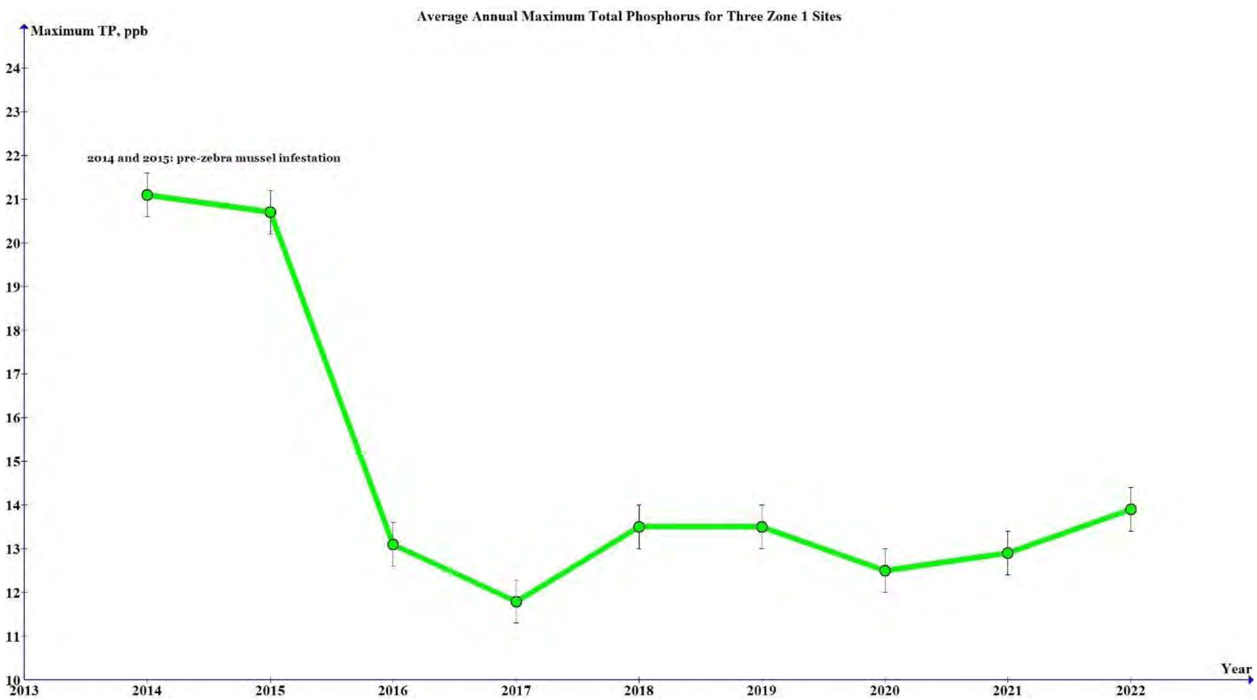
Location	Percent Carbonate*
Village Basin	47.2
The Canal	46.6
Hayes Bay	37.5
Bane Bay	18.2
*average of two measurements	

Sediments from the first three locations: Village Basin, The Canal and Hayes Bay, all have very high carbonate content and are documented sources of marl[7]. Although there is a relatively high percent content of carbonate in Hayes Bay sediments, it is less than for the two other sites. Bane is even further away from the marl-producing sediments and shows even lower carbonate levels.

[6] M. Murphy and J. Vermaire, Carleton University, 2019; personal communication.
[7] W.E. Logan, The Geology of Canada, Geological Survey of Canada; 1863, p. 765.

6.1 Annual Trends in Total Phosphorus Concentrations

The figure below shows the annual average total phosphorus concentration for three deep water sites in Zone 1 (Main Water Body of White Lake).



Total phosphorus concentrations declined significantly from those in 2014 and 2015 (and years prior to that) when in 2016 the zebra mussel infestation took full effect. Maximum phosphorus concentrations declined by about 50% or more from 2015 onwards.

However, the explosion of zebra mussel populations in White Lake during the 2016 season explains why total phosphorus levels have decreased significantly over previous years. Zebra mussels can remove over 90% of the plankton and other particles normally found in an unaffected lake. Zebra mussels are efficient at removing particulate phosphorus from the water column and transferring it to sediments via feces and pseudo-feces. It is also reported that the concentration of soluble reactive phosphorus remains unchanged allowing for further phytoplankton production. However this type of phosphorus is a primary food for zebra mussel veligers (larvae). The phosphorus transferred to sediments by zebra mussels eventually becomes available for algae growth and results in an increase in both green and blue-green algal blooms. This is exactly what we have observed in White Lake in recent years.

Even though we know that the population levels of zebra mussels in White Lake can both increases and decrease from year to year, it is evident from the above graph that the impact of zebra mussels on total phosphorus concentration levels changes very little as evidenced by the relatively constant total phosphorus concentrations measured from 2018 onwards.

It may be useful to remind ourselves of the relative sources of phosphorus entering White Lake[8] and note that not all of the phosphorus is converted to the 'total phosphorus' that we measure every month during the ice-free season.

The pie chart below indicates that taken together land run-off, septic systems and shoreline development account for about 70% of the phosphorus entering White Lake. This clearly shows the importance of effective shoreline management to improve water quality and help control nuisance and toxic algal blooms such as those which we have been documenting during the past nine years.

The chart also shows that we, as users of the lake, can have an effective role in maintaining and even improving White Lake water quality.

Returning now to the results obtained for total phosphorus from 2016 to 2022: One might be tempted to explain the sudden decrease in total phosphorus levels to lower levels (compared to previous years) as a decrease of input into the lake. Unfortunately, there is no evidence to support this assertion. More likely, however, is the introduction of a new pathway by which phosphorus is removed from the water column and it is this phenomenon which results in lower overall total phosphorus measurements.

Measured total phosphorus concentrations are derived from water samples filtered through an 80-micron (80 one-millionth of a metre) filter. Phosphorus taken up by certain algae which form colonies larger than 80 micrometres (e.g., chrysophyte) would tend to lower the measured total phosphorus in the water column.

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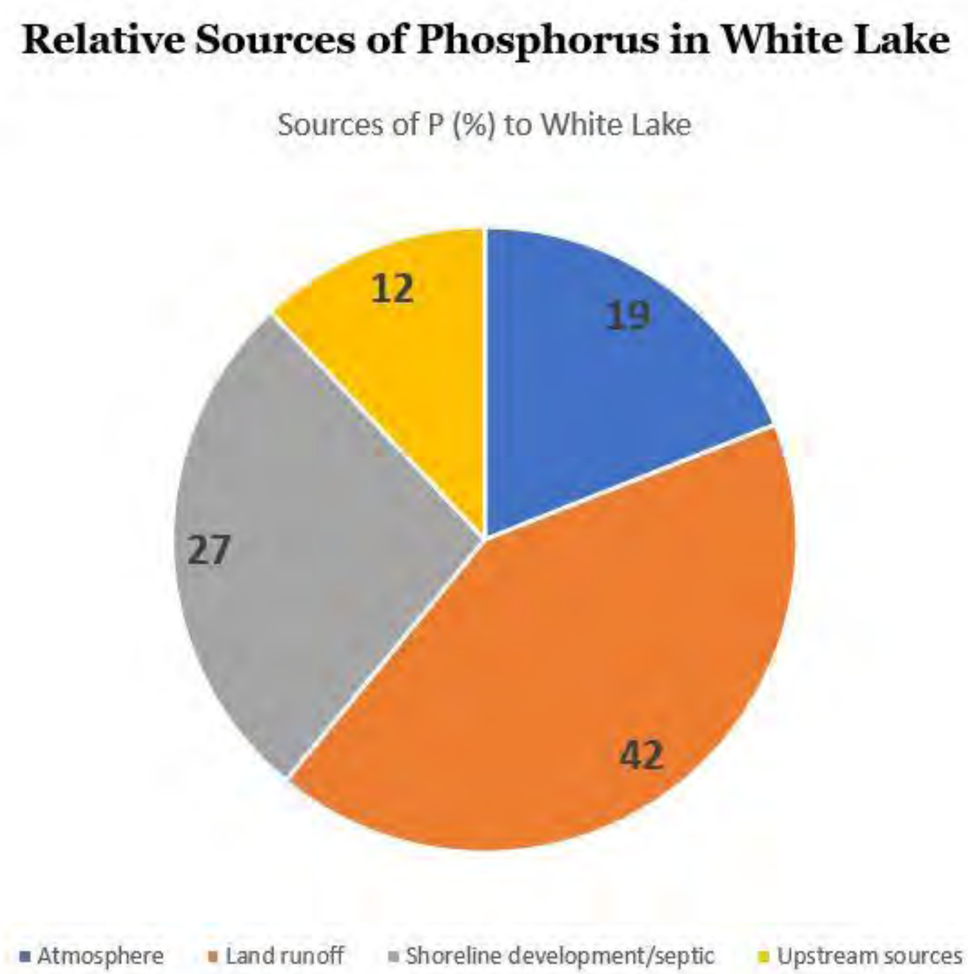
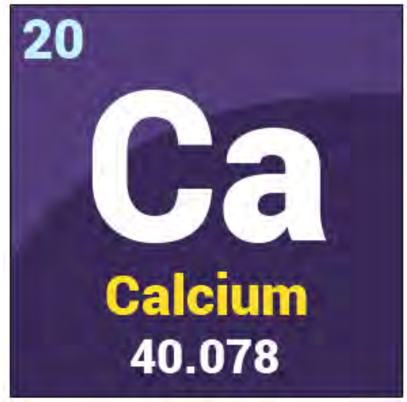
[8] [8] These data are outputs of the Lakeshore Capacity Model for White Lake reported by Bev Clark. Bev Clark is a retired senior career research scientist from the Ministry of the Environment, Conservation and Parks. He was the director of the Lake Partner Program at its inception and both collected research data and contributed to the develop of the Lakeshore Capacity Model used by the Ontario Government Ministry of the Environment..


Relative Sources of Phosphorus in White Lake
Sources of P (%) to White Lake
12
19
27
42
Atmosphere
Land runoff
Shoreline development/septic
Upstream sources

7.0 Calcium



The table below contains values for calcium concentrations measured in White Lake waters. Data are tabulated on a monthly basis and also for each individual site sampled. Analyses were performed by the Lake Partner Program laboratories in Dorset, Ontario.

Across the entire lake during May to October, the concentration of calcium varied from a low of 26.0 ppm to a high of 38.0 ppm. Although the average values for all individual sites (green) are within one standard deviation of one another, the absolute values for Hayes Bay were significantly higher. This site, in particular, has a total dissolved solid content which is 20% higher than at all other sampling sites on White Lake. Because of this, calcium values are excluded from calculated means and are treated separately. The higher values found in Hayes Bay could be due to a higher concentration in waters entering the bay and/or increased rates of evaporation relative to the rest of the lake. Hayes Bay is very shallow (1.5m), has a large surface area and usually warmer than the rest of the lake; all of these factors increase the evaporation rate resulting in higher calcium concentrations.

When looking at mean calcium values for all sites for a given month (red), variation is very small and within one standard deviation. This indicates that lake waters are well mixed.

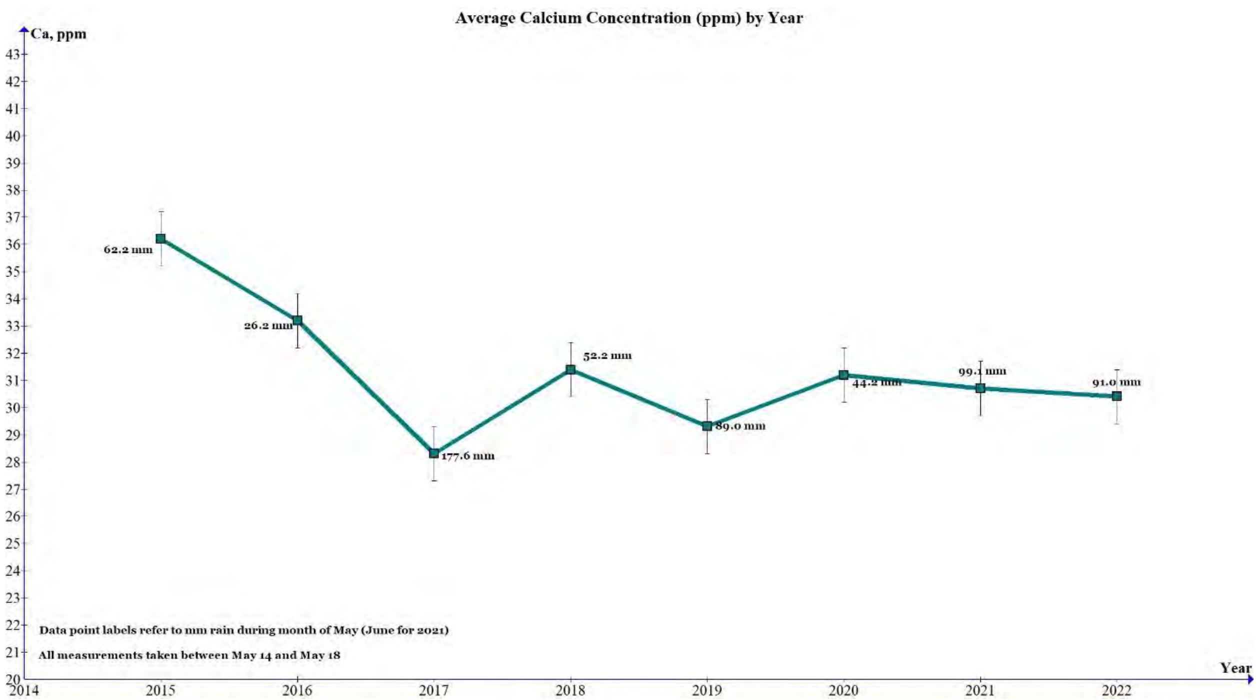
Calcium (ppm) – Sampling Site by Month: 2022

Sampling Site	May	June	July	Aug	Sept	Oct	Average
Three Mile Bay	31.2	28.8	29.6	26.3	28.4	27.5	28.6
N. Hardwood I.	32.0	28.7	30.0	28.0	28.5	26.6	29.0
Middle Narrows	31.3	30.8	29.5	28.2	28.2	27.6	29.3
Jacob's Island	31.2	29.9	27.8	27.5	26.0	28.5	28.5
The Canal	28.8	29.6	27.9	26.2	28.3	31.4	28.7
Hayes Bay	33.5	33.3	38.0	35.0	36.0	34.7	35.1
Village Basin	28.1	27.2	29.1	27.5	27.6	26.8	27.7
Mean	30.4±1	29.2±1	29.0±1	27.3±1	28.1±2	28.0±2	

The table below compares calcium concentrations for individual sites over an eight-year period. With the exception of 2015, where values appear to be anomalously high, calcium concentration at each individual site in White Lake do not appear to be changing appreciably over time. We have noted in other studies that rainfall is an important factor when interpreting changes in calcium concentrations. Higher levels of precipitation results in a 'dilution effect' causing calcium levels to decrease following high rain events.

