WHITE LAKE PROPERTY OWNERS ASSOCIATION ENVIRONMENT VOLUNTEERS

REPORT

Water Quality Monitoring Program and Research Activities: 2023

Conrad Grégoire, PhD and David Overholt, BA

White Lake at Peace; May 5, 2023 - C. Grégoire

Water Quality Monitoring Program And Research Activities 2023

TABLE OF CONTENTS

PART IV – Acknowledgements and Author Profiles

PART V– Appendices

PART I
Water Quality Monitoring Program

WHITE LAKE PROPERTY OWNERS ASSOCIATION ENVIRONMENT VOLUNTEERS

2023 Water Quality Monitoring Program and Research Activities

Summary and Highlights

Conrad Grégoire PhD and David Overholt BA

1.1 Introduction

2023 marked the 10th 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 2023. For a complete referenced account of our work, we ask that you access the White Lake Science 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 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 - 2023

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.

There were three blue-green algal blooms starting in early September. The first bloom was reported to the Ministry of the Environment and sampling did not turn up any toxins, at least in the single sample recovered. The remaining blooms were not sampled because the MNR does not have the resources available. They do caution that every blue-green algal bloom should be treated as potentially toxic since toxins can be released at different times and at different locations around the lake.

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 (ppb), which is below the Provincial Objective of 20 ppb. 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. (see p. 49, this report.)

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. On average, water clarity for 2023 was the same as for 2022.

Temperature

At the beginning of the summer, water temperatures were in the higher range when compared to previous years, in the lower range in mid-summer and higher after that when compared to 10 years of accumulated data.

Water Levels

With the exception of early spring, water levels followed planned levels according to the Ministry of Natural Resources and Forestry. In the spring, large mats of cattail marsh were carelessly released into the lake as part of a private shoreline project near the dam blocking the dam spillways and causing the lake to rise 30 cm above the highest level planned. Some damage was reported on the lake and Ministry crews had to use heavy equipment to clear the dam and remove chunks of cattail marsh from the creek bed.

1.5 Loon and Cormorant Counts

In 2023, there were a total of 19 confirmed loon nests, each with two adults. These nests produced a total of 22 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 five years, we have been observing the number of double-crested cormorants using White Lake. So far, our observations indicate that the population is growing at about 1.3 individuals per year. Our data indicate that there are from 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 ten 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 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.

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.

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

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.

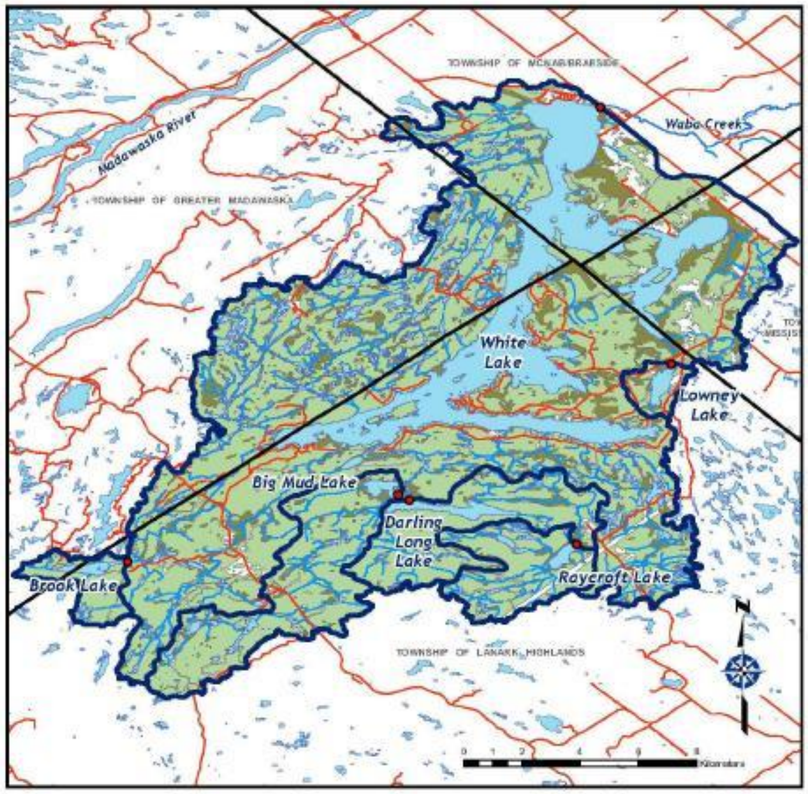
White Lake Science Booth, Herbfest, Waba Cottage Museum and Gardens, August, 2023

Part II

Water Quality Parameters

2.0 2023 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 such as granite, whereas the remainder of the shoreline and the rocks under the lake are mainly calcium rich in nature (alkaline). It is the calcium rich rocks that give the lake its chemical signature with a high pH and high calcium content. Both of these factors strongly favour the growth of algae and 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 largely deforested landscape including some farms nearby.

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 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. Since 2021 zebra mussel populations have rebounded. We know that zebra mussel numbers will fluctuate from year to year, however, our water clarity and total phosphorus measurements indicate that the total biomass (weight of all zebra mussels in the lake) changes only marginally.

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.

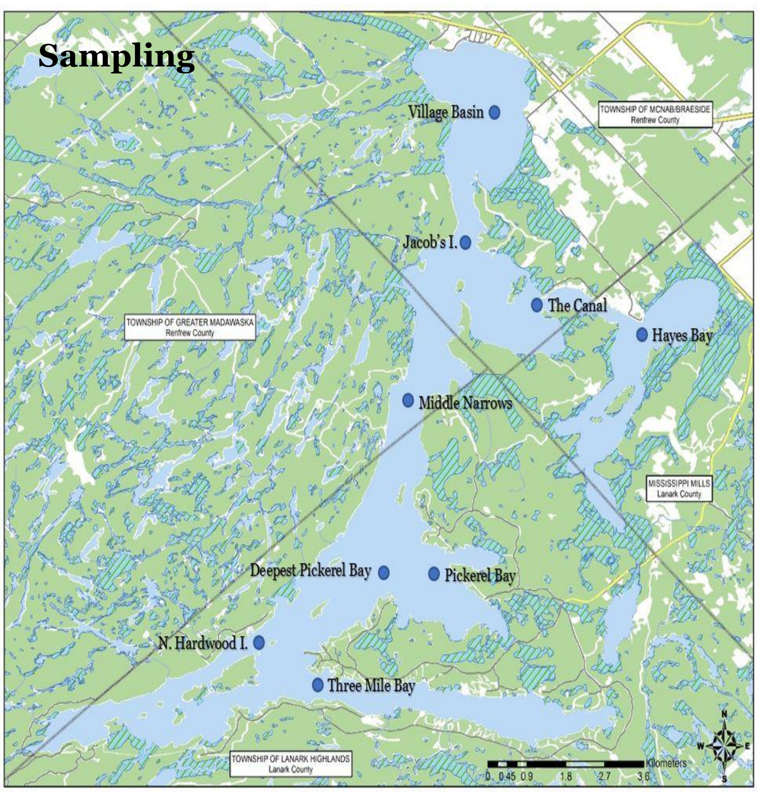
We should also become organized as a society to pro-actively work to prevent the infestation of White Lake with other invasive species some of which have effects far worse than zebra mussels. They are just around the corner. We should also be pro-active in preventing the spread of zebra mussels from 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 2023 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 – 2023

During 2023 four 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 this year covered the deeper 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"*[3,4]

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, especially were zebra mussels reside.

In 2023, the filamentous green algal bloom was less extensive than in previous years with fewer occurrences. However, there was an increase in this alga which accompanied one of the Blue-Green algal blooms (September 5 to 10, 2023).

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

[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.

[4] Cyanobacterial blooms in Ontario, Canada: continued increase in reports through the 21st century; Elizabeth J. Favot, Claire Holeton, Anna M., DeSellas & Andrew M. Paterson; Lake and Reservoir Management, 39:1, 1-20, DOL: 10.1080/10402381.2022.2157781.

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.

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. Three such algal blooms were recorded in 2023 starting on September 5.

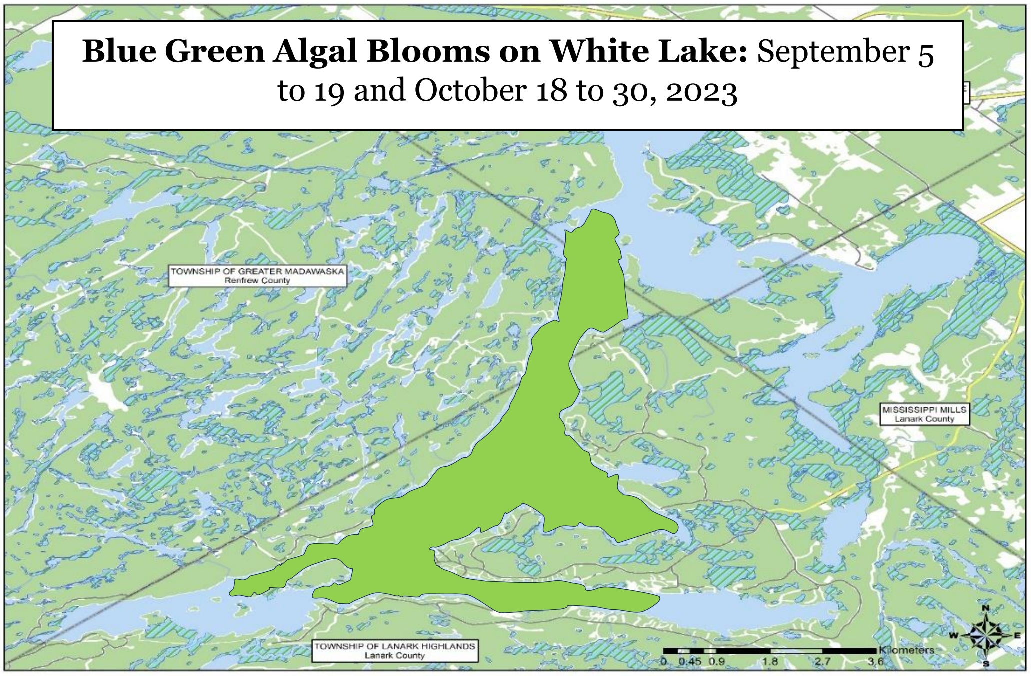
September 5 to 19, 2023 and October 18 to 30, 2023

In 2023, White Lake hosted three blue-green algal blooms. The first occurred on September 5 to 19; the second from September 30 to October 10; and the third from October 18 to 30.

The bloom affected areas from the southern end of Hardwood Island all the way up to the narrows including Three Mike and Pickerel Bays. Some surface scum derived from this bloom was visible in some of these areas. In all of these areas, significant concentrations of the anabaena blue-green algae were seen in the water column and later confirmed using a microscope.

The September 15 and October 18 blue-green algal blooms are discussed together because they had the same range of occurrence on White Lake. This is illustrated on the map below. The only difference between the two algal blooms is that the September bloom consisted mainly of anabaena blue-green algae whereas the October 18 bloom included significant concentrations of microcyctis alga.

The photo below shows the appearance of the blue-green algal bloom along part of the shoreline of White Lake.



The Ministry of the Environment Conservation and Parks was notified and a staff scientist took a number of water samples for analysis for toxins. The results, shown below, indicate that the level of toxins was at or below the level of detection for the analytical method used. This result indicates that dangerous toxins had not developed in this algal bloom at time of sampling. However, one must keep in mind that there is a possibility that toxins were produced at a later date or even at another location on the same date.

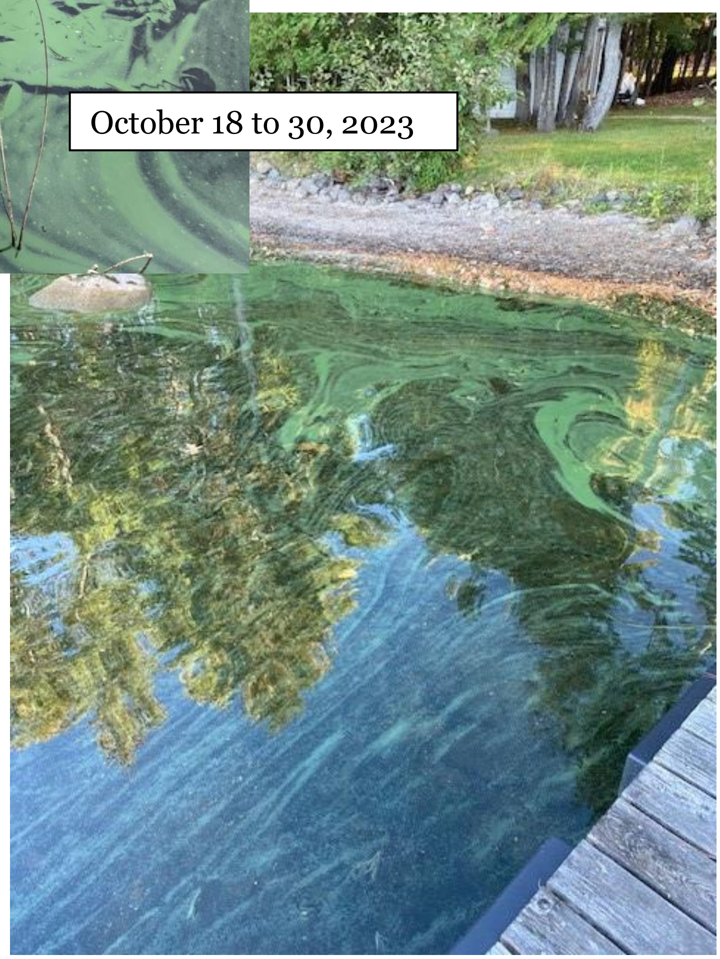
Analytical Results

Lab ID: 12257001 **Date Collected:** 9/5/2023 3:59:00 PM
Field ID: 1-3T6PF4 **Matrix:** Water

Parameter	Result	Units	RDL	Rmk	Analyzed
E3469					
Total Microcystins	<0.10	µg/L	0.10		09/08/2023
E3568					
Anatoxin-A	<0 20	µg/L	0 20		09/08/2023
ORGANIC CHEMISTRY					
E3450					
3-Desmethyl-microcystin-LR	<0 050	µg/L	0 050		09/07/2023
3-Desmethyl-microcystin-RR	<0 050	µg/L	0 050		09/07/2023
Anatoxin-a	<0 050	µg/L	0 050		09/07/2023
Microcys in-HilR	<0 050	µg/L	0 050		09/07/2023
Microcys in-HtYR	<0 050	µg/L	0 050		09/07/2023
Microcys in-LA	<0 050	µg/L	0 050		09/07/2023
Microcys in-LF	<0 050	µg/L	0 050		09/07/2023
Microcys in-LR	<0 050	µg/L	0 050		09/07/2023
Microcys in-LW	<0 050	µg/L	0 050		09/07/2023
Microcys in-LY	<0 050	µg/L	0 050		09/07/2023
Microcys in-RR	<0 050	µg/L	0 050		09/07/2023
Microcys in-WR	<0 050	µg/L	0 050		09/07/2023
Microcys in-YR	<0 050	µg/L	0 050		09/07/2023

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.

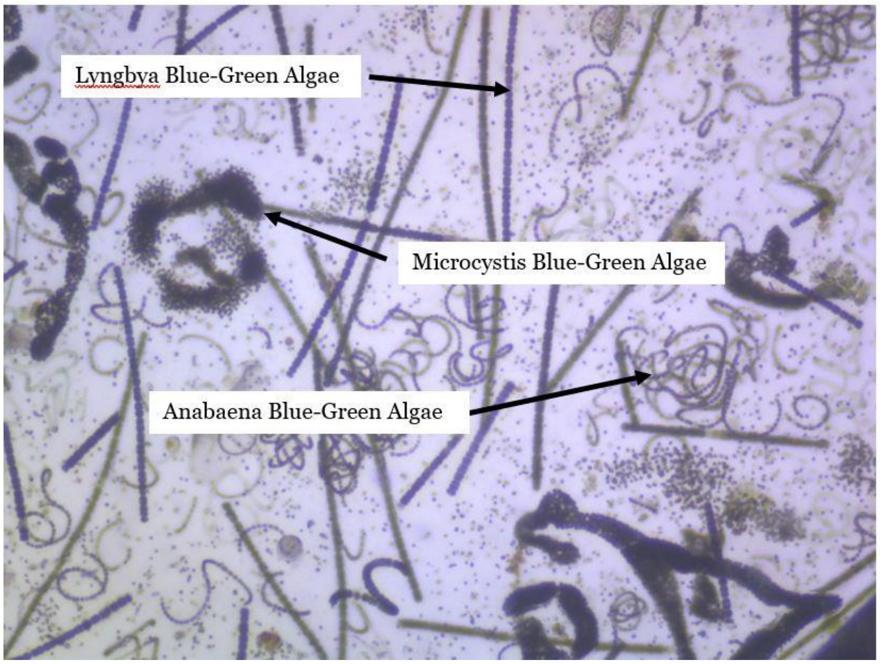
Below is a photo of the appearance of the October 18 to 30 blue-green algal bloom taken along the shoreline at different locations and contributed to us from cottagers.