Sampling Site	2022	2021	2020	2019	2018	2017	2016	2015
Three Mile Bay	28.6	31.6	30.6	28.8	32.8	28.4	36.4	36.2
N. Hardwood I.	29.0	31.3	30.8	28.6	33.0	28.5	31.8	37.3
Middle Narrows	29.3	31.4	31.2	30.3	33.4	28.4	31.1	35.3
Jacob's Island	28.5	30.5	30.6	28.4	34.0	27.7	31.4	36.2
The Canal	28.7	30.2	30.7	30.8	34.4	29.4	34.3	35.8
Hayes Bay	35.1	34.3	32.6	30.4	37.8	31.0	36.6	-
Village Basin	27.7	29.6	30.0	27.9	31.6	27.3	31.0	-

The graph below shows calcium concentrations for each year from 2015 to 2022 for the month of May (June for 2021). Individual data points are provided with an error bar indicating the standard deviation of ± 1 ppm. The size of the error bars relative to the actual plotted value indicates that the changes in calcium concentration from year to year are significant.



In our 2017 report we published a correlation graph of average calcium concentrations, measured monthly from 2015 to 2017, plotted against monthly rainfall. A linear regression analysis of these data indicated that the calcium concentration in White Lake waters was dependent on the amount of rainfall entering the lake. The correlation coefficient (R^2) obtained was 0.783 which is relatively high indicating that the relation between the two parameters is significant. When the correlation plot was extrapolated to zero rainfall, a calcium concentration of 36.8 ppm was calculated. This concentration was taken as the actual calcium concentration of water entering the lake from springs or other ground water sources. The variance in the actual measured calcium concentrations, which accounts for the different monthly values obtained, were the result of a dilution effect from rain water and surface runoff, which contain little or no calcium.

At each point in the above plot is given the total precipitation for the month of May for each year. When this data is plotted, as was done in 2017, but including all data to 2020, 'zero rainfall' intercept gave a calcium value of 35.1 ppm calcium. This value is (within error) identical to the value obtained in 2017.

These results support the conclusion (see 2017 Water Quality Monitoring Report report) that more than 80% of the water entering White Lake is derived from ground water sources with the remainder coming from rain and surface water runoff.

8.0 Chloride

The table below contains values for chloride concentrations measured in White Lake waters. All samples were collected between May 14 and May 18 of any given year. Analyses were performed by the Lake Partner Program laboratories in Dorset, Ontario.

The concentration of chloride does not vary significantly from site to site especially when comparing deeper water sites (such as the first three in the table below) with values obtained for shallower sites, such as Hayes Bay. Hayes Bay has higher chloride concentrations that at any other location on the lake. These concentrations are nearly three times those of other locations, especially those in Zone 1, the main water body. Water draining from Hayes Bay into the Canal Area and downstream on the way to the Village Basin is responsible for elevated chloride values at The Canal sampling site as well as the Village Basin sampling site.

Chloride (ppm) – May, 2015 to 2022

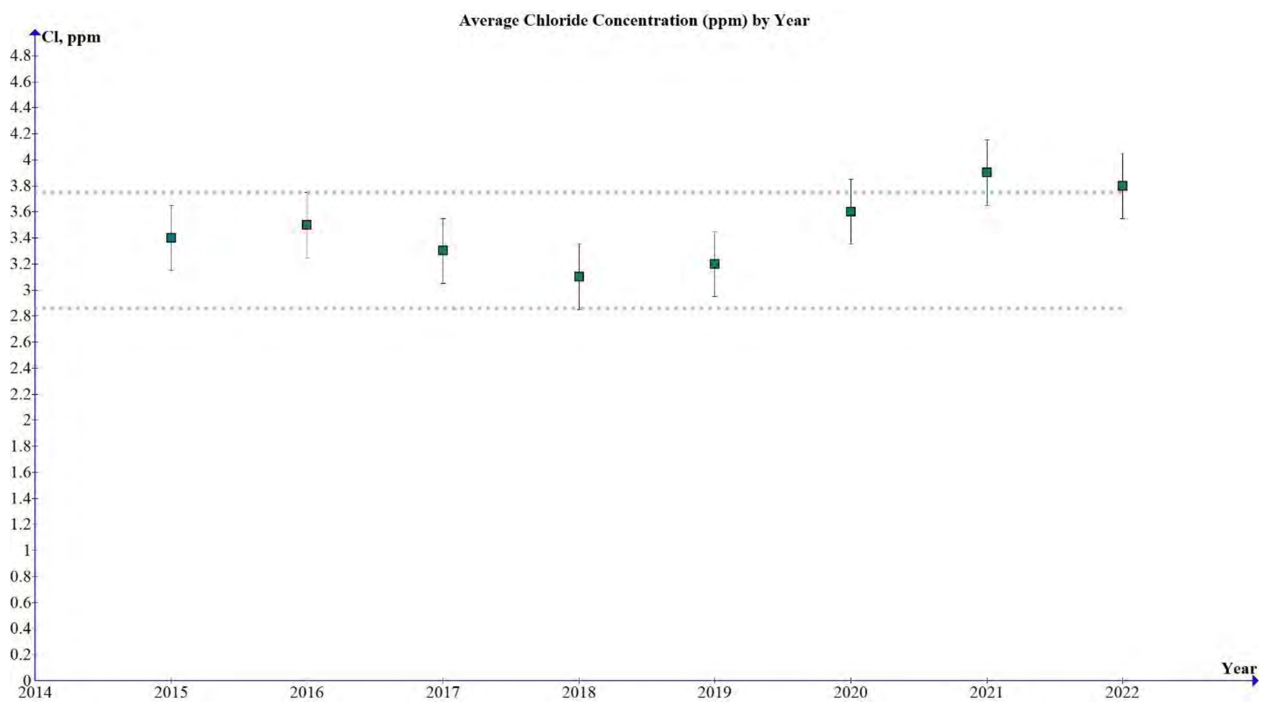
Sampling Site	2022	2021	2020	2019	2018	2017	2016	2015
Three Mile Bay	3.9	-	3.4	2.8	2.9	2.8	3.4	3.5
N. Hardwood I.	3.8	-	3.4	2.8	2.9	3.1	3.4	3.3
Middle Narrows	3.8	3.8	3.5	3.2	3.5	3.3	3.5	3.5
Jacob's Island	4.4	3.9	3.7	3.6	3.2	3.7	3.7	3.5
The Canal	5.1	4.8	4.7	4.1	4.1	6.2	5.4	3.9
Hayes Bay	10.0	9.0	9.0	7.6	8.3	9.5	10.0	-
Village Basin	3.9	3.9	4.0	3.6	3.6	3.8	3.7	-

Average chloride data for 2015 to 2021 are given in the table below. Data from The Canal and Hayes Bay were excluded from this table so as not to skew results for the remainder of White Lake.

Average Chloride Concentration (ppm) 2015 to 2022

Year	Average ± SD
2022	3.8 ± .2
2021	3.9 ± .1
2020	3.6 ± .3
2019	3.2 ± .2
2018	3.1 ± .3
2017	3.3 ± .4
2016	3.5 ± .2
2015	3.4 ± .1

When these data are plotted (below), it is clear from the error bars on each data point that it is difficult to conclude that chloride levels are increasing over time. Longer term monitoring may reveal a trend in chloride concentrations. At any rate, chloride levels are very low and do not pose a threat to wildlife or water quality parameters.



Conductivity measurements (see 2018 Water Quality Monitoring Program Report) showed that the total dissolved solids in Hayes Bay waters were 20% higher than in any other part of the lake.

The source of the additional chloride in Hayes Bay waters (see table above) could be from the intrusion of road salt from the nearby road. A second possibility is that Hayes Bay receives additional chloride from subterranean brines fed by a spring(s) or aquifer. Road salt may not be the source of the chloride because year over year, the concentration of chloride is not changing significantly. Also, if road salt were significantly involved, one would expect that the concentration of chloride would be highest in early summer and taper off to normal lake levels (~3.5 ppm) by mid-summer. For the Hayes Bay site during 2022, chloride values started at 10.0 ppm in May, was 9.6 ppm in June, 10.5 ppm in July, 10.4 ppm in August, 10.5 ppm in September and 11.4 ppm in October. rose to 4.4 ppm on June 30 and fell slightly to 4.1 ppm by July 13. At no time did the concentration of chloride equal the much lower values obtained in other parts of the lake.

9.0 Weather Conditions: 2014 – 2022

When interpreting data such as total phosphorous and calcium concentrations as well as other parameters, it is often useful to take into account weather conditions. This report contains comparisons of data and interpretations of such data from 2014 to 2022. For this reason, we have included meteorological data from all of these years. The data contained in these tables are those taken at the Ottawa International Airport. Available data from other locations near White Lake (e.g., Pembroke, ON) show similar trends and are not substantially different from those reported below.

An examination of the table below indicates that, with the exception of 2017, total precipitation during the ice-free season for White Lake is generally about 0.5 metres. In that respect, 2022 was an above average year for precipitation when compared to values for other years. The number of rain events of greater than 1 mm was average.

Total Precipitation April to October: 2014 to 2022

Year	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
2014	561	81
2015	518	61
2016	431	44
2017	990	81
2018	553	70
2019	631	77
2020	532	56
2021	586	64
2022	661	65

During the six-month period from April to October 2022, White Lake received 661 mm of rain and experienced 65 days with precipitation of 1mm or more of rain. Monthly meteorological tables for previous years starting in 2014 can be found in our previous annual reports on White Lake Science and Information website.

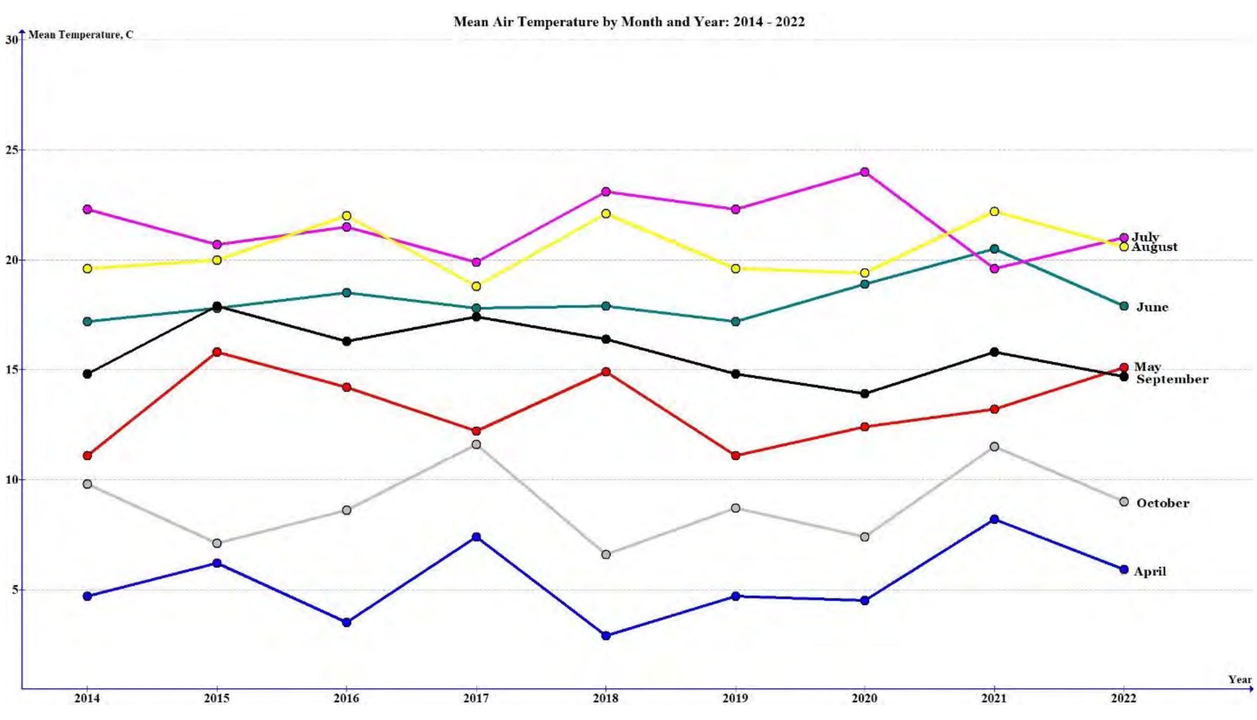
The table below presents monthly meteorological data from April to October, 2022. Tis table does not reveal a year-by-year comparison of monthly temperature values. This data is important, because of the important mechanisms by which White Lake loses water is by evaporation. Prolonged periods of high temperatures with little or no rain could make evaporation the major water-loss mechanism during periods of high atmospheric temperatures. This would be especially significant for shallower parts of the lake such as Hayes and Bane bays and the White Lake Village bas