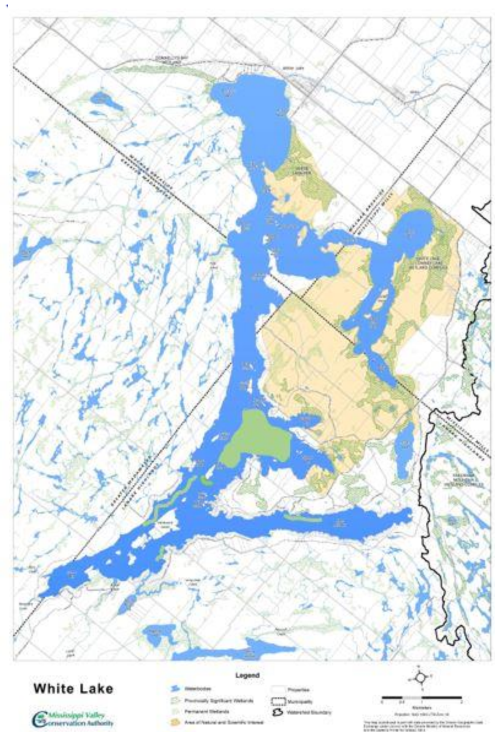


October 18 to 30, 2023

September 30 to October 10, 2023

Between the two algal blooms discussed above came an additional bloom with different characteristics than the other two: First; the range of distribution was smaller than the other two and the bloom contained comparatively equal concentrations of three different (taxa) blue-green algae. The map below and the photomicrograph illustrate our observations.





For all of the algal blooms discussed above, it should be noted that these blooms occurred in the deeper parts of White Lake. Shallow areas were not affected. This may be because during the fall months and in periods of low or no wind, that the lake becomes thermally stratified. This means that upper warmer waters are not mixing with deeper cooler water. At the same time, the level of oxygen close to the bottom of the lake is greatly reduced by consumption arising from decaying organic matter and microbial action.

Under these conditions, phosphorus stored in sediments, which is 200,000 times more concentrated than in the water column above, can be released and result in algal blooms.

During the late summer and fall of 2023 we experienced long periods of calm weather with low or no winds. These conditions would favour the release of phosphorus from sediments (also known as internal loading) as discussed above.

This phenomenon is one of the collateral effects of global warming and climate change.

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%.

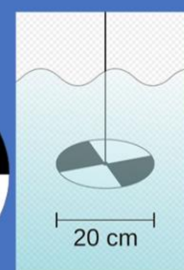
In July of 2015, the Secchi depth in Three Mile Bay was 2.1 metres and by July 2018, the Secchi depth had increased to 5.0 metres. We are now measuring Secchi depths of over 9 metres at some locations. So what?

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:

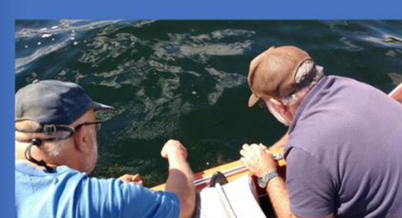
- Aquatic plants will propagate in deeper parts of the lake.
- Aquatic weed beds will thicken in shallow areas where weeds currently exist.
- More zebra mussel habitat will be created on new plant beds.
- Enhanced water clarity means less food for small creatures, including fish.
- The presence of filamentous 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.

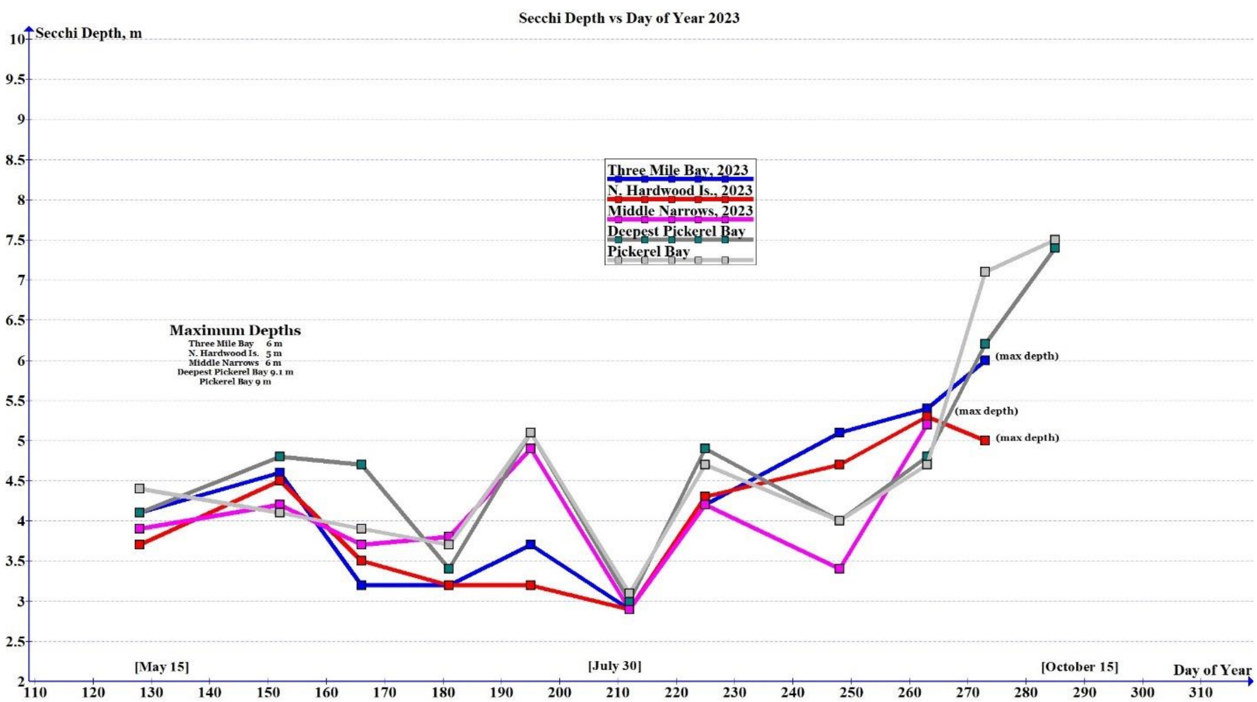


4.1 Secchi Depth Data:

Below is a graph containing the Secchi depth readings for White Lake taken during the 2023 ice-free season.

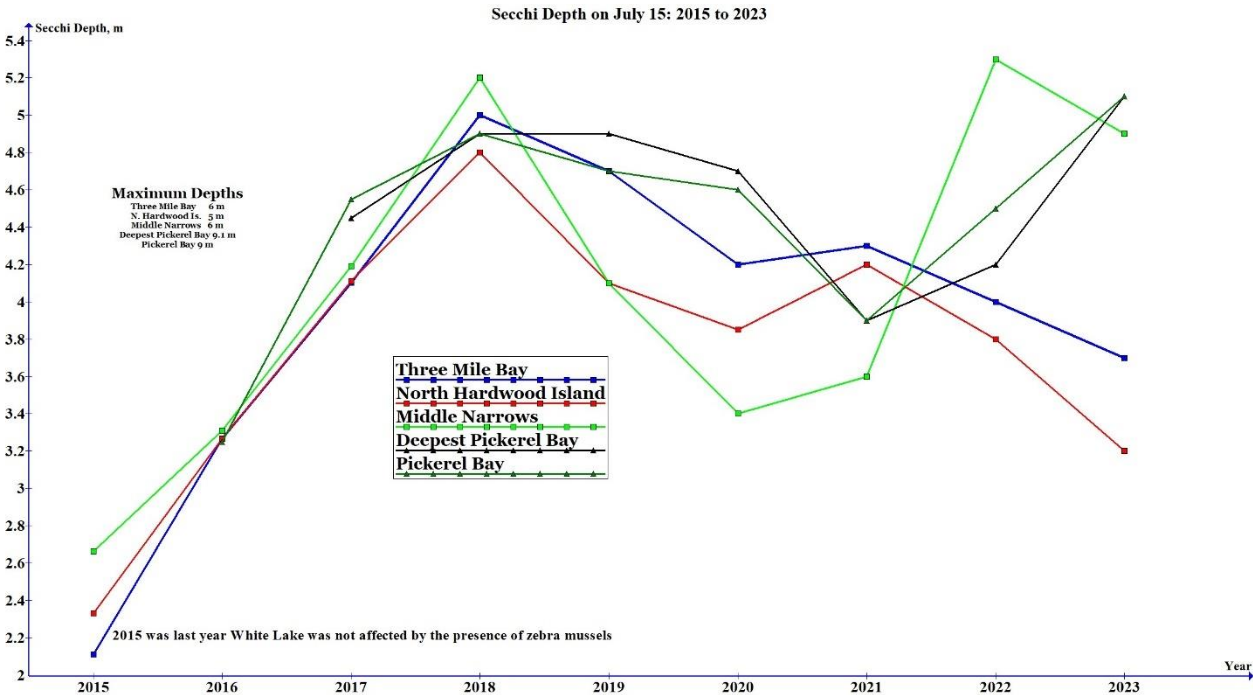
Of the nine sites we sampled, there were only five that had measurable Secchi depths. The remainder of sites were too shallow or the water was too clear at all times. The pattern of Secchi depth readings in 2023 is similar to that of previous years. Secchi depths increase as the lake water column becomes 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 m (lowest water clarity) were recorded in early-August with a maximum of 7.5 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, but it is possible that nutrient levels in the lake have increased 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 2023. 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 were typical of those measured in previous years prior to 2015, when no zebra mussels were present in the lake.

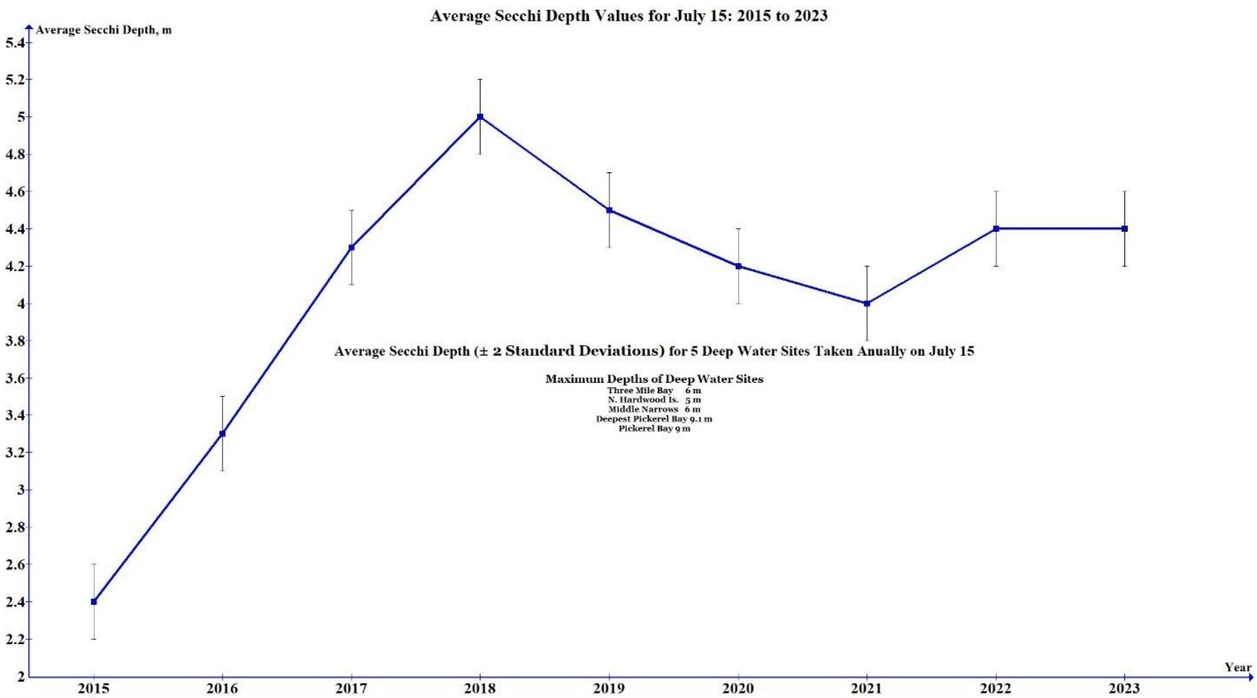


In 2019, this trend was suddenly reversed with Secchi depths decreasing from values obtained in 2018. This trend continued into 2020 with even lower values recorded. During 2021 and 2022, water clarity began to again increase, probably due to fluctuating zebra mussel numbers. In 2023, the change in Secchi depth appears to be site specific with some sites showing a decrease while increasing at other sites, in particular the deepest sites located near or in Pickerel Bay.

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 starting in 2022.

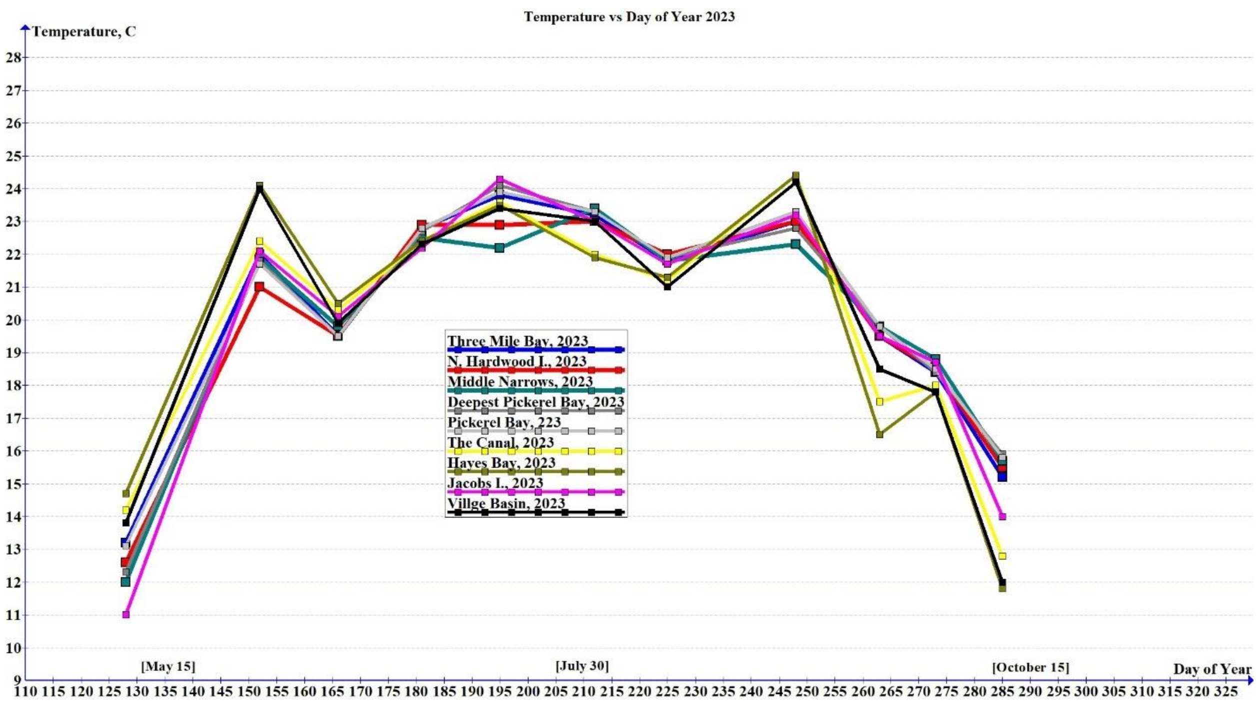
We believe these trends are significant and show that water clarity is now annually changing by no more than about 0.5 metres. Continued monitoring of water clarity in future years will reveal if trends are again changing significantly or only marginally year over year.



Folded Slush: Pickerel Bay Dec. 4, 2023

5.0 Water Temperature

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 could 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.