Monthly Meteorological Values – Environment Canada: *2022*

Ottawa Intl. Airport	Mean Temp., °C	Lowest Monthly Min. Temp	Highest Monthly Max. Temp.	Total Precip., mm	Number of Days with Precip. of 1mm or More
April	5.9	-4.0	20.7	83.6	11
May	15.1	1.1	31.2	91.0	11
June	17.9	6.1	31.4	103.3	11
July	21.0	10.2	31.3	89.0	7
August	20.6	8.7	32.5	189.1	13
September	14.7	1.8	29.1	65.3	8
October	9.0	-3.0	24.3	39.6	4
Total				**660.9**	**65**

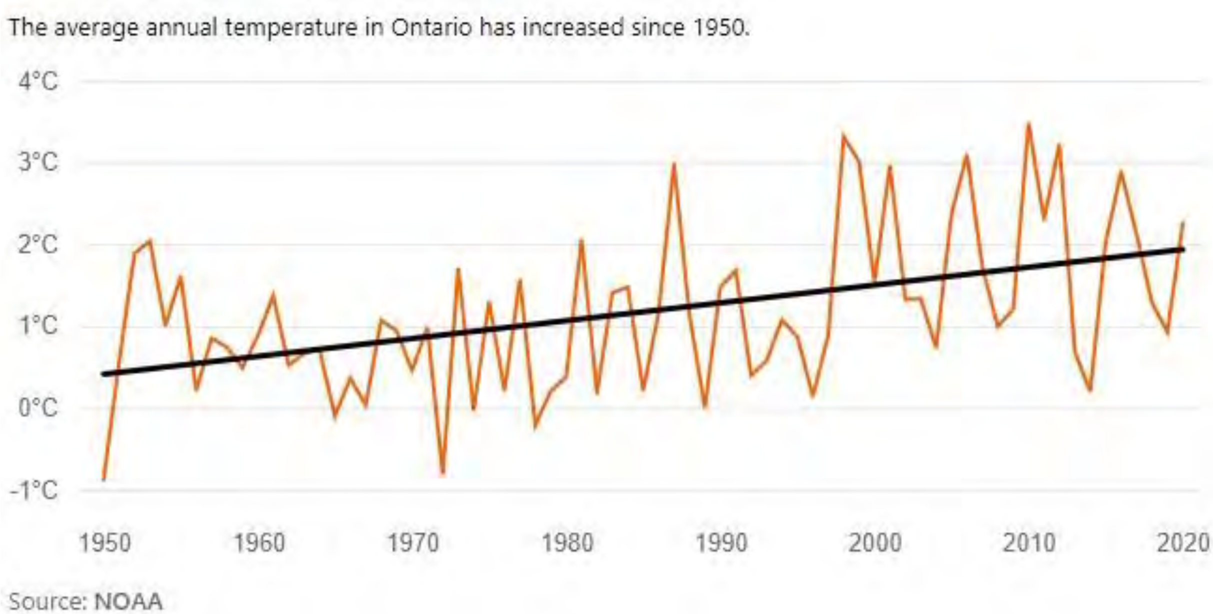
The figure below shows the change in mean air temperature for individual months over the years spanning 2014 to 2022.

Although there is some variation from year to year in air temperatures, it is very difficult to discern any trends over the 9-year period. Air temperatures were cooler in 2022 than for 2021. These differences are due to local weather conditions.



It is important to take note of these temperatures because ambient air temperature will affect the temperature of lake water as well as that of sediments. This in turn could have an impact on aquatic plant growth, plankton succession over the summer as well as the timing of the zebra mussel reproduction cycle.

Recent data published by the US National Oceanic and Atmospheric Administration shows that air temperatures in Ontario have risen by 1.6 degrees since 1950.



The actual weather on and just before lake water sampling dates is also very important. Heavy rains just prior to sampling could result in sharp changes in the concentrations of chemical species as well as the temperature of the lake. Just as important are dry hot spells which can result in warmer water and increased concentration levels of some parameters due to evaporation.

Below is a table showing the actual atmospheric conditions prevalent on our water sampling days. Information in this table was used to help interpret some of the chemical and physical parameters studied in this report.

9.1 Sampling Date Weather Conditions 2022

Date	Day of Year	Weather Conditions
May 14	134	Air temp: 19 to 23C; Full sun; No wind. No rain fell for 10 days before sampling; dry conditions.
May 31	151	Air temp: 21 to 24C; Full sun; no wind; 8 mm rain 4 days prior to lake sampling.
June 15	166	Air temp.: 20 -23C; Cloudy to light overcast; 12 mm rain 3 days before sampling; wind 5 km/h.
June 28	179	Air temp: 18-20C; Bright sunshine, clear skies; No rain previous 4 days; No wind. Depth 148 vs 143.3 planned – 4.7 cm high.
July 15	196	Air temp: 20 – 22C; Bright sunshine, clear skies; 8 mm rain 3 days prior to sampling; no wind. Depth 139 cm; Planned 140.4 cm.
July 29	210	Air Temp: 19 – 22C; Bright sunshine, clear skies; no rain previous 3 days prior to sampling; wind 15-20 km/hr; Depth 137 cm vs 137 cm planned.
August 11	223	Air temp: 22-25C; Overcast with sunny breaks; 81 mm of rain two days before sampling, lake rose 6 cm.; wind 15 to 20 km/hr
September 2	245	Air temp:13 – 15C; Partially overcast with many sunny periods; Wind: 0 to 5 km/hr.; 10 mm rain 2 days before sampling.
September 12	255	Air temp.: 21-24C; Clear sunny day; wind: 0 km/hr.; No rain for previous 5 days.
September 30	273	Air temp: 8-12C; Clear sunny day; no wind; no rain for previous five days.
October 15	288	Air temp: 5010C; Sunny with some clouds; wind 5-10 km/hr; 5 mm rain three days before sampling.

10.0 Water Levels – White Lake Dam: 2022

White Lake Dam is managed by the Ministry of Natural Resources and Forestry, Kemptville District office. The operational plan is part of the Madawaska River Water Management Plan, 2009.

The White Lake Dam is a concrete structure, 29 m (98 ft.) long incorporating three log sluices: one central 2.44m (8 ft.) stoplog bay between two 4.27 m (14 ft.) bays. Each bay contains six 12-inch by 12-inch stoplogs. Half logs and spacers are available to fine tune operations.

The table at right gives the target water levels for White Lake as read on the water level gauge at the dam. The water level gauge is calibrated in decimal feet.

The White Lake Dam Operating Regime is described on page 194 and 195 of the Madawaska River Management Plan and is quoted directly below:

The compliance framework for MNR facilities in the Madawaska River watershed does not require the use of mandatory level or flow limits. The level of White Lake is usually maintained between 3.5 and 5.2 feet. A minimum flow (baseflow) requirement for the White Lake Dam has been established. A flow of 0.14 m^3/s will be maintained at the dam at all times to ensure a sufficient flow is discharged into Waba Creek. This will provide a flow for the maintenance of fish habitat and address other ecological concerns during low flow conditions. A notch will be placed between the second and third log of the middle stop-log bay.

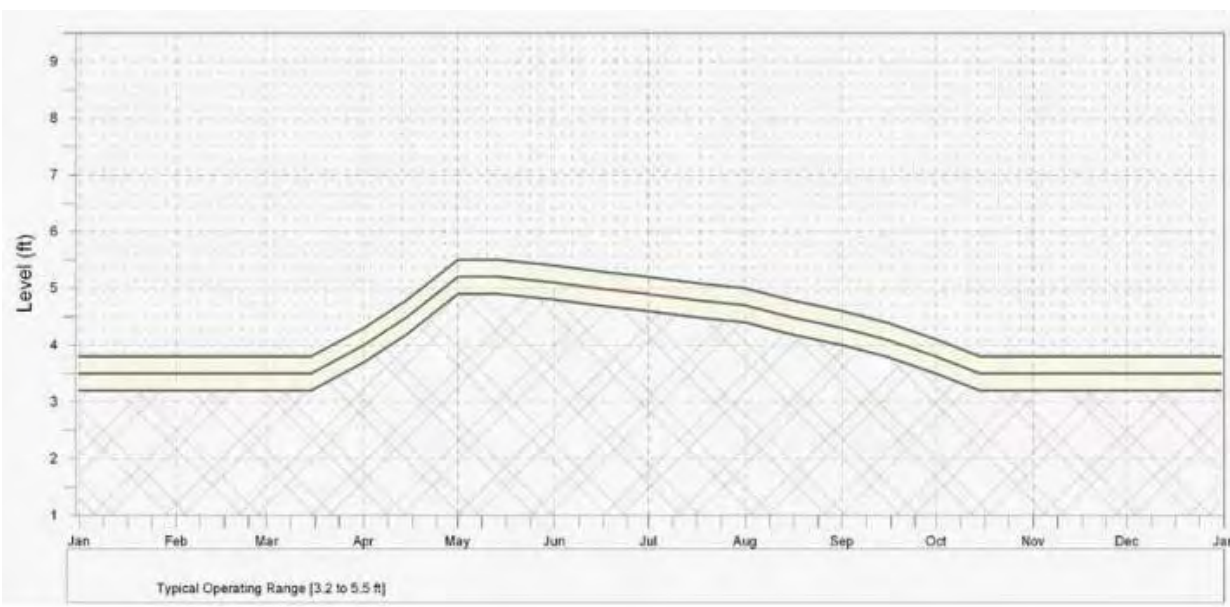
The annual variation of the operating band is given below. Water levels will decrease gradually from the spring flood peak in April to a constant level through the first half of May. In the middle of May, the summer drawdown will commence, which will bring the lake down to the winter holding level.

The typical annual mode of operation of White Lake Dam is summarized as:

Spring: The logs should be left at the winter setting until the water level rises above 3.5 feet on the gauge, at which point the logs should be replaced. By May 1, the water level should attain a target level of 5.2 feet. However, depending on the timing of the spring freshet (to avoid ice damage), all attempts should be made to attain the 5.2 feet level by April 15 to facilitate pike spawning. Stop logs should be manipulated through the remainder of the spring period so that water levels follow those prescribed by the operation plan. The drawdown is to begin May 15.

Summer: The target level for July 1 is a gauge reading of 4.9 feet, and the dam should be operated to reach this level. During the period from May 1 to September 1, water levels should be dropped gradually to reach 4.3 feet.

Fall & Winter: The fall/winter holding level is 3.5 feet which should be reached by October 15. If this level is not achieved by November 1, then that recorded level on this date will be considered the fall/winter holding level. Levels throughout the Fall and Winter should be maintained within ± 0.3 feet of the holding level. If the level should drop below 3.5 feet, it will be as a result of natural variation. Within the management plan the operating curve for water levels is shown in the graph below.