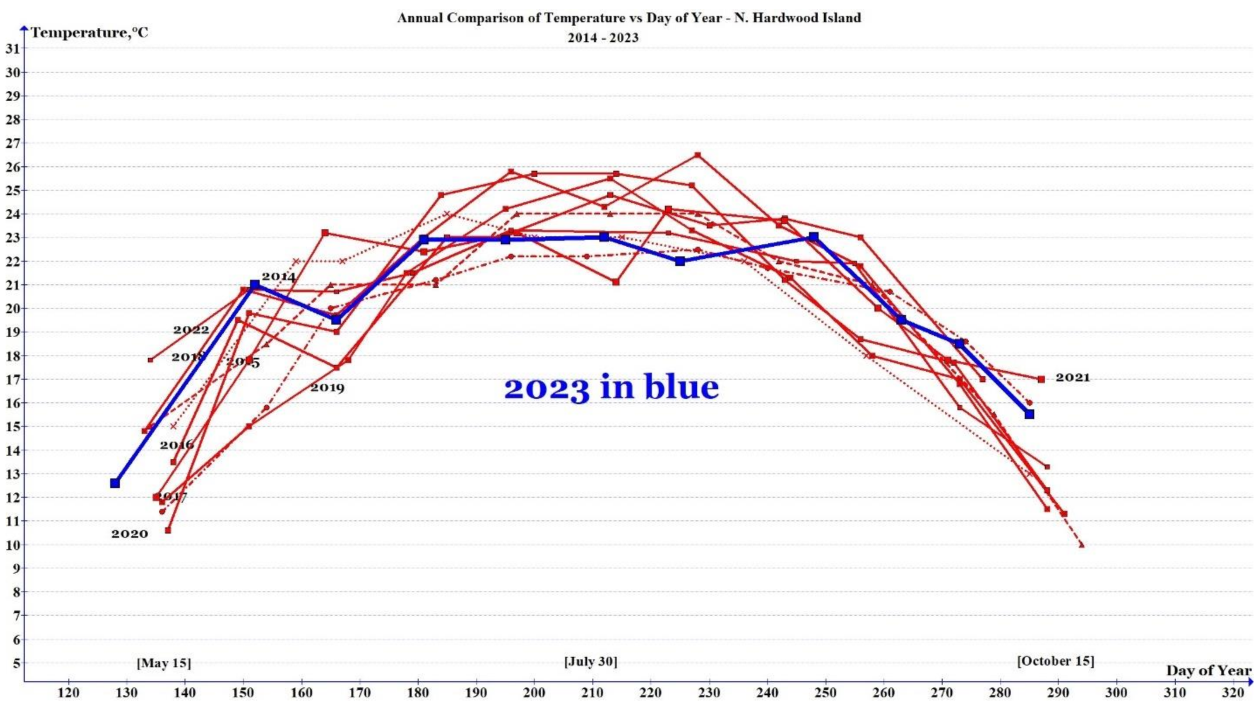
The graph above shows the temperature of White Lake water during the 2023 ice-free season.

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 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 10 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 2023. The thick blue line is 2023 data.

The 2023 data (thick blue line) shows that temperatures were generally within the range of temperatures measured over the past decade.

The table below gives maximum temperatures recorded for White Lake during the past 10 years. 2018 had the highest water temperature recorded to date was 4.1 ◦C higher than the lowest temperature recorded during 2017. Maximum temperatures were almost always recorded in the shallow parts of the lake.

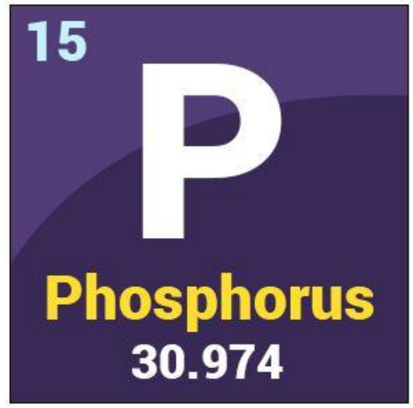
Year	Day of Year	Maximum Temperature, ˚C
2014	199	24.1
2015	217	24.0
2016	223	24.7
2017	216	22.9
2018	196	27.0
2019	213	25.6
2020	214 and 227	26.0
2021	181	25.2
2022	210	24.3
2023	152	24.1

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 <u>Phosphorus</u>

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[5] 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

[5] 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)[6]. 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!

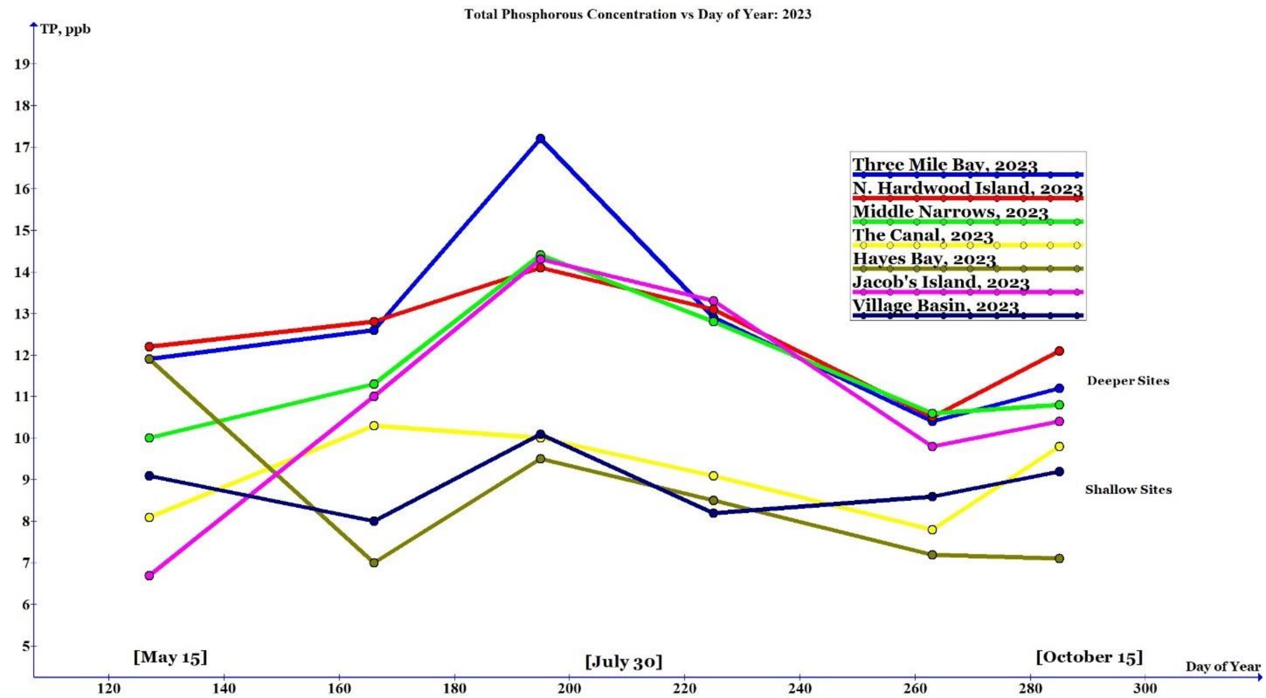
The phosphorus contained in sediments is just as complex if not more so. It is easy to realize that the study of lakes as well as other bodies of water is very challenging and requires the highest levels of science and ingenuity to completely describe the complexity of an aquatic system.

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 2023.

The graph below shows the change in total phosphorus concentrations during the 2023 ice-free season.

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



The data for 2023 (above) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in July. After this date, the total phosphorus concentration decreases 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 especially at the Three Mile Bay sampling site. Over the past decade, the Three Mile Bay and N. Hardwood Island sites have consistently had the highest total phosphorus concentrations when compared to all sampling sites. These results and trends are in agreement with measurements recorded during the last ten years by government agencies and lake association volunteers.

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 total phosphorus 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[7].

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[8]. Although there is a relatively high percent content of carbonate in Hayes Bay sediments, it is less than the two other sites. Bane Bay is even further away from the marl-producing sediments and shows even lower carbonate levels.

6.1 Annual Trends in Total Phosphorus Concentrations

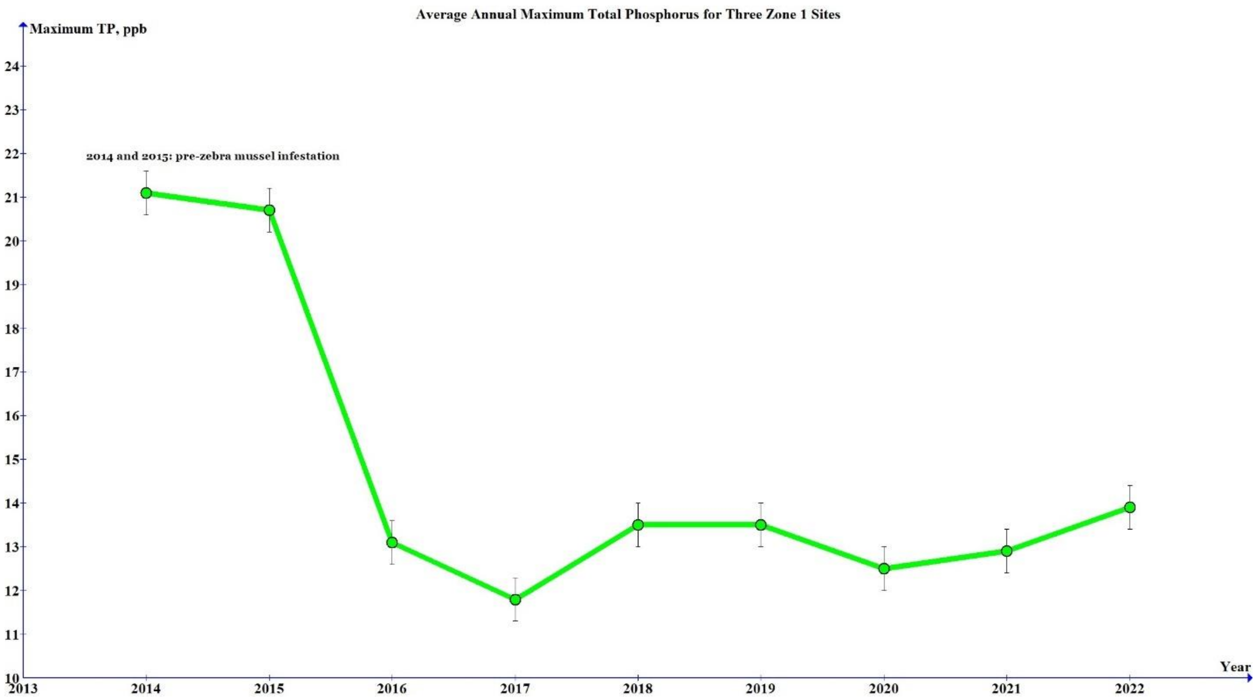
The figure below shows the annual average total phosphorus concentration for three deep water sites in Zone 1 (Main Water Body of White Lake – see Appendix 1).

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-

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

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 increase 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[9] 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 land run-off, septic systems and shoreline development account for about 70% of the phosphorus entering White Lake.

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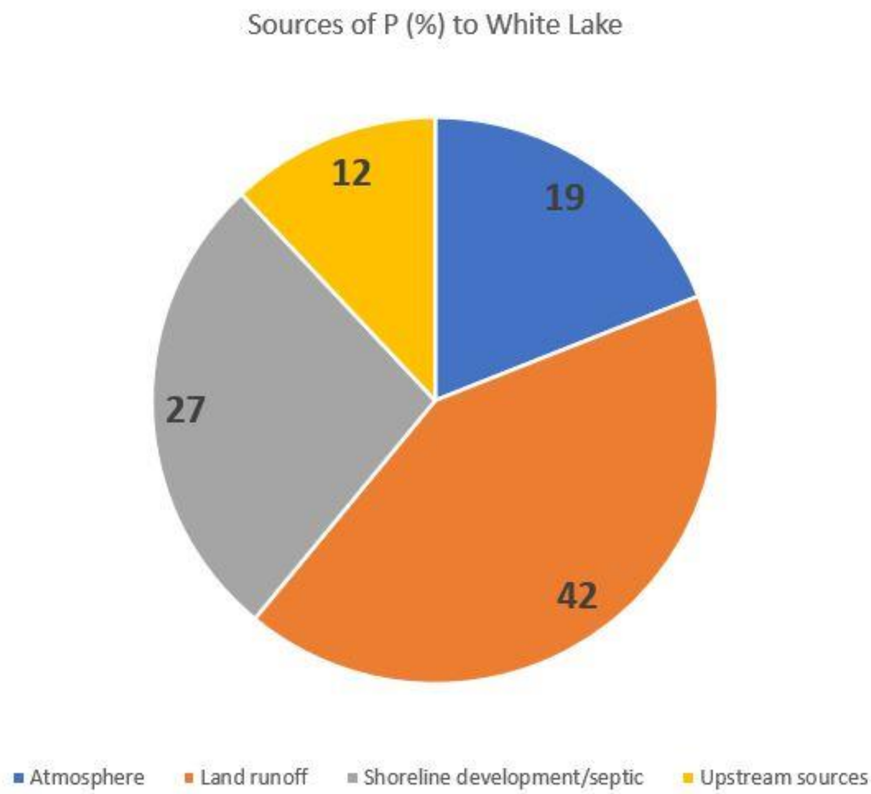
[9] These data are outputs of the Lakeshore Capacity Model for White Lake reported by Bev Clark. Bev Clark is a retired senior career research scientist from the Ministry of the Environment, Conservation and Parks. He was the director of the Lake Partner Program at its inception and both collected research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



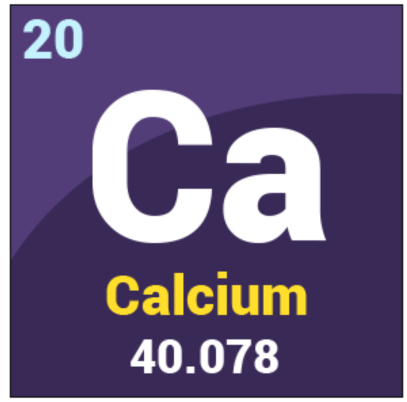
This clearly shows the importance of effective shoreline management to improve water quality and help control nuisance and toxic algal blooms such as those which we have been documenting during the past nine years.

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 2023: One might be tempted to explain the sudden decrease in total phosphorus levels to lower levels (compared to previous years) as a decrease of <u>input</u> 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 <u>removed</u> 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 <u>measured</u> total phosphorus value underestimating the actual amount of phosphorus in the water column.

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 26.1 ppm to a high of 36.4 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, these 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 is 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.

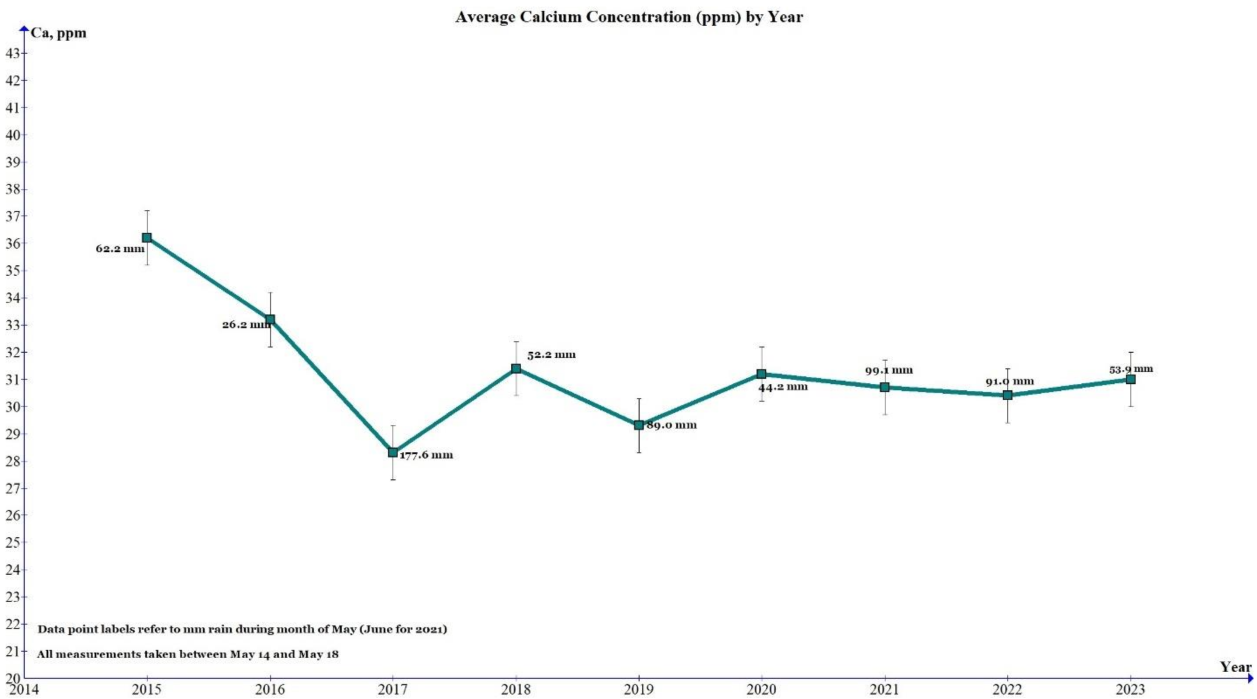
Calcium (ppm) – Sampling Site by Month: 2023

Sampling Site	May	June	July	Aug	Sept	Oct	Average
Three Mile Bay	31.8	32.4	32.1	29.6	26.1	28.7	**30.1**
N. Hardwood I.	30.6	31.9	31.9	29.9	26.9	28.7	**30.0**
Middle Narrows	31.0	31.9	32.1	30.6	29.0	29.5	**30.7**
Jacob's Island	31.8	31.4	31.3	28.5	26.4	30.1	**29.9**
The Canal	30.8	32.4	32.0	28.4	27.0	31.0	**30.2**
Hayes Bay	32.7	34.6	34.8	32.2	31.1	36.4	**33.3**
Village Basin	28.6	31.4	30.2	27.3	26.4	30.0	**29.2**
Mean	31.0±1	32.3±1	32.1±1	29.5±2	27.6±2	30.6±3	

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 result in a 'dilution effect' causing calcium levels to decrease following high rain events.

Sampling Site	2023	2022	2021	2020	2019	2018	2017	2016	2015
Three Mile Bay	30.1	28.6	31.6	30.6	28.8	32.8	28.4	36.4	36.2
N. Hardwood I.	30.3	29.0	31.3	30.8	28.6	33.0	28.5	31.8	37.3
Middle Narrows	30.7	29.3	31.4	31.2	30.3	33.4	28.4	31.1	35.3
Jacob's Island	29.9	28.5	30.5	30.6	28.4	34.0	27.7	31.4	36.2
The Canal	30.2	28.7	30.2	30.7	30.8	34.4	29.4	34.3	35.8
Hayes Bay	33.3	35.1	34.3	32.6	30.4	37.8	31.0	36.6	-
Village Basin	29.2	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 2023 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 but have remained nearly constant since 2017.



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 8 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 2023

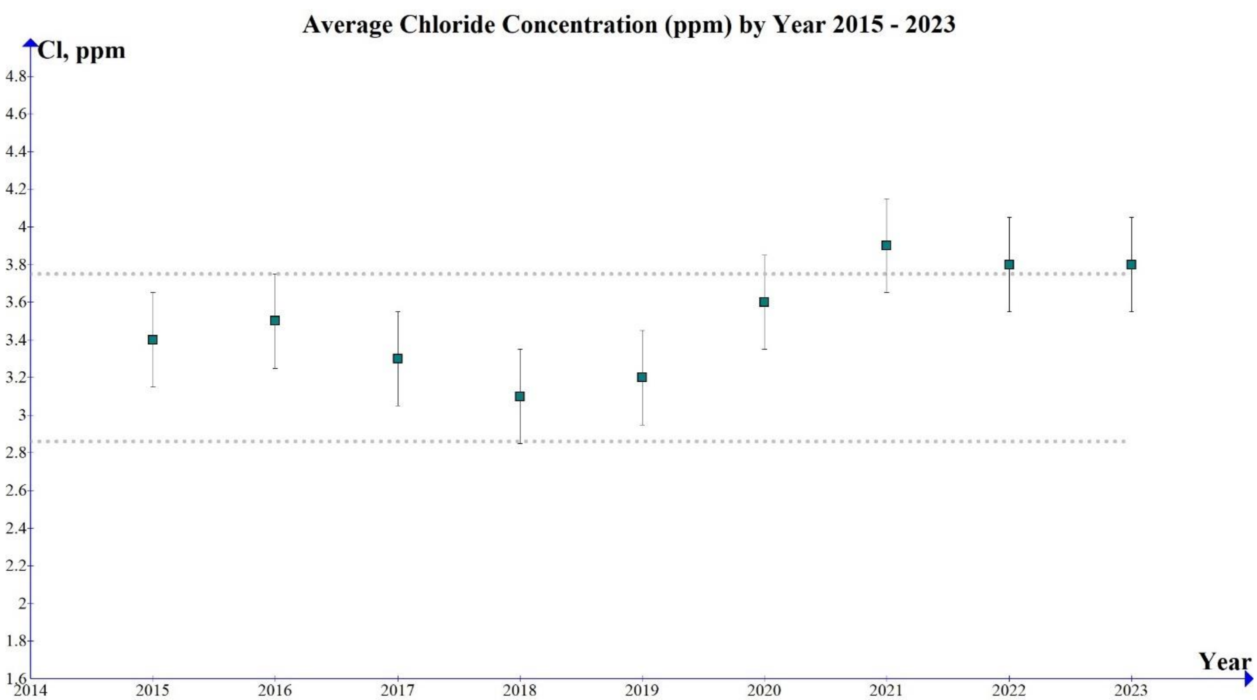
Sampling Site	2023	2022	2021	2020	2019	2018	2017	2016	2015
Three Mile Bay	3.4	3.9	-	3.4	2.8	2.9	2.8	3.4	3.5
N. Hardwood I.	3.3	3.8	-	3.4	2.8	2.9	3.1	3.4	3.3
Middle Narrows	3.6	3.8	3.8	3.5	3.2	3.5	3.3	3.5	3.5
Jacob's Island	3.7	4.4	3.9	3.7	3.6	3.2	3.7	3.7	3.5
The Canal	4.5	5.1	4.8	4.7	4.1	4.1	6.2	5.4	3.9
Hayes Bay	8.4	10.0	9.0	9.0	7.6	8.3	9.5	10.0	-
Village Basin	3.6	3.9	3.9	4.0	3.6	3.6	3.8	3.7	-

Average chloride data for 2015 to 2023 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 2023

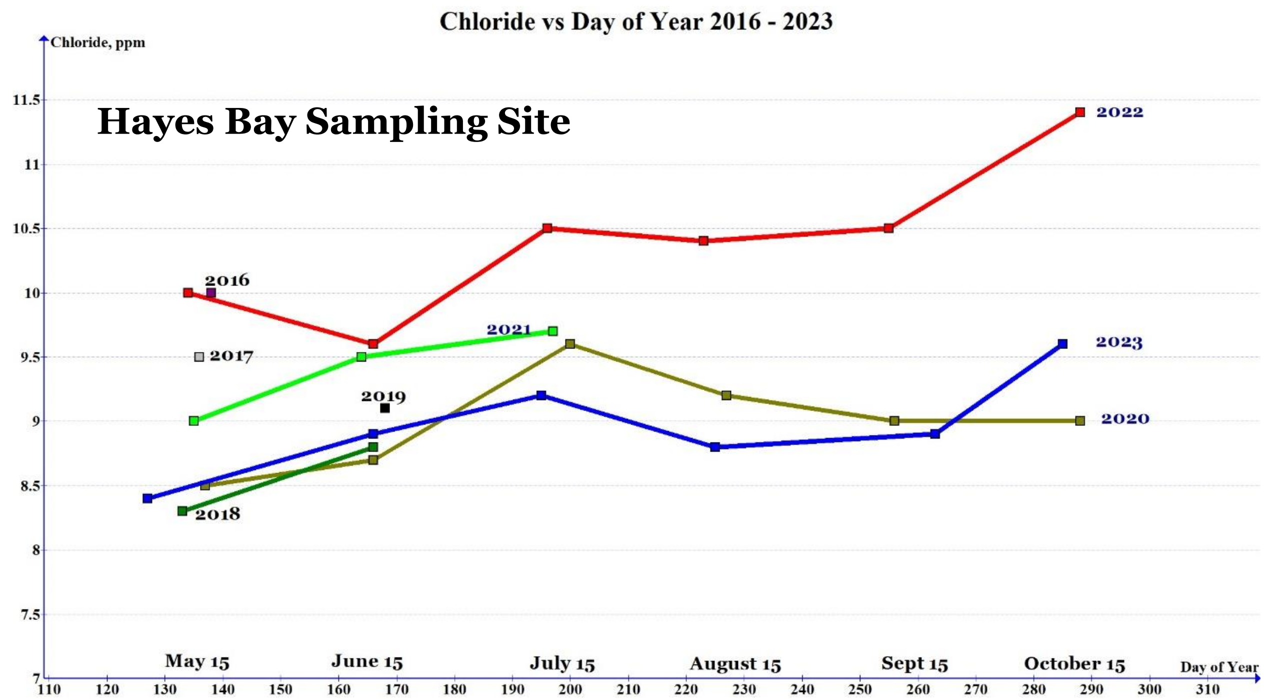
Year	Average ± SD
2023	3.8 ± .2
2022	3.8 ± .2
2021	3.9 ± .1
2020	3.6 ± .3
2019	3.2 ± .2
2018	3.1 ± .3
2017	3.3 ± .4
2016	3.5 ± .2
2015	3.4 ± .1

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.



The above graph plots chloride concentrations measured at the Hayes Bay site during the ice-free season. In general chloride concentrations are low during the spring and tend to increase over the summer. The data for 2020 also shows low chloride concentrations in the spring, with values peaking mid-summer and then slightly decreasing over time.

Road salt may not be the source of the chloride because we 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 all years, at no time did the concentration of chloride equal the much lower values obtained in other parts of the lake.

This makes the possibility of a year-round source of chloride, such as from a salt spring, more likely. Variations over time in chloride concentrations may be due to changes in weather conditions such as rain and periods of drought.

9.0 Weather Conditions: 2014 – 2023

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 2023. 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 to 0.6 metres. In that respect, 2023 was an 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 2023

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
2023	601	64

During the six-month period from April to October 2023, White Lake received **601** mm of rain and experienced **64** days with rain of 1mm or more. Monthly meteorological tables for previous years starting in 2014 can be found in our previous annual reports on the White Lake website.

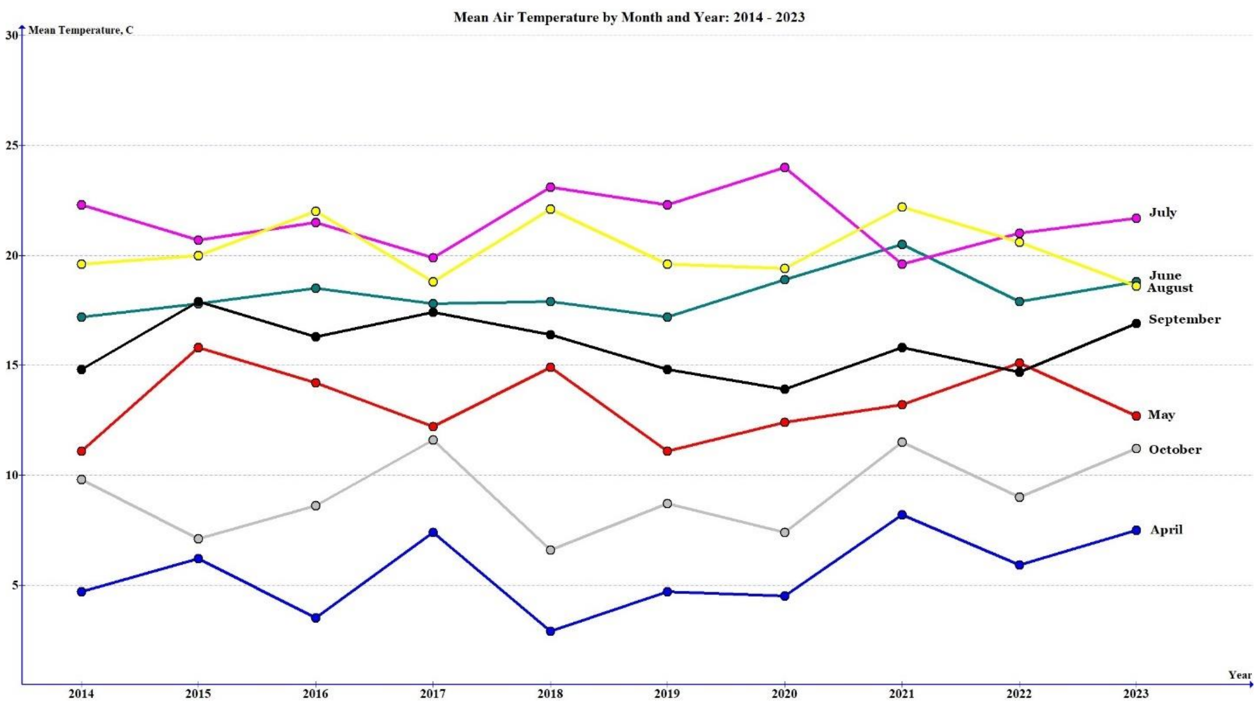
The table below presents monthly meteorological data from April to October, 2023. This table does not reveal a year-by-year comparison of monthly temperature values. This data is pertinent because one of the most important mechanisms by which White Lake loses water is by evaporation. Prolonged periods 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 Basin.

Monthly Meteorological Values – Environment Canada: *2023*

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	7.5	-9.5	30.2	107.9	8
May	12.7	-3.1	32.5	53.9	5
June	18.8	6.2	35.1	82.8	9
July	21.7	8.5	33.7	142.4	14
August	18.6	6.2	28.3	110.8	11
September	16.9	5.2	32.6	24.7	4
October	11.2	-5.3	30.9	78.4	13
Total				**601**	**64**

The figure below shows the change in mean air temperature for individual months over the years spanning 2014 to 2023.

Although there is some variation from year to year in air temperatures, it is very difficult to discern any trends over the 10-year period. Air temperatures were generally cooler in 2023 than for 2022. These differences are due to local weather conditions.

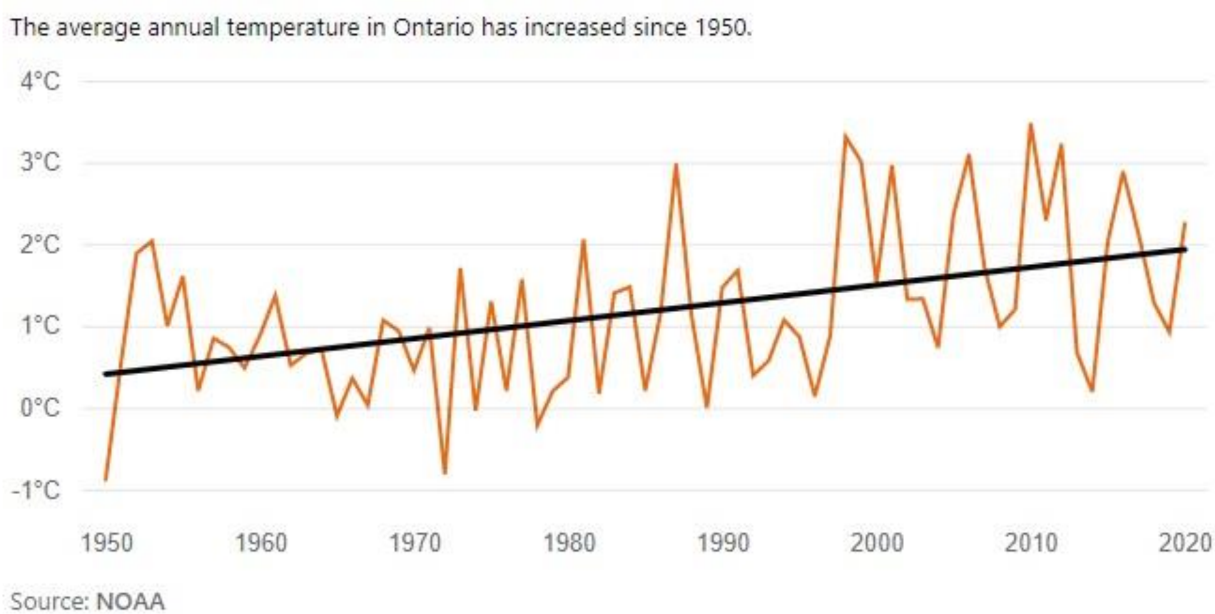


It is important to take note of these temperatures because the ambient air temperature will affect the temperature of lake water. This in turn could have an impact on aquatic plant growth, plankton succession over the summer as well as the timing of the zebra mussel reproduction cycle.

The above data describes local weather and not climate change or global warming. Data related to climate change and global warming is taken from longer term studies (decades) and reference much larger geographical areas.

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.

Data reported in our 2022 Water Quality Report documents that since 1980, the time White Lake is free of ice cover has increased y 15 days as a result of global warming.