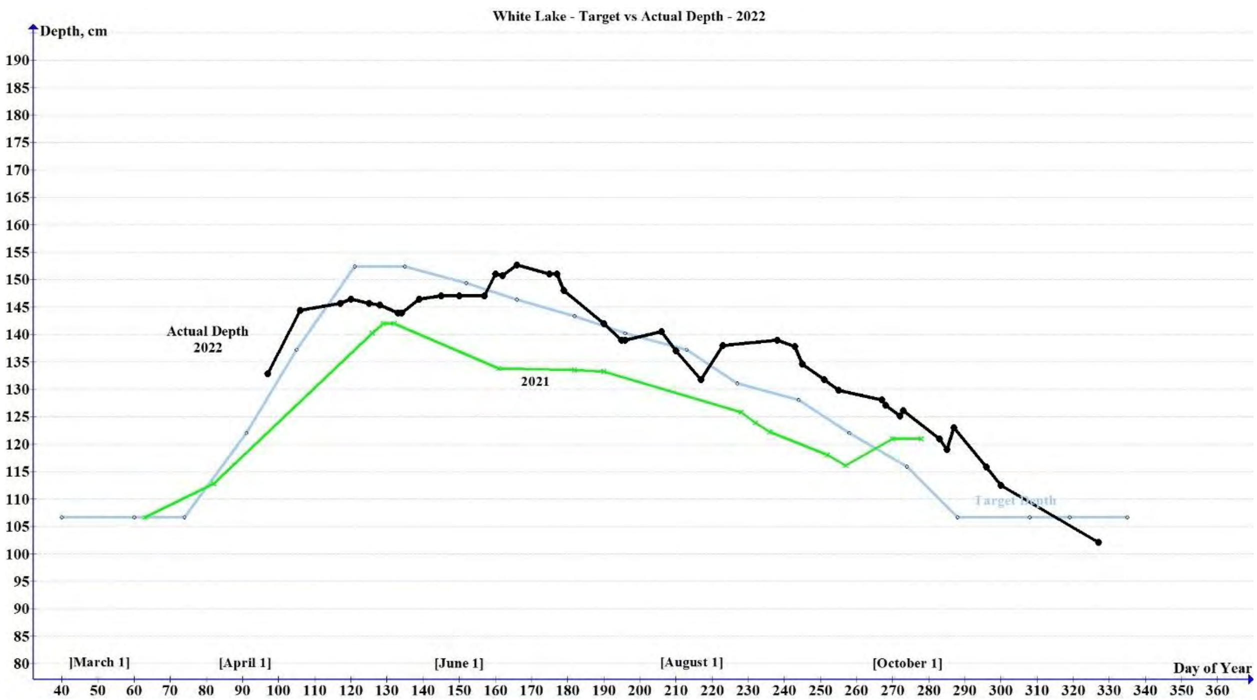
During dry years, such as 2016, the challenge is to balance

October 1	3.8	115.9
October 15 to December 31	3.5	106.7

water levels in the lake since a flow of .14 m^3/s must be maintained at the dam at all times to ensure a sufficient flow into Waba Creek.

In order to monitor water levels in White Lake, the authors took regular and frequent readings of water levels at the White Lake Dam using the gauge fixed to the dam structure.

The figure below shows actual depth measurements read at the dam. The heavy black line is for 2022 and the green line is for 2021 for comparison purposes. The blue line is for the target water levels set by the managers of the dam.



It is clear from the graph that for most of 2022 water levels were higher than those mandated by Madawaska River Management Plan. These high water levels were the result of a particularly wet year. Abundant rains during the summer provided a steady flow of water into the lake. Last year, in 2021, the opposite weather cycle was predominant with little water entering the lake resulting in low water levels.

PART III

Research Activities and Environment Bulletins

11.0 Zebra Mussels in White Lake - 2022

We have followed the story of zebra mussels since 2015, the year they successfully invaded White Lake. These uninvited intruders altered the ecological processes in White Lake to such a degree that the flow of nutrients and energy within the lake system were altered significantly. This is why zebra mussels are often labeled "environmental engineers".

However, in 2022 lake residents made anecdotal observations suggesting zebra mussels appeared to be on the decline in White Lake. Is there any evidence for such a decline?

Bulk Weight Samples

Each year since 2020 zebra mussels have been harvested from 4 square feet of a dock float (located on the North shore of Three Mile Bay) and the wet weight recorded. This annual harvest represents successful survivorship of new mussels from each year's spawning event. The data below shows this production of new mussels at time of harvest.

Zebra mussels harvested from a dock float		
Immersion Date dd/mm/year	# of Days Immersed	Wet Weight, grams
25 05 2020	120	478
13 05 2021	122	357
07 05 2022	122	26

Compared to 2020, we recorded a 90% decline in sample weight in 2022 for first year zebra mussels.

Step Sample Counts

A more complete data set tracks first-year survivorship using counts and measurements on zebra mussels settling on a boarding ladder located on the same location as the float described above. The data covers six years, from 2016 to 2022. No data is available for 2020.

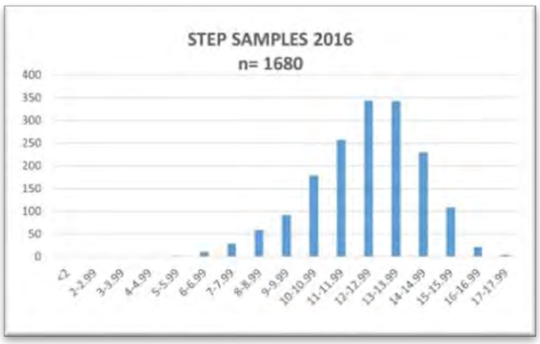
In 2022 a remarkable decline in the overall count of new mussels was recorded. This decline parallels the loss in the float sample weight as shown in the previous table.

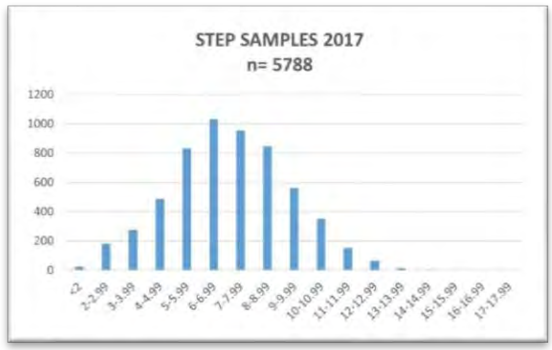
Size Frequency Distributions

We can break down bulk counts (above) into frequency data based on shell length. These graphs show size frequencies for first-year cohorts surviving at the end of each season for six years.

2016 and 2017

The initial invasion began in 2015 with few zebra mussels occasionally found on hard surfaces. A huge wave followed in 2016 that dramatically influenced water clarity and lake chemistry.



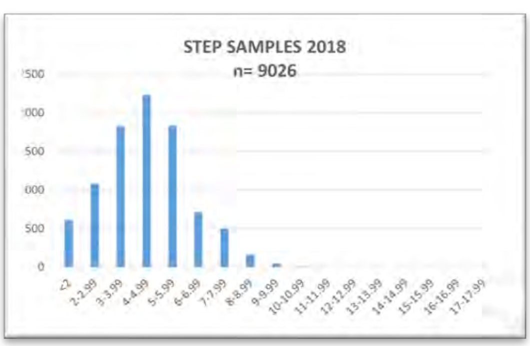


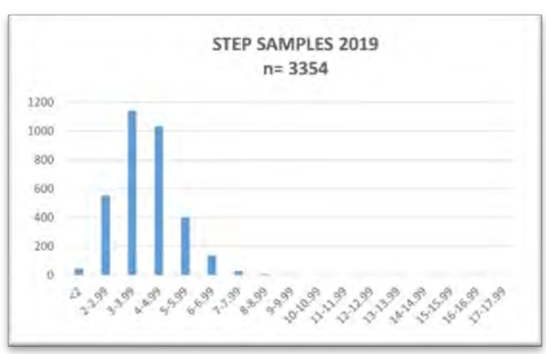
The skewed data for 2016 show most first-year zebra mussels achieved adult breeding sizes by the end of the season. This reflects a prolific spawning event coupled with a fast rate of growth which is expected for a pioneering invasion in pristine conditions.

By 2017 the size range had reached a more normal distribution with sub-adults under 6mm forming a major part of the sample. Mature zebra mussels established in the previous year likely reproduced a second or third time during a single season. The 2017 data indicates multiple spawning events have occurred during the summer as over 25% of the sample (1500 individuals) are below 6mm in shell length at the end of the season.

2018 and 2019

In 2018 we retrieved the largest number (9025) of zebra mussels to date. The majority of these were sub-adults below 6mm in shell length with new adults forming only 17% of the sample.





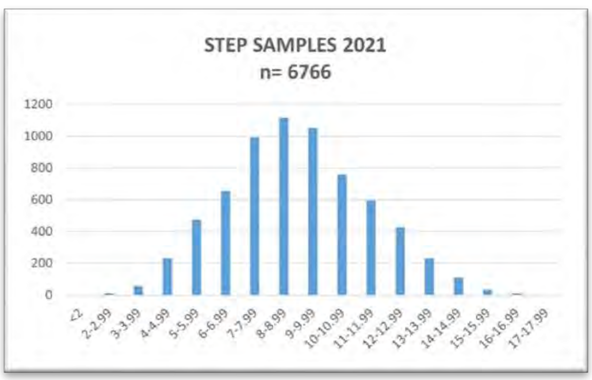
By 2019 size frequencies of zebra mussels had very few adults, only 4% of the sample achieved a reproductive size that year.

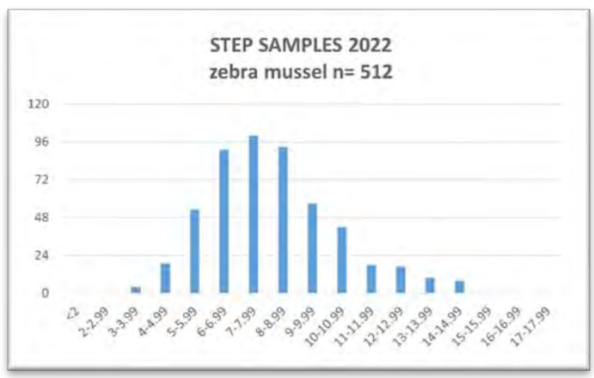
Corresponding with this was the massive die off of large-sized adults (30^{+}mm). Senescence of the pioneering adult population was evident in lake colonies where clusters of large empty shells were still attached to surfaces with their undecomposed byssal threads (fibres used by zebra mussels to attach to solid surfaces).

2021 and 2022

We were unable to provide step data in 2020, but by 2021 zebra mussel productivity returned to a size range and frequency distribution that exceeded the numbers and the size range we witnessed in 2017. Because of this, we anticipated that zebra mussels would do very well in 2022. However, to our surprise this was not the case.

Our 2022 data clearly shows that survivorship of first year zebra mussels was drastically reduced in total numbers (512),





If this reflects the population of zebra mussels in White Lake, then a drastic reduction in total breeding numbers may limit successful reproduction the year following as egg fertilization depends on density of timed spawning events. This could be mitigated by an increase in the number of spawning events as possibly more adults will be available to spawn at the beginning of the new breeding season in 2023 as compared to 2018 and 2019.

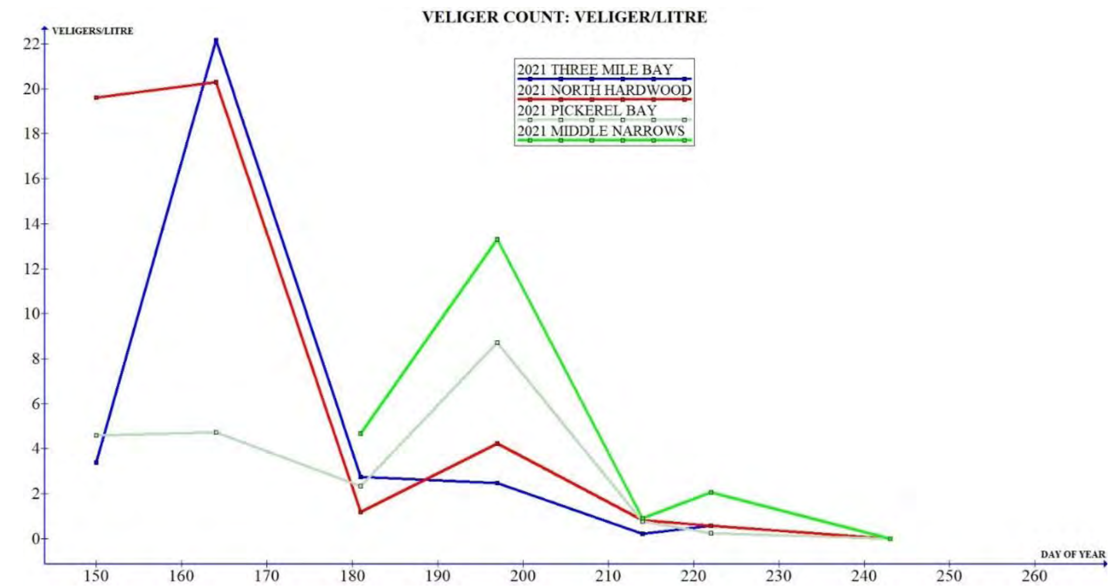
Comparing Veliger Occurrences: 2021-2022

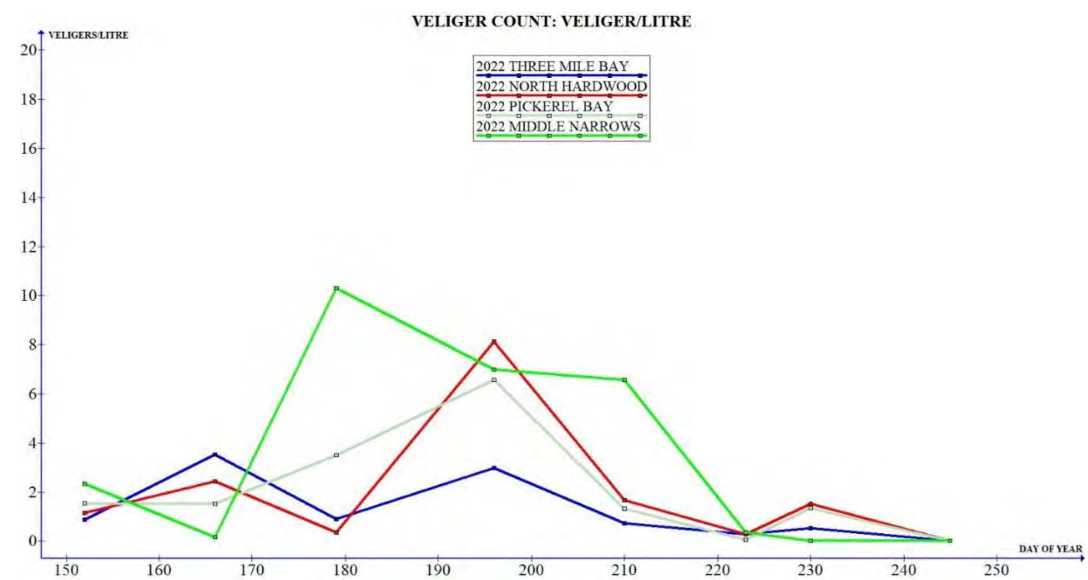
A third data set comprises a record of free-swimming mussel larvae called veligers collected over the last two years. These samples were taken at the same time and same locations as our Lake Partner water samples analyzed for phosphorus, etc. The two graphs below show counts of larvae and are recorded as <veligers per litre>.