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 2023

Date	Day of Year	Weather Conditions
May 8	127	Clear sunny day; winds of 5 to 15 km/h; no raid for previous 5 days, but very heavy rains before that. Lake level very high at 180 cm. Air temperature 10 to 12C.
June 1	152	Slightly hazy but otherwise bright sunny day. No wind. Air temperatures of 2 to 27C.No rain or previous 5 days. Water levels correspond to planned regime….normal.
June 15	166	Sunny day. Air temperature 28C, light winds of 5-10 km/hr; No raid for previous 5 days; pollen storm during previous week.
June 30	181	Overcast day with high density of forest fire smoke; Air temperature 19-22C; no wind; some light scattered showers. Secchi depths may be too shallow because of reduced sunlight. 11 mm of rain prior two days. Water level 14 cm which is on target.
July 14	195	Bright sunny day; no wind; Air temperature 23 – 26 C; 18 mm rain fell day before sampling; Water depth at 142 cm (140 cm planned)
July 31	212	Partly cloudy with winds of between 5 and 10 km/hr; air temperatures from 15 to 18C; 5 mm rain day before sampling; water depth 141 cm with target depth of 137.
August 13	225	Partly cloudy with winds of between 5 and 10 km/hr; Air temperature ranges from 21 to 23C during the sampling period. Lake level was 8 cm higher than planed. Nine mm rain fell day before sampling and 20 mm the few days before that.
September 5	248	Full sun with no wind. Sampling taken during a hot dry weather period. Air temperatures ranged from 23 to 28C. Water level was 129 cm, the target depth. Major anabaena algal bloom encompassing 80% of lake surface. MOE staff sampled lake for toxin analysis. Also, filamentous green algal bloom occurred simultaneously.
September 20	263	Full sun, no wind; 8 mm rain fell day before sampling; air temperature between 12 and 15 C; Water levels are right on target.
September 30	273	Fog quickly lifted just at start of sampling run. Full sin; no wind; air temperature 15-19 C; no rain previous 15 days. Lake depth 117 cm with target depth of 116 cm. Algal bloom (3 species) along with dead daphnia located at mouth of Pickerel Bay…halfway into bay and halfway across the lake. Second BG algal bloom of the season.
October 12	285	Partial cloud with a wind of about 10 km/hr; air temperatures 8 to 1 1C; 18 mm of rain fell one to three days before sampling. Lake depth 115 cm compared to 107 mm planned by current water level rule.


Water Sampling on a Calm Day

10.0 Water Levels – White Lake Dam: 2023

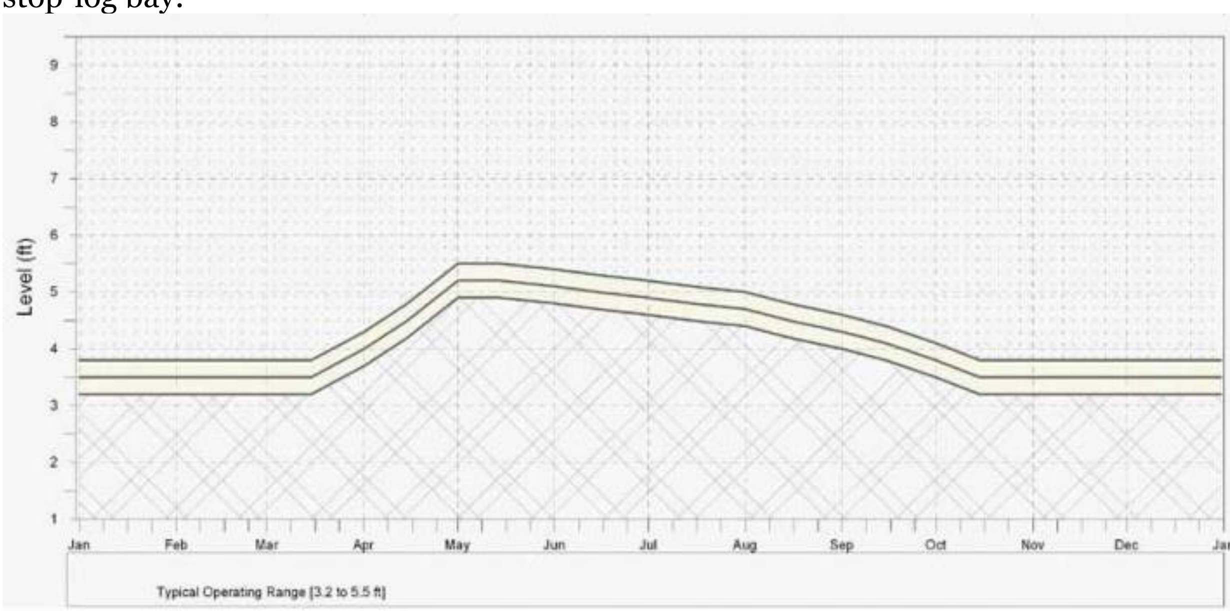
White Lake Dam is managed by the Ministry of Natural Resources and Forestry, Kemptville District office. The operational plan is part of the Madawaska River Water Management Plan, 2009.

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.

Over the ten-year period during which we have monitored the lake level, the Ministry of Natural resources has changed the depth gauge at the White Lake dam several times. Originally calibrated in decimal feet, this gauge was changed for one calibrated in centimetres above the sill of the dam. In 2023, the gauge was again changed with one calibrated in metres above sea level.

The conversion table below gives the relationship among the three systems of depth measurement used to set the target levels of the lake.

CONVERSION TABLE FOR RULE DEPTHS – WHITE LAKE DAM/WABA CREEK			
Dates	**Target Levels**		
	Decimal Feet Above Sill	**Centimetres Above Sill**	**Metres Above Sea Level**
January 1 to March 15	3.5	106.7	162.310
April 1	4.0	122.0	162.467
April 15	4.5	137.2	162.631
May 1	5.0	152.4	162.781
May 15	5.2	158.5	162.843
June 1	4.9	149.4	162.750
June 15	4.8	146.3	162.718
July 1	4.7	143.3	162.687
July 15	4.6	140.2	162.655
August 1	4.5	137.2	162.631
August 15	4.3	131.1	162.561
September 1	4.2	128.1	162.529
September 15	4.0	122.0	162.467
October 1	3.8	115.9	162.405
October 15 to December 31	3.5	106.7	162.310

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.

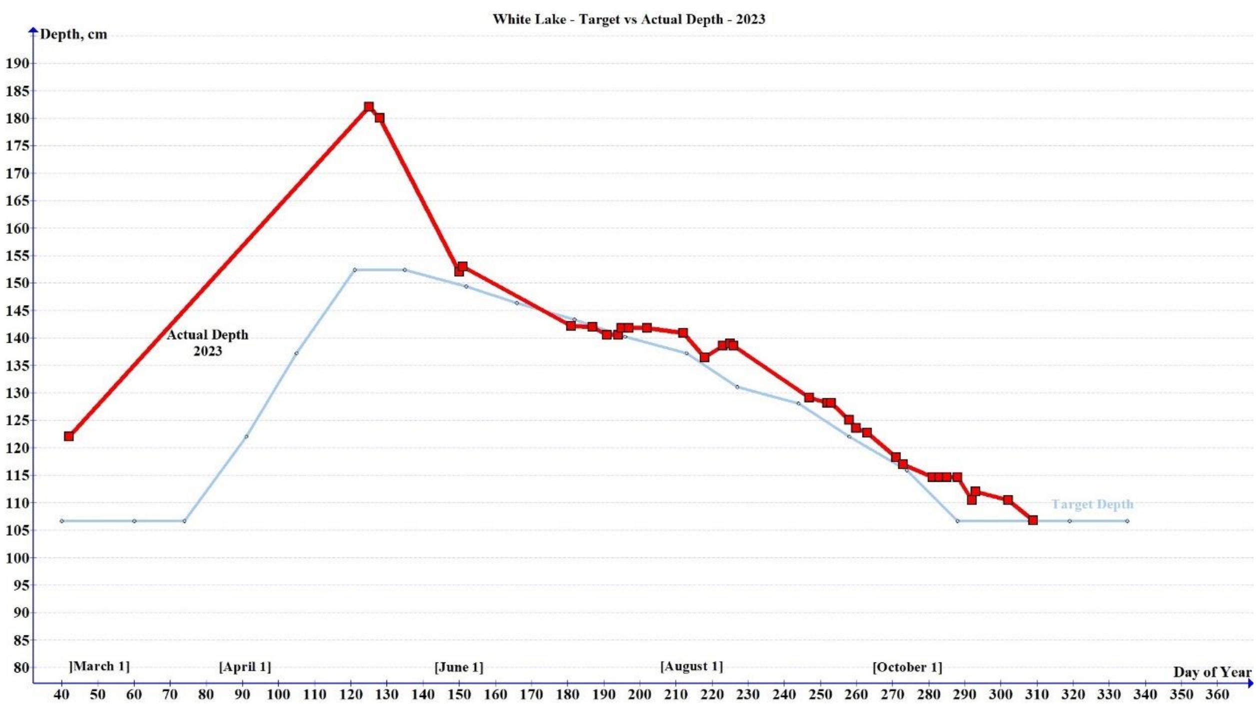
Summer: The target level for July 1 is a gauge reading of 4.9 feet, and the dam should be operated to reach this level. During the period from May 1 to September 1, water levels should be dropped gradually to reach 4.3 feet.

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 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 red line is for 2023. The blue line is for the target water levels set by the managers of the dam.



It is clear from the graph that after late May 2023 water levels were very close to target depths. However, in the early part of the season, lake depths shot up 30 cm above target levels.

Below are photos of the White Lake dam at Waba Creek taken on May 14, 2023.

The dam is comprised of three spillways. During spring, the two spillways on either side of the central spillway are blocked by stop logs. The central spillway is where most of the water leaves the lake and in order to create a controlled flow, only one stop log (of a possible 6) was used at that time.

At some time before this photo was taken, a property owner or contractor working not far from the dam cut loose several large chunks of cattail marsh presumably as part of a shoreline alteration project. The chunks of marsh were set adrift into the lake and quickly found their way to the dam.

On reaching the dam, the vital central spillway was completely blocked and the left and right spillways either totally or partially blocked. The previous photo shows one chunk of marsh which had passed though the dam and can be seen just below the left spillway. With a blocked central spillway, the lake rose to the level dictated by the left and right spillways which were set at a level much higher than the central spillway. This resulted in the entire lake rising an extra 30 cm.

As a result of the high water, some property owners sustained damage to their docks as well as partial flooding of low-lying lots. The high water level may have affected nesting birds such as loons, ducks and geese whose nests could have been flooded.

The Ministry of Natural Resources Forestry was obliged to bring in heavy equipment once to free the dam and again later to remove blocks of cattail marsh located downstream of the dam.

This careless act inconvenienced property owner's lake-wide and incurred significant costs to the taxpayer.


White Lake Wetland – Hardwood Island

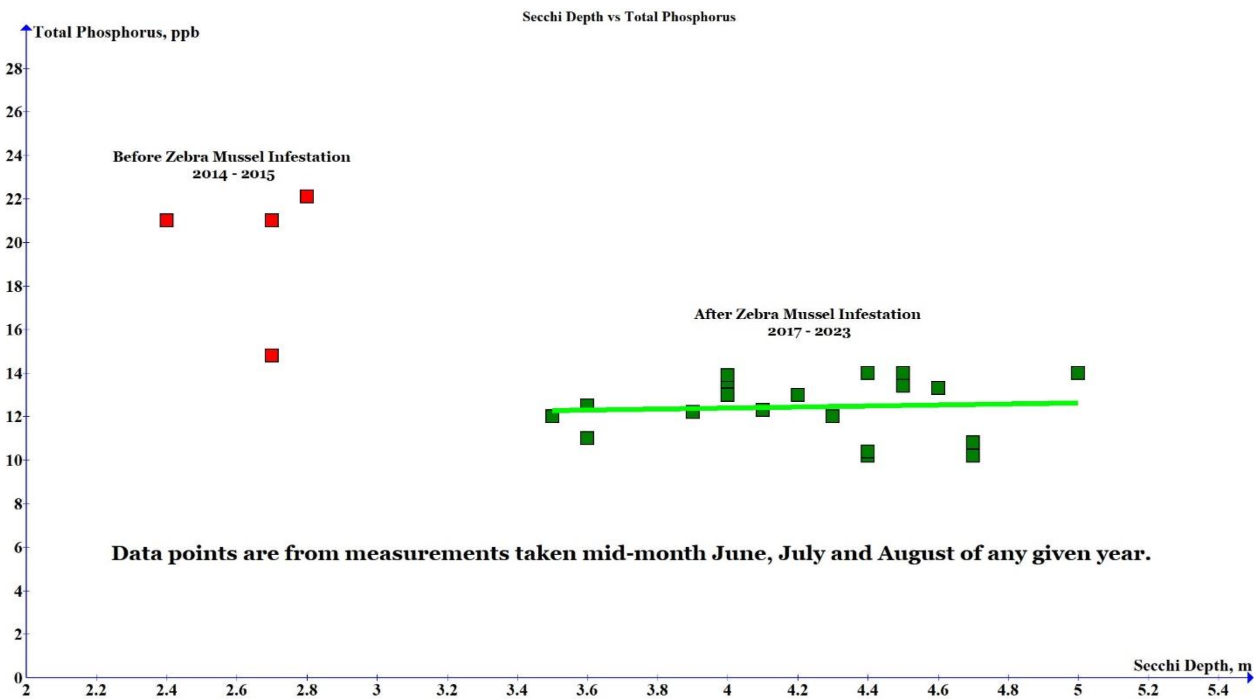
PART III
Research Activities and Environment Bulletins

11.0 Observations on the Relationship Between Total Phosphorus, Water Clarity Trophic Level Determination and Zebra Mussels

During the past ten years we have been collecting data on the total phosphorus concentration of lake water, water clarity (expressed as the Secchi depth) and the health of the zebra mussel population.

The advent of zebra mussels in White Lake in 2015 permanently changed the way nutrients were cycled in the lake. An immediate change in water quality which was evident to many was an increase in water clarity, especially on calm wind-free days.

The graph below is a plot of Secchi Depth (in metres) and Total Phosphorus (parts per billion or nanograms/mL). Each data point is the average of data from three deep-water sites[10] taken on the same day. The data set includes measurements taken mid-month in June, July and August from 2014 to 2023.



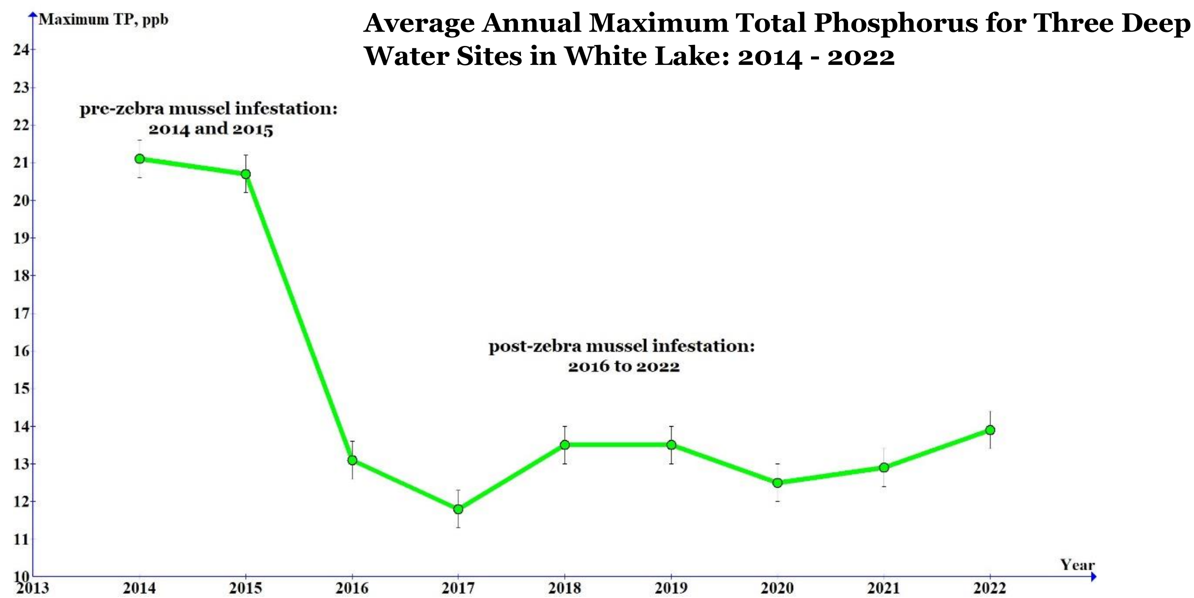
The points on this graph are separated into two separate fields. The first (in red) contains data collected before the infestation of zebra mussels and the second (in green) for data collected after the infestation. The light green line is the statistical best fit line for this data. The green line has essentially a zero slope which indicates that both Total

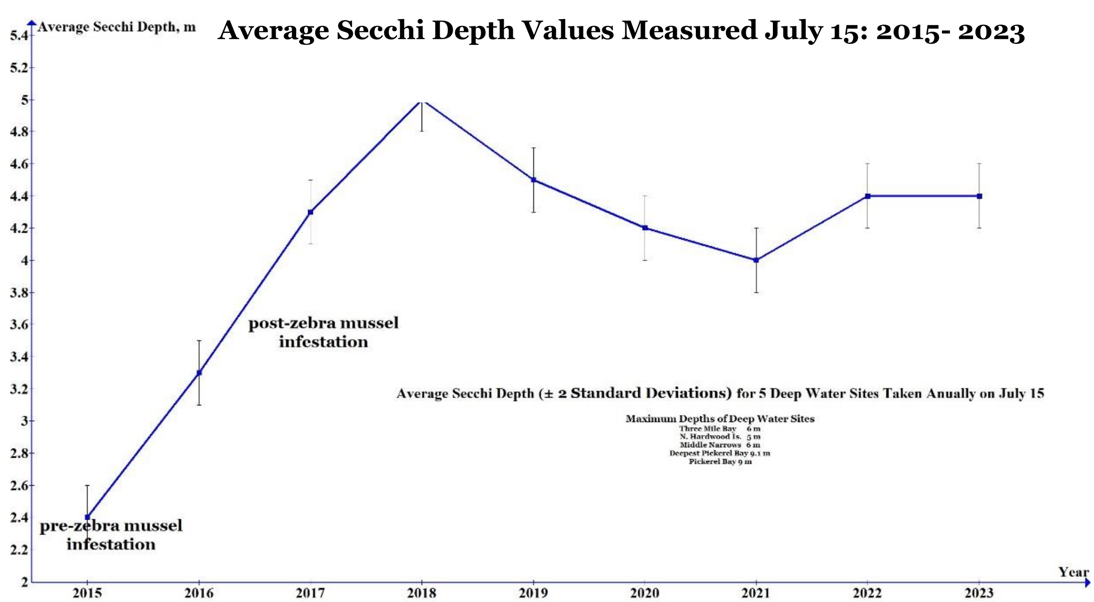
[10] Sampling sites: Three Mile Bay; North Hardwood Island; Middle Narrows

Phosphorus and water clarity are not changing appreciably with time, at least for the period under study.

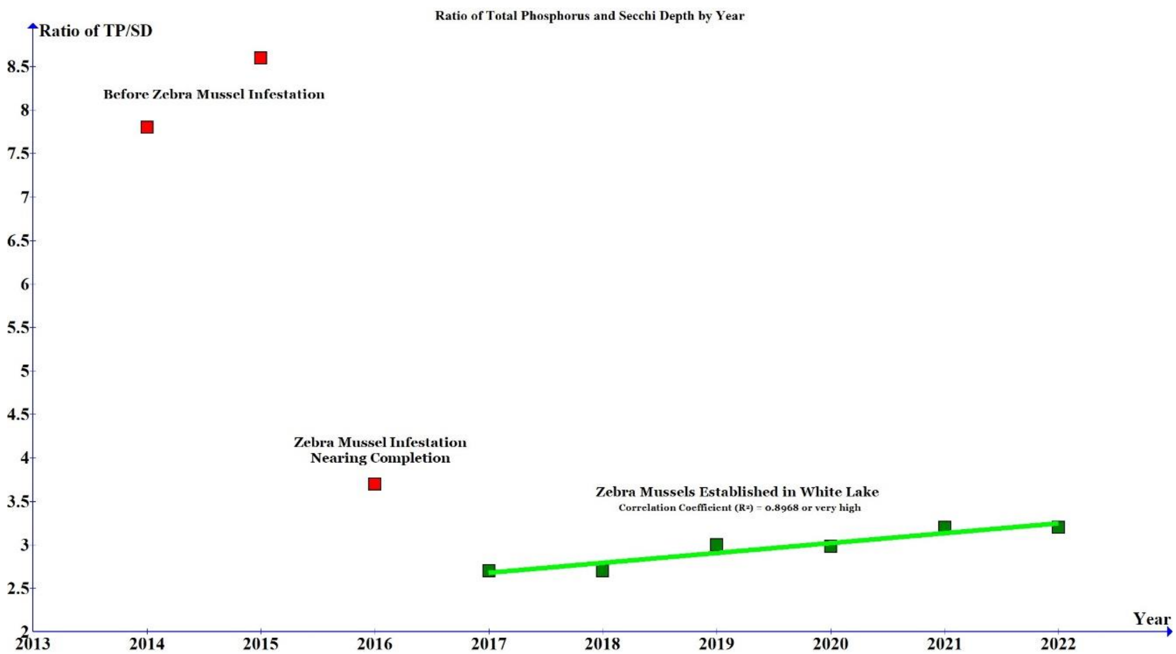
The fact that the red and green dots are in different fields just indicates that a fundamental change has occurred in White Lake water chemistry. The field containing the red dots is characterized by lower water clarity and higher total phosphorus concentrations. Data points in the green field are characterized by higher water clarity and lower total phosphorus concentrations.

This may be better demonstrated by showing the changes in both parameters over the same time period:





For both Total Phosphorus and Secchi depth, it is unambiguous that once zebra mussels infected the lake, changes in lake water quality were dramatic and permanent. To be sure, there are small variances in both parameters after 2018, but these are not significant in comparison to the overall change documented here.



The graph above plots the ratio of Total Phosphorus and Secchi depth . Again, we see a very clear demarcation between pre and post zebra mussel infestation in the ratio of these two parameters. The data presented in this graph are for measurements taken in mid-July. Data plotted for June and August produced the same result. These are omitted here for the sake of clarity.

The green statistical best fit line in this graph has a positive slope indicating that over time Total Phosphorus is marginally increasing relative to Secchi depth or that Secchi depth is decreasing relative to Total Phosphorus concentrations.

One of the questions we have is whether either Total Phosphorus or Secchi depths measurements can be used to ‘track’ changes in the zebra mussel population of White Lake? In other words, does any variance in either or both of these parameters reflect changes in the health or influence of the zebra mussel population on White Lake water quality measurements?

Definitions

One of the difficulties in interpreting these results is rooted in the definition of the parameters used.

Secchi Depth

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, corresponds to 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.

A change in Secchi depth reflects changes in light transmission due to any suspended materials be they alive or dead.

Total Phosphorus

The term 'Total Phosphorus' implies that the measurement being taken reflects to total amount of phosphorus found in lake water at time of sampling. Unfortunately, this is not true. This is because Total Phosphorus is an operationally defined parameter. Total Phosphorus is defined as the sum of the concentration of phosphorous-containing compounds in solution and the phosphorus contained in particulate matter (living or dead) which will pass through an 80-micron filter. A micron is one millionth of a metre or one hundredth of a millimetre.

Whereas Secchi depth readings are affected by all particles in the water column both big and small, Total Phosphorus concentrations reflect the phosphorus content of only a fraction of these particles; that is those which will pass through an 80-micron filter.

This presents problems when one is trying to interpret Total Phosphorus concentration and water clarity results in relation to a third factor such as the presence and proliferation of zebra mussels.

Our results (discussed below) may bring into question the validity of using the Provincial Water Quality Objective of 20 ppb Total Phosphorus as the level above which nuisance or blue-green algal blooms are more likely to occur. Similarly, our results casts doubt as to whether Total Phosphorus and or Secchi Depths can be used to determine lake trophic levels once zebra mussels have invaded a water body.

Zebra Mussels

Zebra mussels are filter feeders and are known to filter out particles as small as a few microns (bacteria) to a millimetre or more. When one takes into account the definition of Total Phosphorus it is easy to see that zebra mussels are capable of filtering out both particles smaller than 80 microns (the filter size we use when taking a water sample for analysis) as well as those larger then 80 microns, which are outside of the particle size restriction for Total Phosphorus concentration measurement.

The significant drop (50%) in measured Total Phosphorus concentrations measured once zebra mussels invaded White Lake (see graphs above) can be explained by examining the components which contribute to Total Phosphorus measurements. For the sake of simplicity, Total Phosphorus can be separated into two phases: a dissolved phase of phosphorus-containing compounds (like sugar dissolved in water), and a particulate phase which can be compared to a solid suspended in the water column, such as pollen. Zebra mussels will filter the suspended materials, eat these, and leave behind the dissolved phosphorus, which algae can use to live and grow.

Because of the feeding habits of zebra mussels, their presence resulted in both a much lower level of Total Phosphorus and a higher water clarity at the same time.

How then can we use Total Phosphorus and/or Secchi depths data to indicate when zebra mussels reach their natural limitations on growth and proliferation?

Discussion

We can start by asking what are the limitations to growth for zebra mussels in a lake like White Lake. White Lake has abundant amounts of calcium for zebra mussel growth with concentrations nearing 30 parts per million. White Lake has always been a naturally productive nutrient-rich lake and continues to be so. However, the increase in the number of cottages and permanent homes on the lake guarantee that more and more nutrients are entering the lake as time passes.

The most likely limitation to the proliferation (total number) of zebra mussels is the availability of hard surfaces such as rocks or submerged logs or of aquatic plants capable of supporting a 'load' of zebra mussels on their stems.

In fact, suitable substrate material on which zebra mussels can attach and prosper are usually found only in the near-shore areas of White Lake or around islands and submerged shoals. The sediments found in deeper waters away from the shore are not suitable for zebra mussels and any late-stage larvae that alight there will not survive to adulthood.

Once the zebra mussels occupy the maximum 'space' available to them where they can attach, feed and prosper, then the availability of food becomes more important. If there is sufficient food available, then they continue to prosper.

If there is a balance between Total Phosphorus input into the lake and consumption by zebra mussels, then we can expect that parameters such as Total Phosphorus and Secchi depth will remain relatively constant.

If nutrient inputs to the lake are in excess of the capability of zebra mussels to extract and consume, then we can expect that water clarity will deteriorate (lower Secchi depths) and

Total Phosphorus concentrations may increase. Thus, changes in either of these parameters may not be attributable to a change in the zebra mussel population in White Lake.

The data for White Lake reported here and graphed above indicate that zebra mussels have reached an equilibrium between available attachment sites and suspended nutrients filtered and used for food.

Our studies have shown that from year to year that size distribution of zebra mussels in White Lake can vary significantly. However, the measured Total Phosphorus and water clarity measurements indicate that the filtering (feeding, water clarification) capacity of the sum total of the zebra mussels in the lake has not changed appreciably in recent years.

Our observations on the many blue-green algal blooms recorded in White Lake in recent years, after the invasion of zebra mussels, shows that these have occurred mainly when ambient Total Phosphorus concentrations are <10 ppb. This calls into question the Provincial Water Quality Objective of 20 ppb as a goal for avoiding nuisance algal blooms.

Conclusions

This study suggests that the use of Total Phosphorus concentrations, as measured, may not be the best indicator of phosphorus available for algal growth (or algal blooms) and may have limited relevance as a measure of water quality. The measurement of only dissolved phosphorus species (<0.45 micrometres)[11] may be a better measure to use in predicting the potential for algal blooms because dissolved (and not suspended) sources of phosphorus are assimilated by alga. This argument is perhaps even more relevant for instances where zebra mussels are present.

Small annual changes in Total Phosphorus and Secchi depth data may not be indicative of changes in zebra mussel populations, but may be only reflecting an increase in nutrient inputs to the lake or even seasonal changes in water temperature or other factors.

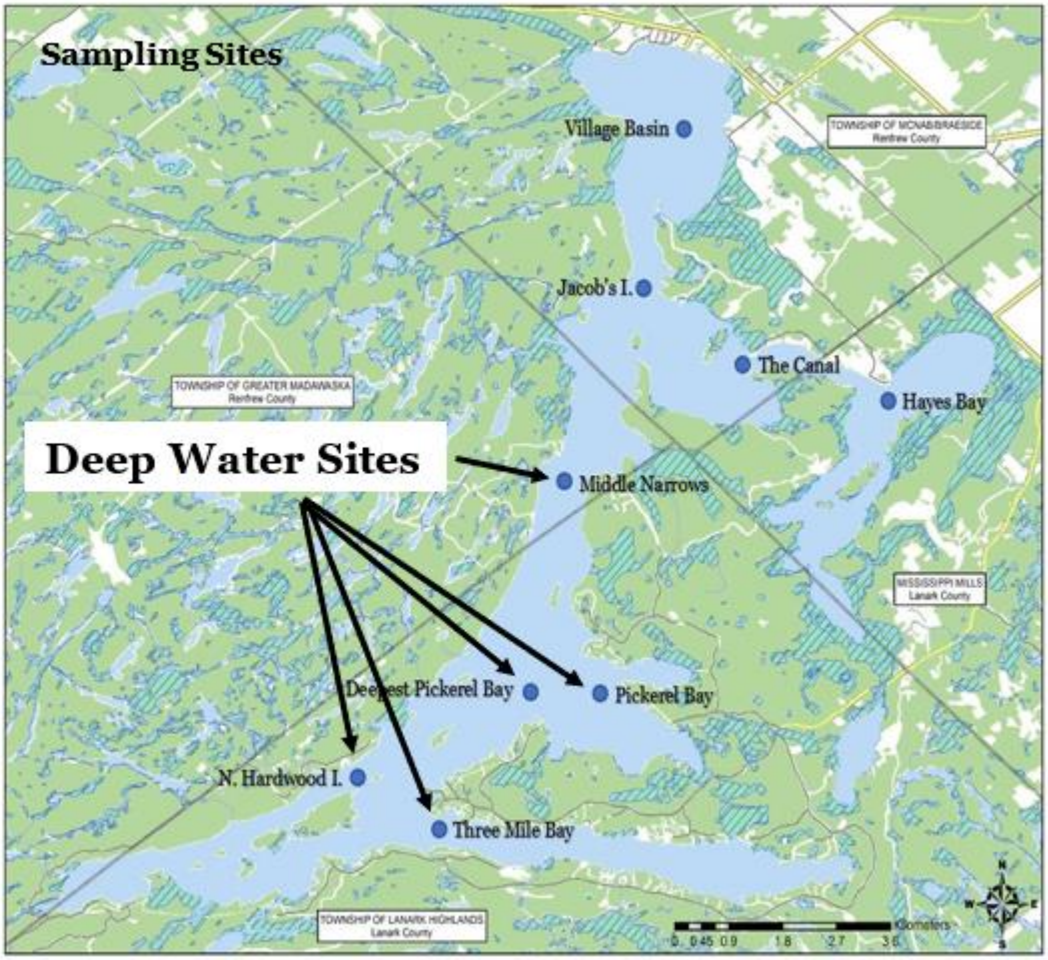
Secchi depth readings, however, take into account the presence of all particulate matter in the water column and as such may be a better measure of the total amount of nutrients entering the lake from all sources.

Total Phosphorus concentrations and Secchi depth data taken together (as in graphical treatment above) may be useful in indicating a sudden significant change in zebra mussel populations or signal the arrival of another invasive such as the Quagga mussel, which would likely further reduce Total Phosphorus concentrations and result in higher water clarity.

Care must be taken when interpreting water quality data to take into account factors outside of a few easily-measurable parameters. It is important to note that all water

[11] 0.45 μm is the accepted (by environmental speciation scientists) particle size below which a substance is considered in solution rather than in suspension.

samples and physical measurements are taken in the central zone of the lake and not in the near-shore where zebra mussels reside[12]. Local conditions in areas where zebra mussels live may be quite different from those at greater depths as found in the middle of the lake. Total Phosphorus concentrations, water temperatures, other nutrient concentrations, shoreline erosion, pH, etc. all play a role in defining water quality in these areas.



[12] Sampling locations are governed by the parameters used by the Lake Partner Program to ensure consistency of data collected from hundreds of lakes by hundreds of volunteers.

12.0 White Lake Loon Report

We are happy this year to have multiple inputs into our annual Loon Survey Report. All of the participants are naturalists and/or photographers and know loons and their behavioural habits very well. The reporting is 'in their own words' and are interesting to read. The last section details the cause of death of a loon found on White Lake this year.

1. **Loon Report and Wildlife Observations: July 1 to 8, 2023** Joyce Bentham and Robert Carrière

Our annual visit to White Lake was pleasant with good food, good friends and lots of Loon photographic opportunities. After the paralyzing heat wave of June, we were pleasantly surprised by wonderful weather; warm and moderate. This year the northeastern forest fires left a light haze above the lake which was occasionally accompanied by the smell of a camp fire. The air was particularly calm with two or three days of perfectly still water with barely a ripple.

We noticed that aquatic plants in the lake appeared to be denser and more prolific than in previous years, particularly in Sunset Bay. In fact, we also observed a greater density of aquatic vegetation in the area below the Hardwood Island chain of small islands, (shown on map below as #1) also in Eggshape Bay and the far reaches of Three-Mile Bay. These plants often necessitated their removal from our propeller by partly lifting the engine and/or running it in reverse.