There are two distinct spikes in larvae productivity suggesting two spawning events occurred in 2021. The smaller second spike could include left over residual eggs finally maturing from the initial spawned event. There was a strong correspondence of spawning events across all sites in 2021 that was not duplicated in 2022.

In 2022, Three Mile Bay and North Hardwood Island sample locations start the season with less than a quarter of the veliger count when compared to 2021. This initial spawning appears suppressed, with the major spawning event occurring 30 days later. This second spawn, around day 195 (mid July) is in agreement for both years.

The Deepest Pickerel Bay sample location exhibits the least variation in veliger numbers between the two years. This may reflect a dampening effect of a large reservoir that can draw on veligers from multiple shoals of zebra mussel colonies.





What Might We Expect in the Future?

The surviving first year zebra mussels from 2022 are adult sized and so they will likely contribute to an early spawning event in 2023. There will also be enough time for a second spawn depending on how many residual eggs females are carrying. The second spawning should fill out the size range of juveniles that was missing in the 2022 data. But whether the population will return to large numbers as in some previous years is not clear.

12.0 White Lake Loon Survey and Wildlife Observations

Brian Houle[9] with Conrad Grégoire and David Overholt

Since 2013, we have been providing loon counts on White Lake. Over the years, nesting pairs of loons have produced an average of 19 chicks per year up until 2020. In that year, an infestation of a specific black fly drove loons off of their nests and reproduction plummeted to only 5 chicks. The results were the same for 2021.

Loon on a Mission *Photo credit: Brian Houle*

[9] Brian Houle is a local wildlife photographer who enjoys observing wildlife and trying to capture behavioural moments to share a deeper appreciation for our fellow wildlife.

Instagram: thehuntingphotographer TikTok: wildlifebybrianhoule Vero: wildlifebybrianhoule

We are happy to report that the loon's fortunes have changed and populations have rebounded.

This year, the loon count took place over the entire summer. Adult pairs and their chicks were observed for a period of about three months. Not all of the lake was surveyed with the eastern part of the White Lake Village basin, the Canal area, parts of Hayes Bay and Sunset Bay omitted. Historically, these locations have hosted several nesting pairs with chicks. Thus, the numbers reported here for both nesting pairs and chicks are a minimum. Juvenile and adult loons which were not nesting were not counted.

In 2022, there were a total of 10 confirmed loon nests, each with two adults. These nests produced a total of 15 chicks with one perishing early in the summer. Typically, only about 50% of chicks survive to join their parents on the annual migration south.

These results are very encouraging and signal a turnaround for Common Loon populations on White Lake. White Lake is a very productive lake surrounded by wetlands. These factors make this lake an ideal habitat for loons.

The table below shows loon counts resulting from 9 years of observations.

Observation	2013	2015	2016	2017	2018	2019	2020	2021	2022
Adults	23	40	32	45	44	38	25	27	-
Nesting Pairs	7	10	11	19	10	12	2	5	10
Chicks	16	17	16	21	18	23	4	5	15

Other wildlife observations included:

- 9 osprey nests located around the lake. Each nest accommodated 2 chicks, although no formal count was made.
- 1 Bald eagle nest (2 in 2021) containing 2 chicks. Two additional eagles were observed.
- There were at least two families of otters located on White Lake

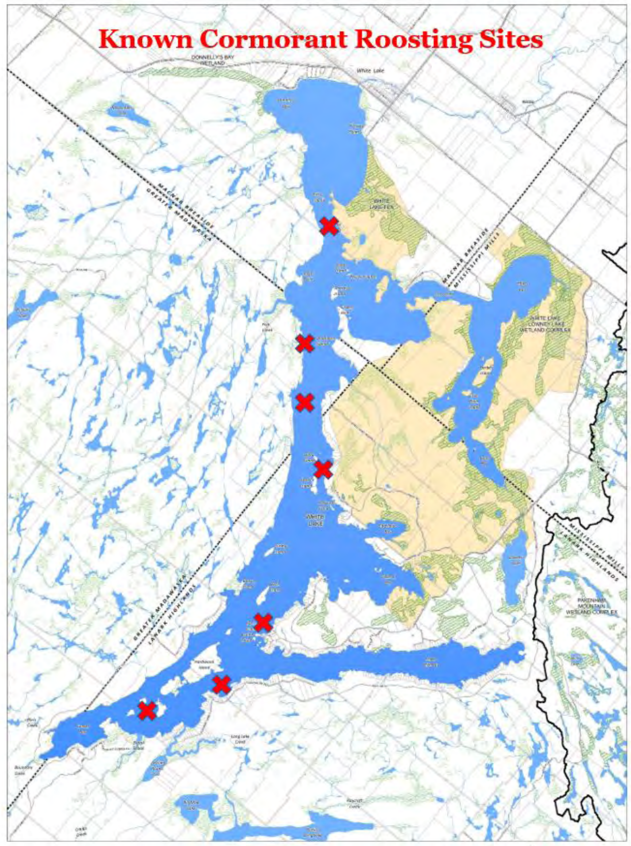
13.0 Double-Crested Cormorant Count

The double-crested cormorant (*Phalacrocorax auritus*) is a member of the cormorant family of seabirds. Its habitat is near rivers and lakes as well as in coastal areas, and is widely distributed across North America, from the Aleutian Islands in Alaska down to Florida and Mexico. They are a native species in Ontario including White Lake.

Measuring 70–90 cm (28–35 in) in length, it is an all-black bird which gains a small double crest of black and white feathers in breeding season. It has a bare patch of orange-yellow facial skin. Five subspecies are recognized. It mainly eats fish and catches its prey by swimming and diving. Its feathers, like those of all cormorants, are not waterproof and it must spend time drying them out after leaving the water. Once threatened by the use of DDT, the numbers of this bird have increased markedly in recent years.

When large numbers of cormorants congregate in a roosting or nesting area, their droppings can kill trees and other vegetation. They also compete for food with loons and other fish-feeding birds. For this reason, the cormorant has been vilified, even though exactly the same can be said of the Great Blue Heron, which also roost communally, and destroy patches of forest or even entire islands where their nests are located. The authors do not support the killing of cormorants because they are a natural species to White Lake and are not present in numbers warranting action.

In fact, the Ontario Federation of Anglers and Hunters (OFAH) web page on cormorants specifically says *“Populations of double-crested cormorants are increasing in number and distribution across Ontario’s shorelines. Where cormorant numbers are high,*



they can negatively affect terrestrial habitats by chemical and physical means through corrosive acidic guano, and stripping/breaking tree branches. In some cases, cormorant colonies have destroyed entire island ecosystems. Many people are also concerned about potential impacts on fish populations and angling opportunities."

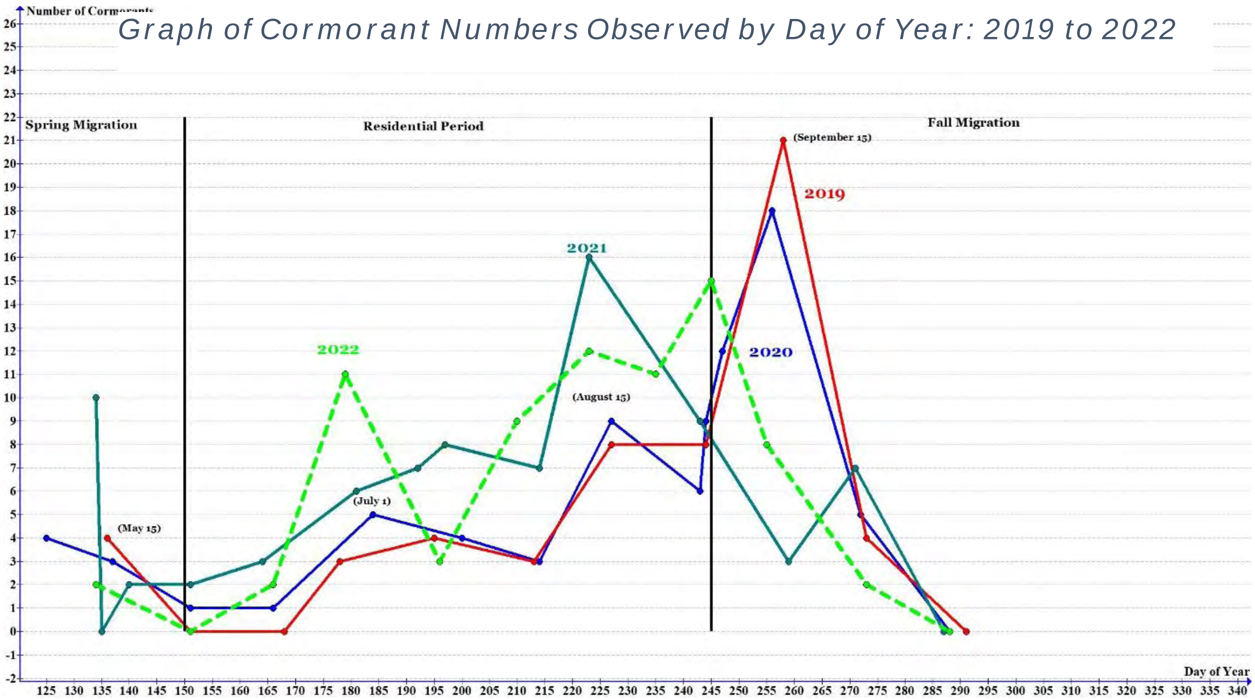
Nobody is calling for the extermination of cormorants, just control of populations 'where cormorant numbers are high'. The goal of our annual cormorant count is to establish baseline population numbers so that we can, in fact, determine when and by how much populations on White Lake are increasing.

Cormorants have been using White Lake for many years. However, their numbers have always remained small. In recent years, we have noticed that the White Lake population of cormorants may be increasing. Also, their roosting habits have changed and they now prefer sites in the southern part of the lake.

As part of our water quality monitoring program, we decided to start monitoring cormorant numbers on White Lake. Every two weeks we patrol the lake by boat and sample 9 sites in all parts of the lake. Water samples for total phosphorus and plankton counts are collected. Water temperature and clarity measurements are also taken.

During this two-hour period, we collect data on the location and numbers of cormorants. We check all of the roosting sites shown on the map to the right as well as any cormorants we spot in flight or fishing in open water. We do not know the location of the nesting sites at this time, but we know from the scientific literature that cormorants can nest kilometres away from the lake they use for food.

The number of cormorants observed for each date in the graph below can be taken as a minimum number of cormorants, since it is possible that birds in flight or feeding were missed. However, cormorants are communal birds and tend to aggregate in groups rather than be spread out over the entire lake. The graph below shows cormorant observations for four consecutive years.



The graph is divided into three sections marked by the two vertical black lines. During spring, as well as at the end of summer, larger numbers of cormorants are often observed. Most of these birds are migrating to other sites and only stop and linger at White Lake for a week or so.

Of greater interest are bird counts taken during the residential period. It is possible that the mid-July cormorant population numbers probably reflects the permanent resident adult population of cormorants on White Lake. This data suggests that there are about 10 to 12 cormorants making White Lake their home. This translates to a minimum of 5 to 6 nesting pairs producing less than 10 offspring, as reflected in the total cormorant count taken in mid-August.

It is clear from the above graph that cormorant numbers may be slowly increasing. We will continue with this initiative and monitor if this increase represents a trend or an isolated occurrence. In any case, the number of cormorants on White Lake remains small.

14.0 Selected Environment Bulletins – 2022

Environment bulletins are published on an approximately monthly interval. These bulletins are intended to inform the public of lake conditions or events as they are unfolding in White Lake. Bulletins are also issued to explain physical phenomena which apply to that lake and also to present historical perspectives on individual topics.

Not all of the Environment Bulletins published in 2021 are included here. Only those which have not appeared in some form in the annual water Quality Monitoring Reports. For a complete listing of all Bulletins, the reader is directed to the Bulletins Page on the White Lake Science and Information Website.

14.1 Glacial Erratics

"The Old Man of the Forest" *photo by David Overholt*

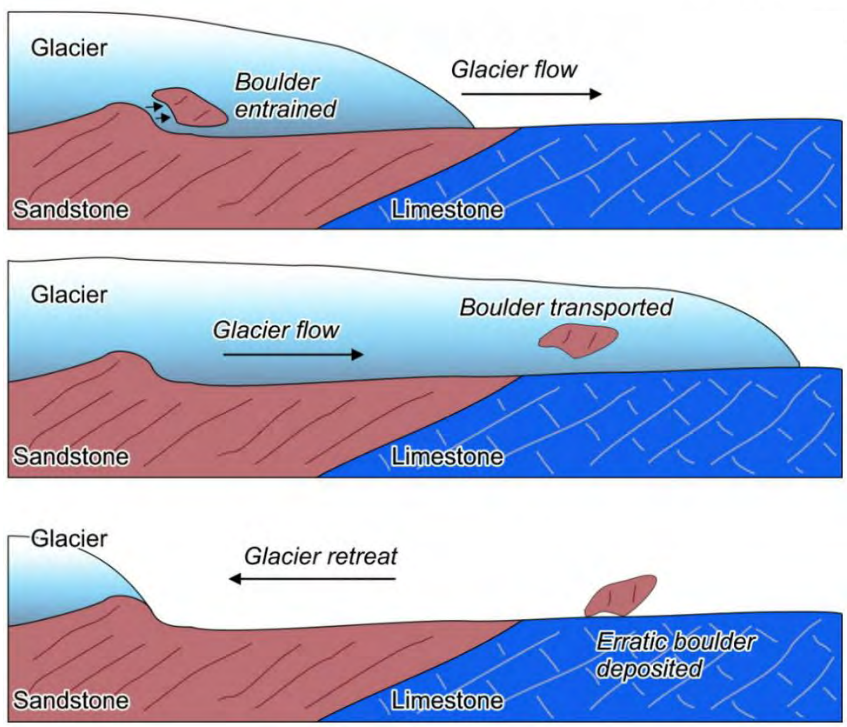
Strewn about the landscape around White Lake are large smooth boulders of varied size and shape. They somehow just don't seem to belong. What are they, where do they come from, and how did they get here?

Boulders, such as the one pictured above, were once considered evidence of a biblical flood. Over time, scientists began to understand that these boulders were connected to an ice age in the earth's past. Their very name, erratics, derives from the Latin word *errare* which means to wander.

Now we know that the erratics we see around us come from glaciers which covered the northern half of North America starting about 79 thousand years ago. At one time, the White Lake area was covered by a layer of ice two kilometres thick.

When glaciers melted away about 11,000 years ago, they left in their wake ample evidence that they were here in the form of gravel eskers and other glacial formations and glacial erratics. Glacial erratics can be very small to as large as a two-story house.

The diagram to the right shows how rocks are broken off by flowing glaciers and carried up to 2000 km from their original locations. As they travel, boulders are ground smooth by contact with other rocks or bedrock.



Erratics can also be carried on top of glaciers when rocks are broken off the sides of mountains by the glacier. These erratics are often more jagged and can also be odd-shaped.

Scientists use the composition of the erratics, their location, distribution, and other glacial markers to show the pathway and direction of flow of the glacier.

Although the start of the next ice age is not talked about very much at present, when it does end, the glacial erratics we are familiar with near White Lake will very likely be found in somebody else's back yard.

For more information on glacial erratics, please consult these references:
https://www.ontariobeneathourfeet.com/ice-age-glacial-erratic https://en.wikipedia.org/wiki/Glacial_erratic
http://fossilslanark.blogspot.com/2013/04/glacial-erratics-and-eskers-in-township.html

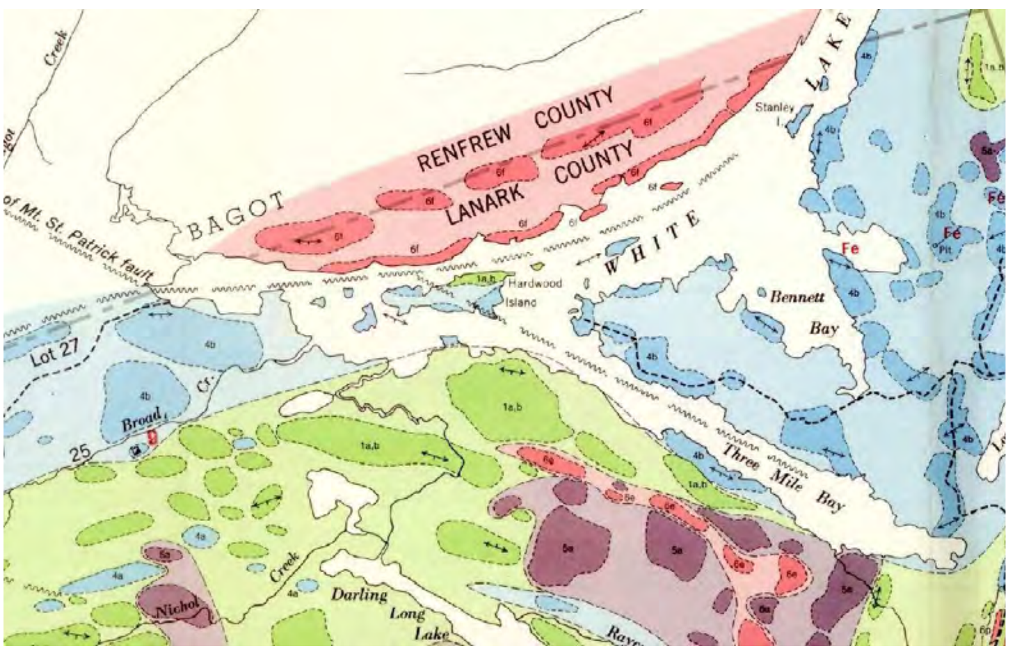
14.2 It's Our Fault!

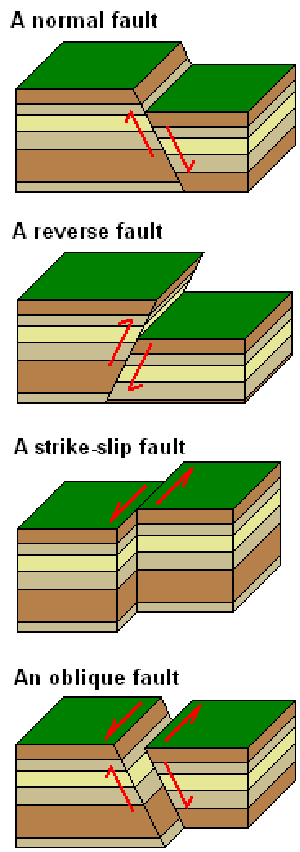
As we stroll out of our cottage or residence towards the lake, how often do we think about the very rocks beneath our feet? What are they? How old are they? How did they get there?

Although the story of Lanark Highlands starts about 4.5 billion years ago when the earth was formed, it's perhaps better to focus on the more recent geological events which led to the formation of what we see today.

Fast forward to a mere 150 million years ago. By then there was still a lot of geological activity in our region, and Ontario was being stretched and uplifted leading to the formation of the Ottawa Valley. At that time, many cracks formed in the earth's crust including some in the White Lake area.

The above map reveals the nature of the surface rocks under and around White Lake today. Geologists refer to these maps as surficial geology maps because they describe the types of rocks anyone can see by just taking a walk.





In this map, the pink and red show Precambrian rocks low in calcium and the blue shows rocks high in calcium. We know that the rocks under the lake are also high in calcium. This is what gives White Lake waters a very low acidity and high calcium concentrations. These conditions are perfect for zebra mussels looking for a home.

If you look closely at the map, you will notice a squiggly line running along the western side of White Lake and another squiggly line running down Three Mile Bay and across

Hardwood Island. These lines show the course of the Mount St. Patrick fault; our fault on White Lake!

A fault is nothing more than a very large crack in an otherwise solid piece of rock. When nature applies stresses on these cracks, several things can happen. Rock on either side of the crack can uplift or depress or, alternatively, both sides can get further apart.

During the last ice age, the sheer weight of the ice pushed the earth's crust down by about 400 meters. Since the ice sheet has disappeared, the crust is still slowly rebounding. The continent under our feet is rising while at the same time moving westwards at the rate of about 1 centimetre per year. As it moves, stresses are built up between rocks on either side of a fault and at some point, these stresses seek relief in the form of an earthquake.

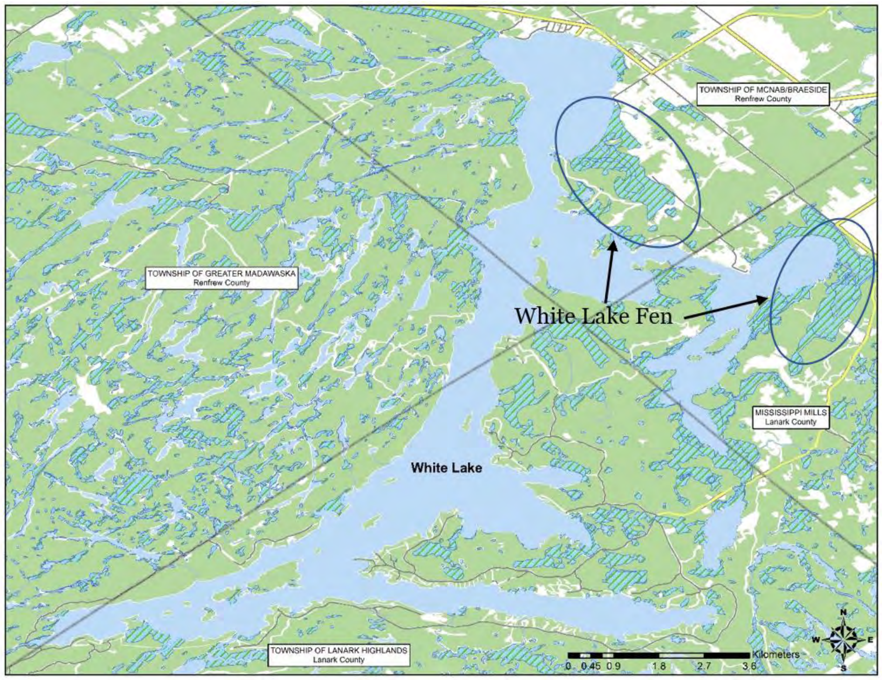
There is no evidence in the scientific literature to suggest that the fault running down Three Mile Bay has ever shifted, but it is entirely possible that it has widened (oblique fault) over the millennia. More likely though, a normal fault (see diagram above) occurred along the other fault line running north south, resulting in the cliffs we see especially on the west side of McLaughlin's and Hardwood Islands (right).

The geological faults running under White Lake may be responsible for the actual shape of the lake we see today.

We may think we are on solid ground, but at any moment Mother Nature may decide that your cottage lot belongs somewhere else.

14.3 White Lake Fen

The White Lake Fen is a special type of wetland which has been designated an Area of Natural and Scientific Interest and a Provincially Significant Wetland. The photo on the right shows the fen divided into two areas: one adjacent to the White Lake Village Basin and the other in Hayes Bay.



Fens are a relatively rare wetland habitat in Lanark and Renfrew Counties. Fens can occur on either marble or limestone bedrock. They are spring fed with waters which are high in minerals but relatively low in nutrients. Part of the White Lake Fen is floating over shallow waters.

The White Lake fen is home to rare plants including several orchids. These include the orchid Pogonia ophioglossoides (left).

Fen at water's edge

Bogbean in full bloom

The White Lake fen is also one of the few Canadian locations where the Bogbean Buckmoth can be found. This is a species of silk moth that feeds on a typical fen plant, Bogbean.

The Bogbean Buckmoth is a rare moth known to occur in North America in only New York State and in Ontario. In Ontario, it is classified as endangered by the Committee on the Status of Species at Risk in Ontario (COSSARO) due to its habitat specificity and extremely limited geographic range. It is currently found at two sites in southeast Ontario: the Richmond Fen Wetland, and the White Lake Fen Wetland Complex. The actual area occupied by the species in Ontario is less than 3 square kilometers and is thought to support approximately 3,000 Bogbean Buckmoths.

It is remarkable that despite the rarity of fens such as the White Lake Fen and the even greater rarity of its plant and insect life, that this area is not a protected wetland.

The endangered Bogbean Buckmoth and its caterpillar

14.4 Murder in the Marshes

INVASIVE PHRAGMITES: Pine Tree Corners 2018

There is an advancing column of an aggressive plant making its way along our roads. It has one objective: to take over our plentiful and diverse wetlands. This invader is well known to a group of White Lake residents who engaged it at Pine Tree Corners during the summers of 2017-2019. We know from that experience just how tenacious this invader can be. As a lake community we should take this plant very seriously. It is Canada's #1 invasive plant and it poses a foremost threat to all Ontario wetlands.

A common name for this plant is the European Common Reed (*Phragmites australis australis*). As indicated on the map below, this invasive plant has progressed beyond our roadsides. It can now be found on the shores of White Lake. There are seven known locations on Three Mile Bay and another cell near an ATV trail. If these cells are ignored they will eventually spread beyond our ability to control them.

LOCATIONS OF INVASIVE PHRAGMITES ON THREE MILE BAY

EDDMapS. 2022. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available online at http://www.eddmaps.org/; last accessed March 19, 2022.

WHY DOES IT MATTER?