The good news is that after a few years of not sighting any loons in Sunset Bay, we did notice on different occasions, two or 3 single loons swimming within the Bay area.

It should be noted that this year we did not venture into the more remote areas of White Lake such as Hayes and Bane Bays.

Even though we were focussing primarily on Loons, it was a pleasant surprise, on a few separate occasions, to observe a young doe browsing in the tall grass on the eastern side of the island below Hardwood I. (#5 on the map). It reminded us warmly of our first visit to White Lake where a doe was observed swimming and island hopping in the same area.

Our reporting on loon populations in White Lake over the years indicate that that the loon population is holding with some yearly fluctuations. No doubt the increase usage of the lake and recent new cottage constructions on its shoreline will continue to challenge loons trying to build a safe and secure nest. Ornithologists have noted that loon populations in North Eastern America are decreasing partly because of increased recreational access and use of our lakes and rivers resulting in loss of habitat.

Detail of Loon and Wildlife Observations

Note: The numbered comments below correspond to identified sites or locations shown on the map attached below.

After leaving the marina on the northeastern shore of White Lake, we were greeted by the first sighting of loons as we entered the Kitty Island/Ryans Point area. A single loon, near the grassed area off the western shore and two more adult loons just before the rocky islands were observed. More single adult loons spotted near Stanley Island. Our first outing took us to the south end of the lake at map point one.

1. The large grassed area at the Broad Brooke inlet produced one pair of adults and one chick; very small but actively fed by the adults.
2. The small bay located near the Sunset Bay channel (Burnt Point) had two adults with a single chick. We ventured into Sunset Bay and found 2 single adults swimming independently and one more adult near the boat launch area. We made repeated visits but never could find a nesting site or adults with chicks. On the west side of the lake near and across the last island of the Hardwood Island chain, three to four adults were observed in late afternoon actively diving and feeding.
3. A blue heron was spotted feeding on the rocky shoreline.
4. On the eastern shoreline two adults were feeding next to docks and rocky shore. No chicks were observed. Four adults we seen at the entrance to Three Mile Bay in the centre of the bay.
5. Majestically situated on the tallest tree at the entrance to the channel between two of the Hardwood Islands, is the Osprey nest as active as it was last year; two very noisy chicks begging for food keeping parents active in and out of the nest. They were trying out their wings but had not left the nest yet. Directly below them, in the small cove, was a loon nest active in 2022 but empty this year.
6. We visited the old loon nesting site on the northeastern tip of the island at the entrance to the shallow channel. The nest was partly flooded and not in use. Our activities there disturbed an adult duck with 5 little ducklings were weaving in and out of the tall grass.

7. We frequently observed two adult loons in and around the small bay on the western shore opposite McLaughlin's Island. This area appeared to be a meeting place for adult loons in late afternoon. We did not find a loon nest in the area but did startle a small fox.
8. Except for the occasional lake gull, this site was otherwise vacant.
9. Along the south shoreline of Three-Mile Bay we spotted adult geese with at least 15 goslings following in tow. One of the few large bald eagles seen was observed high above the Bay circling but giving no clues as to where his/her nest might be. Three or four adult loons were observed feeding in the centre of the Bay totally unnerved by the fact that they were sitting on the main channel used by boaters.

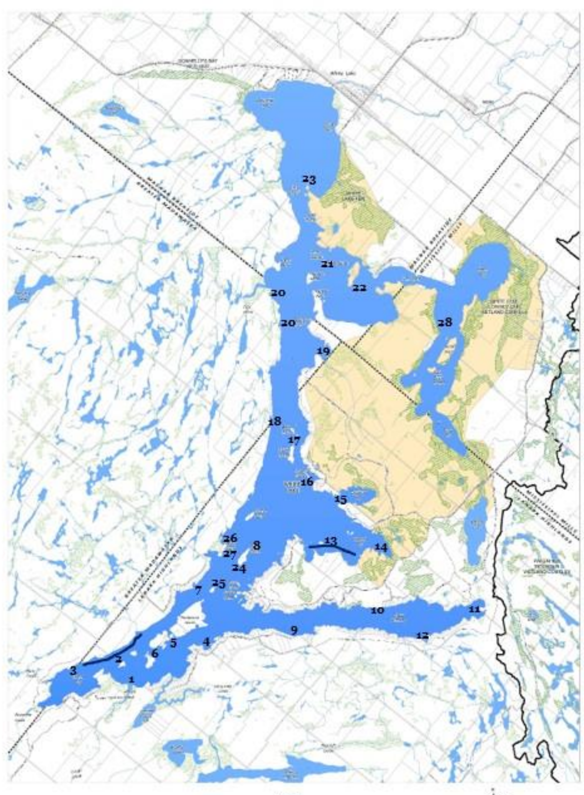
10. Across from the Cedar Cove Resort beach, a single adult loon was swimming near the southern shoreline and was so close to the shore that it may have been guarding a nest or female still brooding.
11. The far end of Three Mile Bay was deserted of loons. In past years, we remember spending hours at this location logging the activities of a pair of loons with chicks. This location has now been emptied of loons for 3 years. The water there is loaded with vegetation and clouds of green nuisance algae floating just below the surface.
12. Moving west on the south shore of Three-Mile Bay 2 adult loons and one medium size chick were spotted.
13. Towards Pickerel Bay, at the entrance to the south cove, we searched for the nesting site on a small island with an apparently abandoned cottage. The nest was found, in good shape but vacant. We did observe 2 adults with one medium size chick who evaded us by going into the bay. The eternal Osprey nest in the centre of Pickerel Bay was quite active with two chicks flapping their wings in preparation of fledging. Repeated visits to the area produced sightings of 3 single adult loons swimming at the entrance to Pickerel Bay. On Tuesday of our week at the lake, we observed (for three hours) two adult loons actively feeding two larger chicks.
14. The far end of Pickerel Bay was very active in previous years, but was very quiet this year with no loons observed.
15. Eggshape Bay was very congested with plant life. In some of the shallow areas where we once could clearly see the bottom is now totally grown over such that we needed to clear the propeller a few times.
16. Exiting Eggshape Bay and heading north, there is a shallow cove with some rocky islands. As was the case in previous years, the area had two sets of adults with two chicks each.
17. Stanley Island, yielded one adult loon. The eagle's nest behind the cottage on Stanley Island seems abandoned and in disrepair. The north end of the island produced a duck and six ducklings swimming within the rocky outcrop. One single adult loon and a pair of adults with two small chicks were observed twice but must have moved on and were not seen again in the same area during the rest of the week. A Blue heron, very intent on feeding, near the large rock outcrops was oblivious to our presence. The lake, being very calm, allowed us to be stationary for quite a while.
18. Except for the occasional Blue Heron, which flew from cove to cove while feeding along this stretch of shoreline, this location was devoid of loons.
19. In the large bay, south of Deadman's Island, two single adult loons were observed swimming independently. The Osprey nest near the cottage was gone as the tree was damaged but there appeared to be a new nest further inland. We could see the adult Osprey flying in and out but the nest was beyond our line of site. Near and just below Deadman's Island, were a couple of adult loons with two chicks. The Channel leading to White Lake Marina was relatively quiet mid-week. A few single loons patrolled the area of Andrews Island and Myrtle Island and were sighted repeatedly.
20. More Blue Herons were observed fishing off the western shoreline just below the entrance to Fish Creek. We ventured deeper into Fish Creek Bay using our electric trolling motor but did not discover any loons. We did observe during late afternoon or early evening groups of 5 to 7

adult loons assembled at the entrance in the shallows in what appeared to be a social feeding ritual.

21. North of Myrtle Island, along the shoreline towards the White Lake Marina, a previously very active area, we spotted a couple of adult loons actively feeding their two small chicks.
22. We did not venture deeper into The Channel, for fear of fouling our propeller in the dense weeds along the shore.
23. This location was not visited this year.
24. The eagle's nest behind the cottage on Birch Island is no longer occupied and in disrepair. However, on the backside of Birch Island was an adult Osprey feeding two junior Osprey that had fledge. The chicks were flying from tree top to tree top while being fed but we could not figure out where the nest site was located. In the north end of Birch Island, we observed 2 adult loons and two chicks.
25. In the open area between the east side of McLachlin's Island and the entrance to Three-Mile Bay, there were late night gatherings of loons. Loons flew in and out and mingled before calling out at night. These are most likely the same loons previously observed during daylight hours tending to the chicks in other nearby bays. The bay at the northeast end of Hardwood Island was harboring a couple of loons with two chicks but were observed on only two occasions, having no doubt moved to a better feeding area.
26. Curley's Island had a vacant eagle's nest and we are not sure if it was used this year.

Loon Observation Sites

July 1 – July 8, 2023



2. White Lake Loon Report: July and September 2023

-Brian Houle and Nora and Donnie Gordon

This survey (BH) was conducted over the month of July and included most of White Lake. A supplementary survey was conducted on a single day on September (N&DG) and included all parts of the lake.

The time of year for taking loon surveys is important. Early in the season, it is possible to miss chicks which have not yet hatched and later in the summer, some of the chicks may have been lost to predation and/or boating encounters.

Perhaps the most difficult population to monitor is the single adult or young adult. Lone birds on the lake or loons engaging in group communal feeding may be part of a nesting pair located in another part of the lake.

Care should then be taken when tallying up the total number of loons on the lake. From past experience, it is reasonable to assume that there are at a minimum ten unattached loons on the lake at any given time during the summer months.

This year we are fortunate to have three sources of data on the loon population of White Lake. The numbers counted for nesting pairs and chicks are close and so in this case, the higher number is accepted as accurate. Statisticians know that when counting objects, such as loons, cottages, boats, etc. the more accurate the count, the higher the count number will be.

Note, that early in the June survey, 2 loon chicks were lost. In the September survey, it was found that an additional 2 chicks were lost. It is not uncommon that only 50% of the chicks produced in a given year survive to adulthood.

2023 White Lake Loon Survey Results	
Nesting Pairs	19
Chicks	22
Total Adults	48

The results in the above table compare very well with the best seasons we have recorded since 2013. Clearly, White Lake is great habitat for loons. White Lake is a shallow and very productive lake producing a good supply of feeder fish for all aquatic species, both fish and fowl.

Deceased Common Loon on White Lake

On May 23, 2023 we received a report of a dead loon on White Lake. Two observant residents of the lake spotted a loon thrashing about as though it was in distress. Located near Hardwood Island, the loon soon died. Two additional loons stayed with the dying loon until it died.

On the advice of the Canadian Wildlife Health Cooperative the loon was recovered in a manner that would not expose anyone to possible pathogens. The loon was picked up and sent to a laboratory for analysis.

The final diagnosis was death by severe aspergillosis. Tests for avian influenza were negative. The internet provides the following information on the fungal infection:

Spergillosis is an infection caused by Aspergillus, a common mold (a type of fungus) that lives indoors and outdoors. Most people breathe in Aspergillus spores every day without getting sick. However, people with weakened immune systems or lung diseases are at a higher risk of developing health problems due to Aspergillus. The types of health problems caused by Aspergillus include allergic reactions, lung infections, and infections in other organs.

Between 5 and 10% of loons die from this fungal infection

Conrad Grégoire and David Overholt
Environment Volunteers, White Lake Property Owners Association


Photo by Joyce Benham

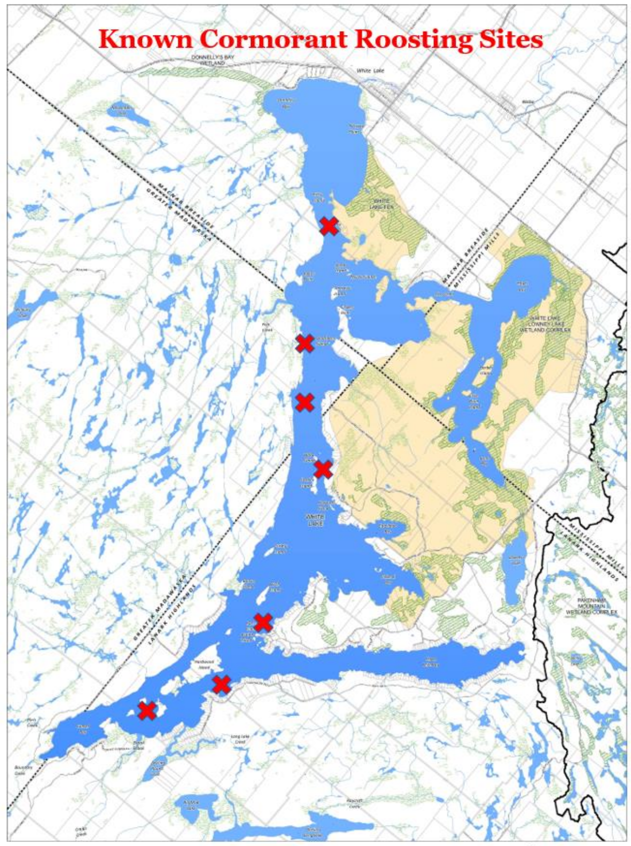
13.0 Double-Crested Cormorant Count

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.

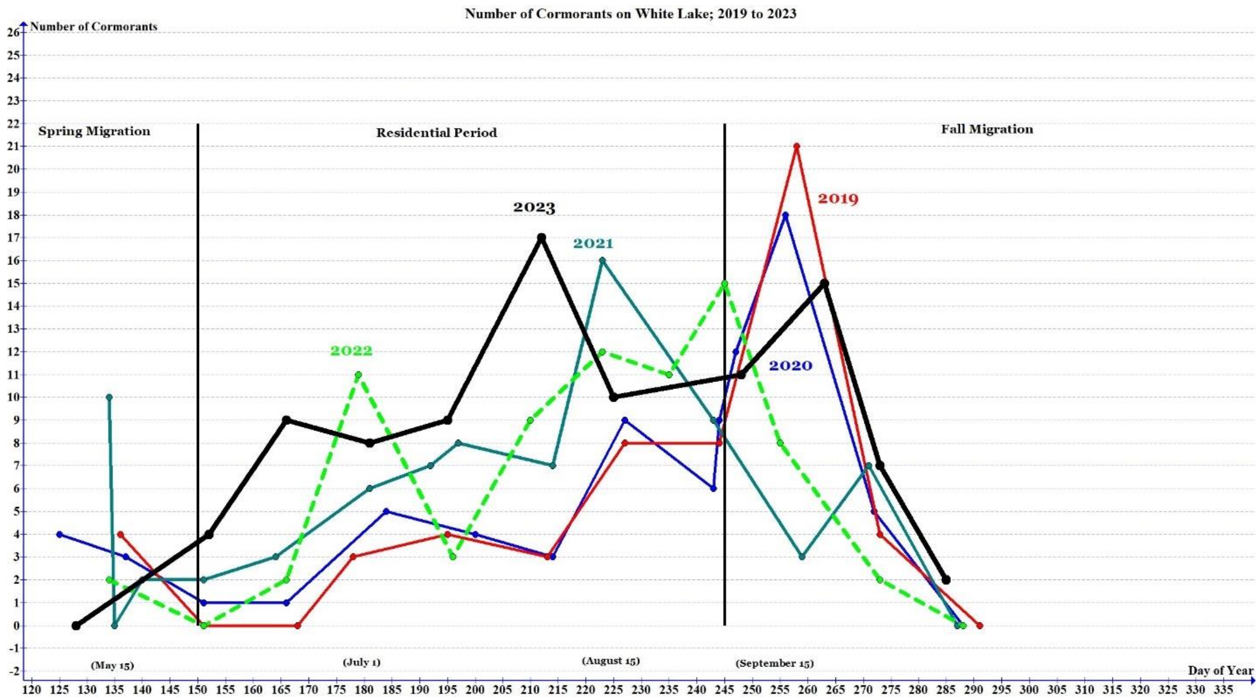
Cormorants have been using White Lake for many years. However, their numbers have always remained small. In recent years, we have noticed that the White Lake population of cormorants may be increasing.

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 five consecutive years. The black line is for 2023.