Ecologists have a long list of reasons why invasive phragmites is a problem; here are some of them:

1. The reduction or elimination in the diversity of plants in wetlands.
   - *Native plants cannot defend themselves against chemicals released from phragmites rhizomes.*
   - *Lower plant diversity reduces the resilience of pollinators during times of drought.*

2. A reduction or elimination of animal habitat in wetlands.
   - *Species-at-risk such as Blandings Turtles are displaced from their habitat.*

3. The reduction in insect populations discourages birds and other insect eaters from living in the affected wetland.
   - *Swallows avoid wetlands dominated by phragmites as there is no food resource for them.*

4. The long term buildup of dead plant material results in permanently drying out wetlands.
   - *Dried out wetlands created by phragmites become a fire risk.*

5. Dense cells of invasive phragmites restrict access and the enjoyment of lakeside properties.
   - *The dead and living stalks of invasive phragmites can totally block out the view of the lake.*

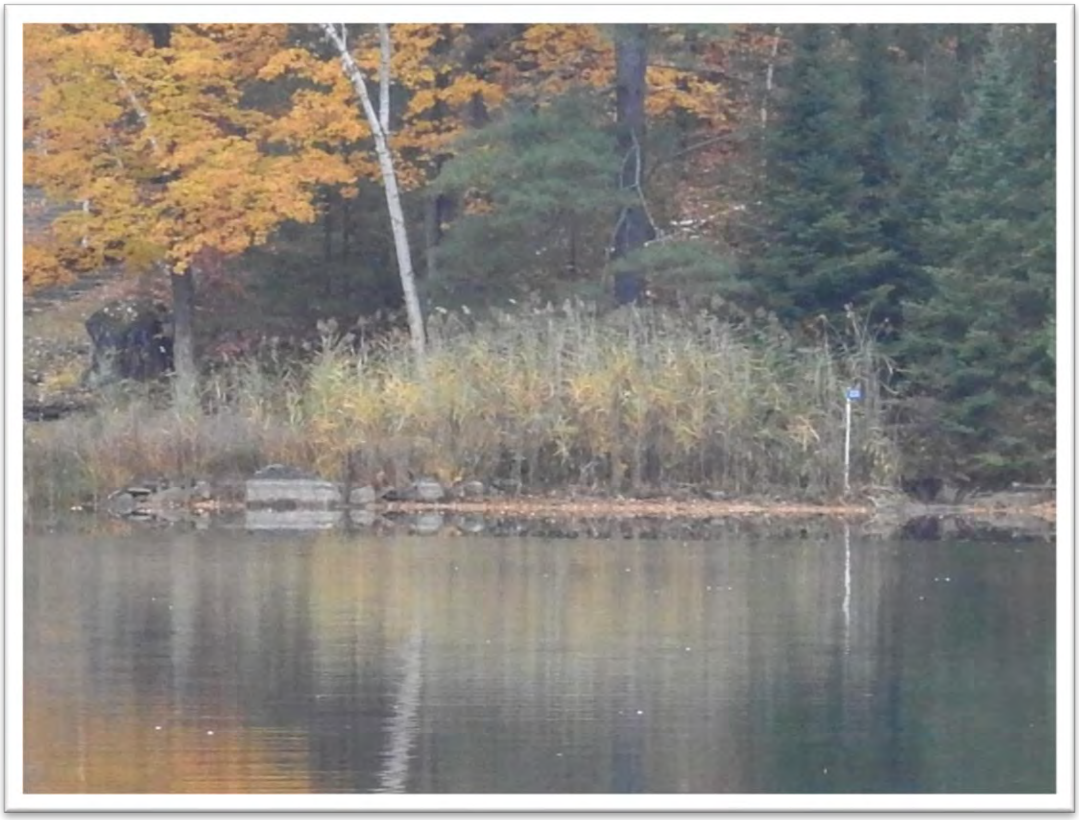
As property owners we can look for solutions to prevent this plant from spreading farther. More can be learned about phragmites at:

EDDMapS Ontario Species Distribution Maps
Phragmites - Ontario Invasive Plant Council (ontarioinvasiveplants.ca)
Ontario Phragmites Working Group (opwg.ca) Invasive Phragmites | Georgian Bay Forever

If you need help or advice, please contact us at whitelakescience@gmail.com or visit the White Lake Science and Information Website .

14.5 Invasive Phragmites; **One Cottager's Approach**

Bruce Waddell, Three Mile Bay, White Lake



Invasive Phragmites on our shoreline 2015

I realized I had an infestation of invasive phragmites on a portion of my shoreline only after our property owner's association talked about the issue at an Annual General Meeting four or five years ago. Until then I viewed these tall grasses with their feathery plumes of seed waving in the breeze as aesthetically appealing. When I learned this was an invasive species, my enjoyment of the tall fronds was curtailed and I started my quest for a practical, cottage-owner friendly way to manage the small infestation on my property.

Invasive Phragmites on our shoreline 2016

I have been asked to share with you my approach to managing invasive phragmites. My intent is to provide other cottage owners with a practical way to deal with small infestations on their properties. The strategy I have developed through trial and error is two-pronged ... first, manually harvest actively growing invasive phragmites to rob the plants of the opportunity to build up energy reserves (starve the plant) so native species can better compete; and, second, prevent the plants from reproducing (seeds or vegetative spread).

Where does one start? First you need to determine if you have invasive phragmites growing on your property by using this guide.

Timetable

As soon as plants have grown enough to be identified I start to cut off the invasive phragmites stalks, usually in late May. I keep an eye peeled for renewed growth and cut back discernable stalks of invasive phragmites, usually in July and in September.

Harvesting

The most effective overall method I have found to harvest phragmites selectively is to use bypass pruning shears to cut the plants growing onshore near ground level, carefully leaving other native species of plants undisturbed. In addition, where possible I pull plants in the water along the shoreline sometimes removing rhizomes as well as the stalk. This manual harvesting is hard on my knees and back, so I don't do it all at one time but spread it out over several days. As noted above I harvest three times during the growing season which has gradually reduced the size and density of the cell.

I wear protective clothing (long pants, boots, long-sleeved top and gloves) and apply insect repellent and work carefully so as not to disturb native plants some of which have cutting leaves and/or spines that can abrade or puncture your skin, even with protective clothing, or that can cause skin irritation (poison ivy). My wife kindly checks me for deer ticks after I change and clean-up after harvesting.

I am careful to ensure none of the harvested material falls into the water and floats away. Some literature talks about 'spading', cutting the rhizomes with a sharp spade. My shoreline is rocky so attempts at spading resulted in damage to my spade and sore joints for the 'spader' with minimal impact on the phragmites.

native plants at shoreline September 2019

Disposal

I have an area of exposed bedrock within 10 meters of the shoreline. I pile all harvested material on the bed rock and leave it undisturbed to decompose naturally. I have not observed any regrowth there or nearby.

I have not eliminated the invasive phragmites from our cottage shoreline but have significantly reduced them, allowing native plant species to flourish and I have prevented or at least limited the spread of invasive phragmites from our property to other areas of the lake. The picture above shows our shoreline without any visible invasive phragmites and with a healthy growth of native plants.

A forager among native plants May 2021

This picture of our shoreline clearly shows that white-tailed deer feed on these native plants. We have never seen them eating the invasive phragmites.

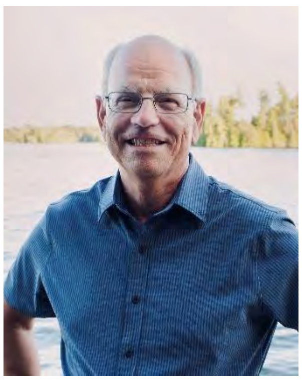
PART IV

Acknowledgements and Author Profiles

15.0 Acknowledgements

We are grateful to the Lake Partner Program of the Ontario Ministry of the Environment Conservation and Parks for providing us with sampling equipment and the analysis of water samples for total phosphorus, calcium, dissolved organic carbon, and chloride. Costs and time related to lake sampling and all other activities were self-funded by Dr. Conrad Grégoire and David Overholt.

16.0 Author Profiles



Conrad Grégoire holds a Ph.D. in Chemistry. He was the Head of the Analytical Chemistry Research Laboratories at the Geological Survey of Canada before retirement where he conducted research in analytical and environmental chemistry. He has authored over 200 scientific papers and other works published in international journals. He was also an Adjunct Professor of Graduate Studies at Carleton University and currently collaborates with Carleton University scientists on White Lake studies. For over 20 years he was a Senior Assessor at the Standards Council of Canada, certifying commercial and government labs for ISO (International Standards Organization) compliance. Conrad is interested in studying the chemistry and biology of White Lake and establishing base line values for water quality parameters. He is the Web Manager of the White Lake Science and Information website.

Dave Overholt is an avid citizen scientist and has, through his own study and research, become knowledgeable in a variety of areas, such as aquatic macrophytes and microorganisms and introduced species. He spends a great deal of time documenting species inhabiting the lake and following the population levels. He is involved in education about introduced species and has motivated and inspired lake residents to become involved in phragmites eradication programs.

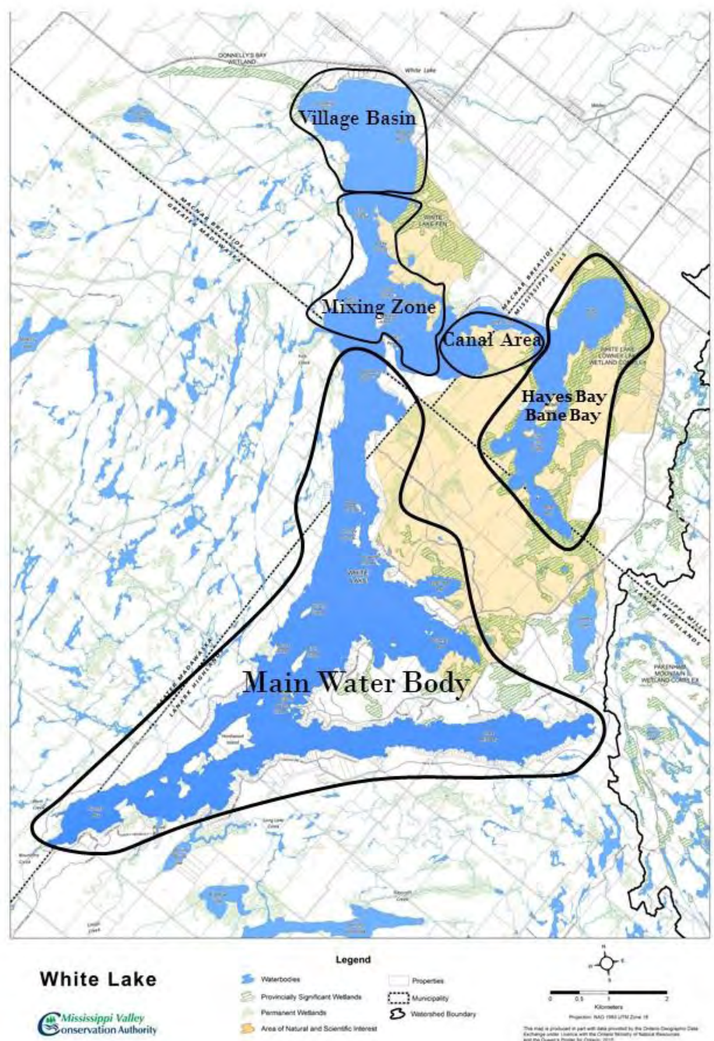
PART V
Appendices

Appendix 1: <u>White Lake Zone Map</u>

Based on our research, we have suggested that White Lake could be thought of as a collection of almost independent interconnected water bodies rather than a unitary lake.

There are a number of criteria which could be used to divide the lake into different zones based on population density, geology, shoreline coverage, etc. We believe that the different zones of the lake can best be described by their chemistry. While all zones have some characteristic in common, there are enough differences between each zone (shown on the map at right) to justify its classification.

As a result of new chemical data, we collected during the past year, we are making some minor changes to the zone map proposed in our 2016 Report. New specific conductivity measurements in addition to temperature measurements in Bane Bay indicate that this water body should be considered as part of the Hayes Bay Zone.



The *Main Water Body (Zone 1)* is the part of White Lake which takes in virtually all of the water with a depth greater than four metres. This zone contains Sunset Bay, Three Mile Bay, Pickerel Bay and surrounding areas. This zone existed as a lake before any dam was constructed which raised the level of the lake by about 1.5 metres. Here one finds very deep layers of sediments (up to 6 metres) and very similar water chemistry. The temperature regime, the pH, conductivity, oxygen content, alkalinity and Secchi depths are very nearly the same everywhere. Although the total phosphorus concentrations differ somewhat (with higher levels further South on the lake), the change in phosphorus concentrations over the summer months follows the same pattern with maximum concentrations reached in mid-July.

Hayes Bay/Bane Bay (Zone 2) is a relatively isolated part of the lake and is only 1.6 m in depth at high water in the spring. It is characterized by black gelatinous sediments and is nearly free of aquatic plants in the central basin. The waters there have a slightly higher pH than the rest of the lake and also higher conductivity. The concentration of salt is higher by a factor of three compared to the rest of the lake probably from saline ground water entering through the sediment layer. Because of its dark sediments and shallow depth, this part of the lake heats up the fastest and to the highest temperatures if there had not been a recent rain event. The concentration 0f total phosphorus is lower here than in the rest of the lake, but slightly higher than concentrations in The Canal area. The waters from Hayes and Bane Bays flow into The Canal Area.

The Canal *Area (Zone 3)* on White Lake is characterized by white marl sediments and a depth of 2.4 metres. For both 2015 and 2016, the lowest concentrations of total phosphorus are found here with levels less than half of those found in the Main Water Body. Our temperature data indicates that in this zone, large quantities of subterranean ground waters are infiltrating into the lake and also leaving the lake relatively more quickly than waters from Hayes Bay or the Main Water Body. This is especially evident immediately after a significant rain event. There are no aquatic plants on the lake bed. These waters have a slightly higher salt content than the rest of the lake due to the mixing of waters originating from Hayes Bay. Note that The Canal Area could be described as a marl area. This could impede the growth of phytoplankton and aquatic plants and exhibit lower phosphorus concentrations due to the coprecipitation of calcium and phosphorus.

The *Village Basin (Zone 4)* zone is characterized by white marl sediments and an almost uniform depth of 1.65 m at high water. The floor of the lake is largely free of aquatic plants save some bulrush and patches of wild rice. Total Phosphorus levels are about 30% lower than found in the Main Water Body. The water sampled here is representative of the water which is leaving White Lake over the dam and into the creek. Temperature data from this area also shows, as in the case of The Canal and Hayes Bay that there is significant ingress of subterranean ground waters mixing in with lake water.

Hayes Bay, The Canal and the Village Basin have several things in common. Prior to the building of the dam, these areas existed as open water only during the spring freshet and then quickly turned into marshes or wetlands with water depths of perhaps half a metre or less. Another commonality is the lack of aquatic plants in these areas. It could be that since each of these areas is partially flushed by ground water ingress that plants do not have a chance to take hold. Certainly, the white marl of The Canal and the Village Basin would provide a poor source of nutrients to plant root systems. For Hayes Bay, the sediment there is organic but made up of a very fine particulate not offering much of a foothold for aquatic plants. For all three areas, the effect of wind and waves would also contribute to low plant growth.

The *Mixing Zone (Zone 5)* encompasses both sides of the narrows including Rocky Island and extends some distance towards the Village Basin. This area is characterized by shallow dark sediments and ranges from 2.5 m to 4 m in depth at high water. In this area, the lake floor is covered with dense mats of aquatic plants. The temperature of the water in this area is intermediate between the waters coming from The Canal and the Main Water Body. The simple reason for this is that this is where waters from both of these zones mix to give water with special characteristics relative to other parts of the lake. Generally speaking, the water in the Mixing Zone is clearer than would be observed in other parts of the lake for a given total phosphorus concentration. Water leaving this area and entering the Village Basin has lost a significant fraction of its phosphorus content to sedimentation and aquatic plants.

Waters originating from the upper four zones have no opportunity to mix with the much deeper waters of the Main Water Basin which contains by far the greatest share of the volume of White Lake. It could be argued that the most vulnerable part of White Lake is Hayes Bay because there is little opportunity for any nutrients entering this bay to be flushed out at a reasonable rate. With the exception of Three Mile Bay whose waters have access to the remainder of the deeper Main Water Body, the shallow areas at the top of the lake contain the densest populated areas with the likely greatest human impact on lake waters.

Appendix 2: Chemical and Physical Data – 2022

Three Mile Bay N. 45º 15.767'; W. 076º 32.521 Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	9:05	134	5.4	17.8	9.0,9.4 (9.2)	31.2	3.9
May 31	8.58	151	5.5	20.8	-		
June 15	8:51	166	3.7	20.7	15.3,14.9 (15.1)	28.8	3.7
June 28	9:13	179	3.9	21.5	-		
July 15	9:07	196	4.0	23.2	12.2,10.4 (11.3)	29.6	3.7
July 29	9:00	210	3.9	23.8	-		
August 11	9:04	223	3.6	23.3	11.2,12.1 (11.7)	26.3	3.8
September 2	9:00	245	4.5	21.9	-		
September 12	9:04	255	4.4	21.9	11.0,11.9 (11.5)	28.4	4.0
September 30	9:21	273	4.9	15.8	-		
October 15	9:00	288	>depth	13.2	9.3,9.7 (9.5)	27.5	4.0

North Hardwood Island N. 45º 16.162'; W. 076º 33.203' Depth: 5.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	9:17	134	5.3	17.0	8.6,8.7 (8.7)	32.0	3.8
May 31	9:15	151	5.4	20.0	-		
June 15	9:02	166	3.6	20.7	13.2,13.4 (13.3)	28.7	3.7
June 28	9:23	179	4.0	21.5	-		
July 15	9:21	196	3.8	23.3	11.8,~~14.0~~ (11.8)	30.0	3.7
July 29	9:12	210	4.1	23.8	-		
August 11	9:18	223	3.5	23.3	13.3,13.3 (13.3)	28.0	3.7
September 2	9:12	245	4.1	22.0	-		
September 12	9:22	255	4.0	21.9	10.6,10.8 (10.7)	28.5	3.7
September 30	9:40	273	>depth	15.8	-		
October 15	9:09	288	>depth	13.3	9.5,9.3 (9.4)	26.6	4.0

Deepest Pickerel Bay N. 45º 16.81'; W. 076º 31.63 Depth: 9.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	9:43	134	5.4	18.2	-	-	-
May 31	9:42	151	5.3	20.0	-	-	-
June 15	9:20	166	4.3	20.5	-	-	-
June 28	9:40	179	5.4	22.0	-	-	-
July 15	9:40	196	4.2	22.8	-	-	-
July 29	9:25	210	3.7	23.8	-	-	-
August 11	9:37	223	3.4	23.8	-	-	-
September 2	9:28	245	4.1	22.2	-	-	-
September 12	9:35	255	4.8	20.0	-	-	-
September 30	10:17	273	5.4	16.2	-	-	-
October 15	9:20	288	6.5	13.8	-	-	-

Pickerel Bay N. 45º 16.33'; W. 076º 31.03 Depth: 7.5 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	9:58	134	5.2	18.2	-	-	-
May 31	9:56	151	5.8	20.8	-	-	-
June 15	9:32	166	4.4	20.7	-	-	-
June 28	9:53	179	5.4	22.0	-	-	-
July 15	9:53	196	4.5	23.0	-	-	-
July 29	9:35	210	3.7	24.0	-	-	-
August 11	9:40	223	3.6	23.9	-	-	-
September 2	9:37	245	4.1	22.1	-	-	-
September 12	9:47	255	4.9	20.0	-	-	-
September 30	10:40	273	5.8	16.3	-	-	-
October 15	9:32	288	6.5	13.8	-	-	-

Middle Narrows N. 45º 18.548'; W. 076º 31.271' Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	10:16	134	4.9	18.8	7.5,7.0 (7.3)	31.3	3.8
May 31	10:14	151	5.8	20.2	-		
June 15	9:45	166	4.6	20.2	13.3,13.4 (13.4)	30.8	3.7
June 28	10:07	179	5.0	23.0	-		
July 15	10:04	196	5.3	23.0	10.0,9.0 (9.5)	29.5	3.8
July 29	9:52	210	5.1	24.2	-		
August 11	10:00	223	3.7	23.8	12.6,12.5 (12.6)	28.2	3.9
September 2	9:57	245	4.3	22.2	-		
September 12	10:00	255	4.3	22.0	10.6,10.0 (10.3)	28.2	3.8
September 30	10:56	273	5.3	16.2	-		
October 15	9:46	288	>depth	13.5	8.2,8.3 (8.3)	27.6	4.4

The Canal N. 45º 19.267'; W. 076º 30.013' Depth: 2.4 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	10:34	134	>depth	20.8	9.0,8.0 (8.5)	28.8	5.1
May 31	10:31	151	>depth	22.3	-		
June 15	10:00	166	>depth	21.5	9.7,10.2 (10.0)	29.6	4.6
June 28	10:31	179	>depth	23.3	-		
July 15	10:20	196	>depth	23.9	7.6,8.1 (7.9)	27.9	5.7
July 29	10:16	210	>depth	23.2	-		
August 11	10:23	223	>depth	23.0	10.4,8.7 (9.6)	26.2	5.6
September 2	10:18	245	>depth	20.0	-		
September 12	10:18	255	>depth	22.2	7.5,7.6 (7.6)	28.3	6.6
September 30	11:18	273	>depth	14.0	-		
October 15	10:05	288	>depth	12.3	7.2,7.5 (7.4)	31.4	6.4

Temperatures taken 1 m from bottom.

Hayes Bay N. 45º 19.037'; W. 076º 28.424' Depth: 1.6 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	10:45	134	>depth	22.3	7.8,8.0 (7.9)	33.5	10.0
May 31	10:42	151	>depth	23.2	-		
June 15	10:09	166	>depth	21.8	9.1,9.4 (9.3)	33.3	9.6
June 28	10:43	179	>depth	23.3	-		
July 15	10:29	196	>depth	23.8	8.3,8.3 (8.3)	38.0	10.5
July 29	10:26	210	>depth	23.0	-		
August 11	10:32	223	>depth	23.2	8.6,8.5 (8.6)	35.0	10.4
September 2	10:27	245	>depth	20.2	-		
September 12	10:24	255	>depth	22.1	6.6,7.3 (7.0)	36.0	10.5
September 30	11:32	273	>depth	14.1	-		
October 15	10:13	288	>depth	11.8	6.0,6.6 (6.3)	34.7	11.4

Temperatures taken 1 m from bottom.

Jacob's Island N. 45º 19.989; W. 076º 30.622' Depth: 4.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	11:00	134	>depth	20.0	8.0,7.4 (7.7)	31.2	4.4
May 31	11:23	151	>depth	21.2	-		
June 15	10:39	166	>depth	20.2	11.9,12.5 (12.2)	29.9	3.8
June 28	10:58	179	>depth	23.8	-		
July 15	10:40	196	>depth	22.9	9.4,9.6 (9.5)	27.8	4.0
July 29	10:39	210	>depth	24.3	-		
August 11	10:39	223	>depth	24.0	10.5,10.8 (10.7)	27.5	4.1
September 2	10:40	245	>depth	22.0	-		
September 12	10:35	255	>depth	22.8	9.7,9.6 (9.7)	26.0	4.3
September 30	11:48	273	>depth	15.8	-		
October 15	10:26	288	>depth	13.0	10.0,9.5 (9.8)	28.5	4.6

Village Basin N. 45º 21.233'; W. 076º 30.303' Depth: 1.65 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 14	11:23	134	>depth	22.0	8.0,8.1 (8.1)	28.1	3.9
May 31	11:39	151	>depth	23.1	-		
June 15	11:00	166	>depth	21.2	8.5,8.5 (8.5)	27.2	3.9
June 28	11:12	179	>depth	23.0	-		
July 15	10:55	196	>depth	23.5	8.7,8.3 (8.5)	29.1	4.1
July 29	11:12	210	>depth	23.2	-		
August 11	10:58	223	>depth	22.8	9.8,8.9 (9.4)	27.5	4.2
September 2	10:54	245	>depth	19.8	-		
September 12	10:54	255	>depth	22.0	9.3,8.3 (8.8)	27.6	4.3
September 30	12:30	273	>depth	14.3	-		
October 15	10:35	288	>depth	11.9	8.3,8.2 (8.3)	26.8	4.4

Temperatures taken 1 m from bottom. B= bottom temperature

Weather Conditions 2022

Date	Day of Year	Weather Conditions
May 14	134	Air temp: 19 to 23C; Full sun; No wind. No rain fell for 10 days before sampling; dry conditions.
May 31	151	Air temp: 21 to 24C; Full sun; no wind; 8 mm rain 4 days prior to lake sampling.
June 15	166	Air temp.: 20 -23C; Cloudy to light overcast; 12 mm rain 3 days before sampling; wind 5 km/h.
June 28	179	Air temp: 18-20C; Bright sunshine, clear skies; No rain previous 4 days; No wind. Depth 148 vs 143.3 planned – 4.7 cm high.
July 15	196	Air temp: 20 – 22C; Bright sunshine, clear skies; 8 mm rain 3 days prior to sampling; no wind. Depth 139 cm; Planned 140.4 cm.
July 29	210	Air Temp: 19 – 22C; Bright sunshine, clear skies; no rain previous 3 days prior to sampling; wind 15-20 km/hr; Depth 137 cm vs 137 cm planned.
August 11	223	Air temp: 22-25C; Overcast with sunny breaks; 81 mm of rain two days before sampling, lake rose 6 cm.; wind 15 to 20 km/hr
September 2	245	Air temp:13 – 15C; Partially overcast with many sunny periods; Wind: 0 to 5 km/hr.; 10 mm rain 2 days before sampling.
September 12	255	Air temp.: 21-24C; Clear sunny day; wind: 0 km/hr.; No rain for previous 5 days.
September 30	273	Air temp: 8-12C; Clear sunny day; no wind; no rain for previous five days.
October 15	288	Air temp: 5010C; Sunny with some clouds; wind 5-10 km/hr; 5 mm rain three days before sampling.

Notes:

1. Temperatures were taken at Secchi Depth. When sampling site depth was less than Secchi depth, temperatures were taken 1 M from bottom.

2. Water samples for total phosphorous were taken at Secchi Depth or when sampling site depth was less than Secchi depth, samples were taken 1 M from bottom.

3. All water samples were filtered through 80-micron filter prior to determination of total phosphorous.

4. Sampling dates were ideally the first of the month for temperature and Secchi depth and the 15th of the month for Secchi depth, temperature and total phosphorus. Some adjustments in timing had to be done to accommodate inclement weather and availability of personnel.

5. Total phosphorous water samples were not taken at the Pickerel Bay or Deepest Pickerel Bay locations as these locations were not part of the Lake Partner Program for.