Graph of Cormorant Numbers Observed by Day of Year: 2019 to 2023

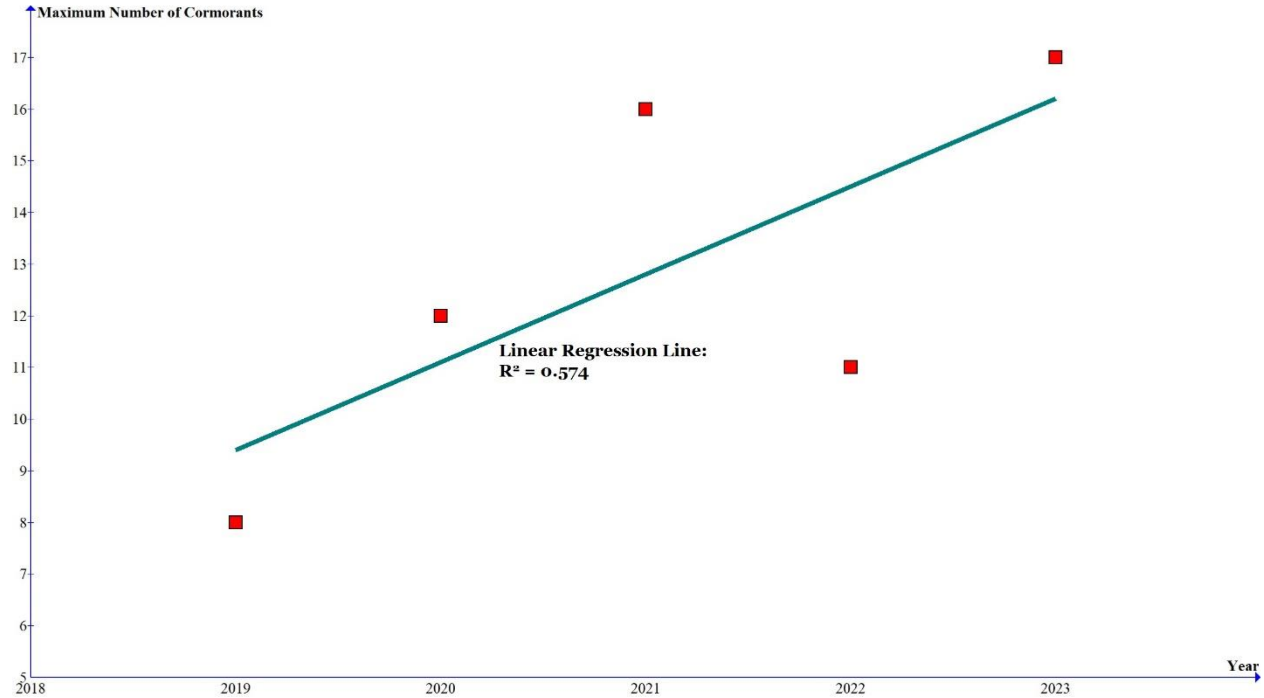


The graph is divided into three sections marked by the two vertical black lines. During spring, as well as at the end of summer, larger numbers of cormorants are often observed. Most of these birds are migrating to other sites and only stop and linger at White Lake for a week or so.

Of greater interest are bird counts taken during the residential period (middle section of the graph). 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 currently less than twenty cormorants making White Lake their home. Taking into account the presence of non-reproductive juveniles, this translates to about 5 to 6 nesting pairs.

The graph below shows the maximum number of cormorants observed on the lake during the nesting period. The green line is the best fit line for these data and indicate that the population of cormorants on White Lake is increasing. The rate of increase over the last five years is about 1.3 cormorants per year.

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.



Canada Geese – White Lake Village

14.0 Selected Environment Bulletins – 2023

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 2023 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 Website.

14.1 What's Going on Down Under?

Dissolved Oxygen

Oxygen is an essential element in any aquatic system. The amount of oxygen dissolved in lake water varies from day to day and even between night and day. Most of the dissolved oxygen in lake water comes from the atmosphere and becomes dissolved into lake water by the action of wind and waves. Oxygen concentration varies significantly with water temperature, with colder waters able to contain more oxygen in solution than warmer waters. Oxygen is also produced during sunlight hours as a result of photosynthesis by phytoplankton and aquatic plants. It is consumed by these same plants during the night, when no photosynthesis can occur, and by the decay of organic materials at the bottom of the lake.

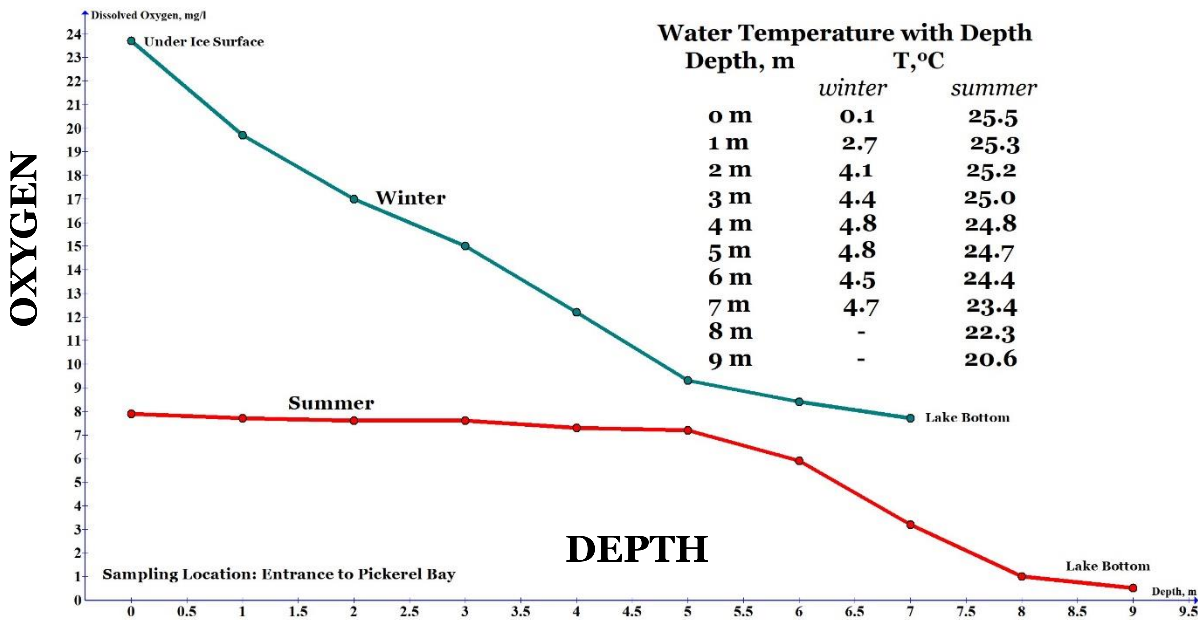
The concentration of oxygen in the water column can seriously affect fish populations. If dissolved oxygen concentrations dip below about 5 mg/L, fish stocks can be severely stressed or even die. Oxygen levels of from 7 to 11 mg/L are good for most fish and other aquatic organisms.

What Happens to Oxygen Levels in Winter Under the Ice?

During winter, ice covers the lake signalling a change in the water below the ice. During summer, the action of the wind and waves constantly mixes the lake as well as exposes water to the atmosphere where it becomes charged with oxygen. In winter, the lake is trapped under the ice and another force is predominant in ensuring the lake is well mixed.

Water Sampling During Winter: Entrance to Pickerel Bay

Because the density of water is at its maximum at +4°C, water expands when heated above or cooled below this temperature. On the frozen lake, water just under the ice is cooled while water at the bottom of the lake is warmed by the sediment. The resulting density difference between the top and bottom waters causes warmer water to constantly rise from the bottom of the lake and cooler water to descend. This effect also explains why even a shallow lake like White Lake does not freeze solid from top to bottom.



The table contained in the graph above shows that in winter, the water temperature is close to a constant 5 degrees from a depth of 2 metres and below. More importantly, the graph shows that the concentration of oxygen dissolved in lake water is far more at all depths in winter than during the summer. A combination of factors is responsible for this: first, lake water can hold more oxygen when cold; second, there is less bacterial action in sediments and less oxygen demand from living things in cold than in warmer waters. This means that both fish and ice fisherman can be happy throughout the winter months!

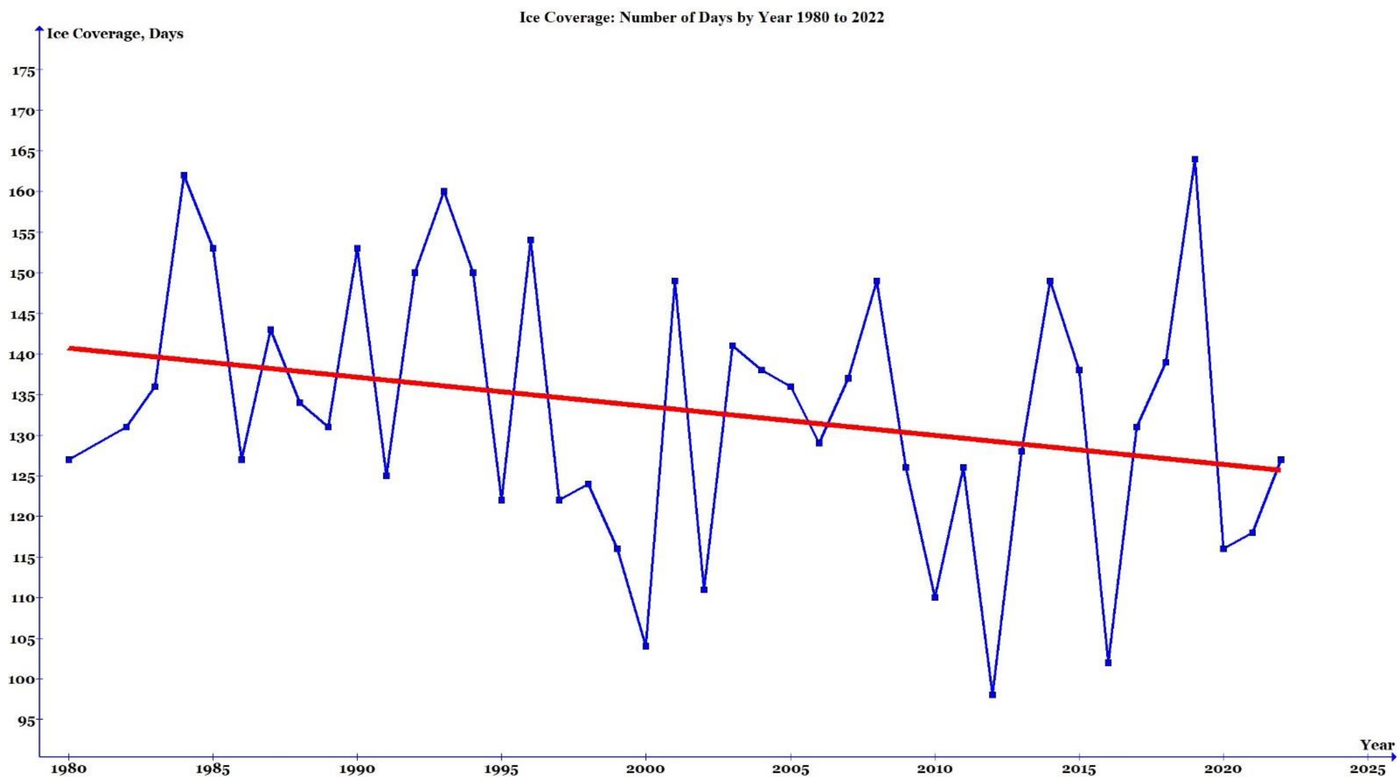
If You Really Want to Know........

The maximum amount of oxygen that can be dissolved in water is not the same in warm and cold waters. For example, water with a dissolved oxygen level of 7.7 mg/L at 4.7 degrees Celsius is 60% saturated whereas an oxygen level of 7.7 mg/L at 25.3 degrees Celsius is 94% saturated clearly illustrating that warmer water cannot hold as much oxygen in solution as colder water.

14.2 Decline in Duration of Ice Cover on White Lake Since 1980[13]

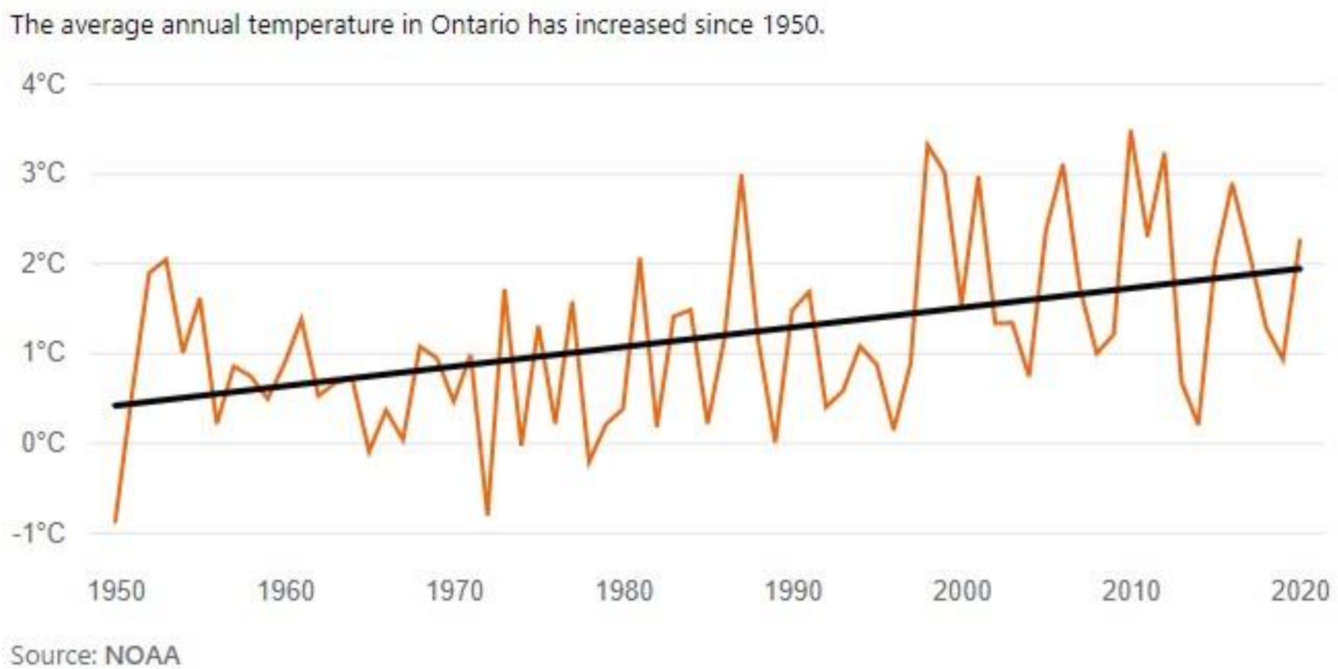
Even before the formation of the White Lake Property Owners Association, White Lake cottagers and residents were keeping track, on an annual basis, of the duration of the ice cover on the lake. Useful data sets were recorded starting in 1980 and are presented in the table below.

The significance of this data is not evident from the table, however when presented graphically, new information can be gleaned. The blue line in the graph below is the actual ice cover duration times by year. This line shows significant annual variation that is, to some extent, caused by changing weather patterns. When the same data is subjected to a least squares statistical analysis, a straight 'best fit' line is produced (in red) which clearly shows that ice cover on White Lake is decreasing over time. In fact, since 1980, the ice cover time has decreased by 15 days. This change in ice cover times is very likely the result of climate change which, in turn, effects the weather.



13 Data Source: White Lake Property Owners Association

The graph below shows the change in the average annual temperatures in Ontario since 1950 and includes the period during which our data was collected. The straight line (least squares) shows that the average temperature has increased by 1.6 °C since 1950. These increased temperatures validate the trends that we observe in our own ice-date data.



A shift towards longer ice-free seasons can impact the physical and chemical properties of the lake. We now have an extra 15 days of cottaging or lake-time during which additional nutrients can enter the lake. The longer ice-free season will promote the growth of aquatic plants and increases in water temperature could promote conditions that will be favourable to the growth of algae including blue-green algae (cyanobacteria).

14.3 White Lake: Inlets and Outlet

White Lake contains about 75 million cubic metres of water; where does it come from?

One obvious source is rainfall. Each year, an average 0.5 metres of rain falls onto the surface of White Lake. Considering that the average depth of White Lake is 3.1 metres, that would account for about 16% of the water in the lake[14].

The remaining 84%[15] comes from surface runoff, ground water flow, and streams. An extensive study completed in 2018[16], showed that most of the water derived from these sources comes from ground water flow (springs) and a smaller proportion comes from streams and surface runoff. Input from streams is most inportant during the spring melt.

Inlets:

As shown on the map below, there are over a dozen streams bringing water into White Lake. Most of these streams are unnamed because they run only in the spring and are dry for most of the year.

There are six major streams which flow continuously: Long Lake Creek, Raycroft Creek, Broad Creek, Boundary Creek, Paris Creek and Fish Creek. With the exception of Fish Creek, all of the creeks are located on the southern end of the lake.

Four of the creeks carry waters which are close in compositon to that of the lake. Paris and Fish Creeks are exceptional because their waters are very soft and low in dissolved salts, especially calcium. These two creeks, and all smaller unnamed creeks between them on the western side of the lake are also soft.

The low calcium contents of Paris and Fish Creeks prevents the growth of zebra mussels. This means that pickerel spawning grounds near these streams are not fouled by the

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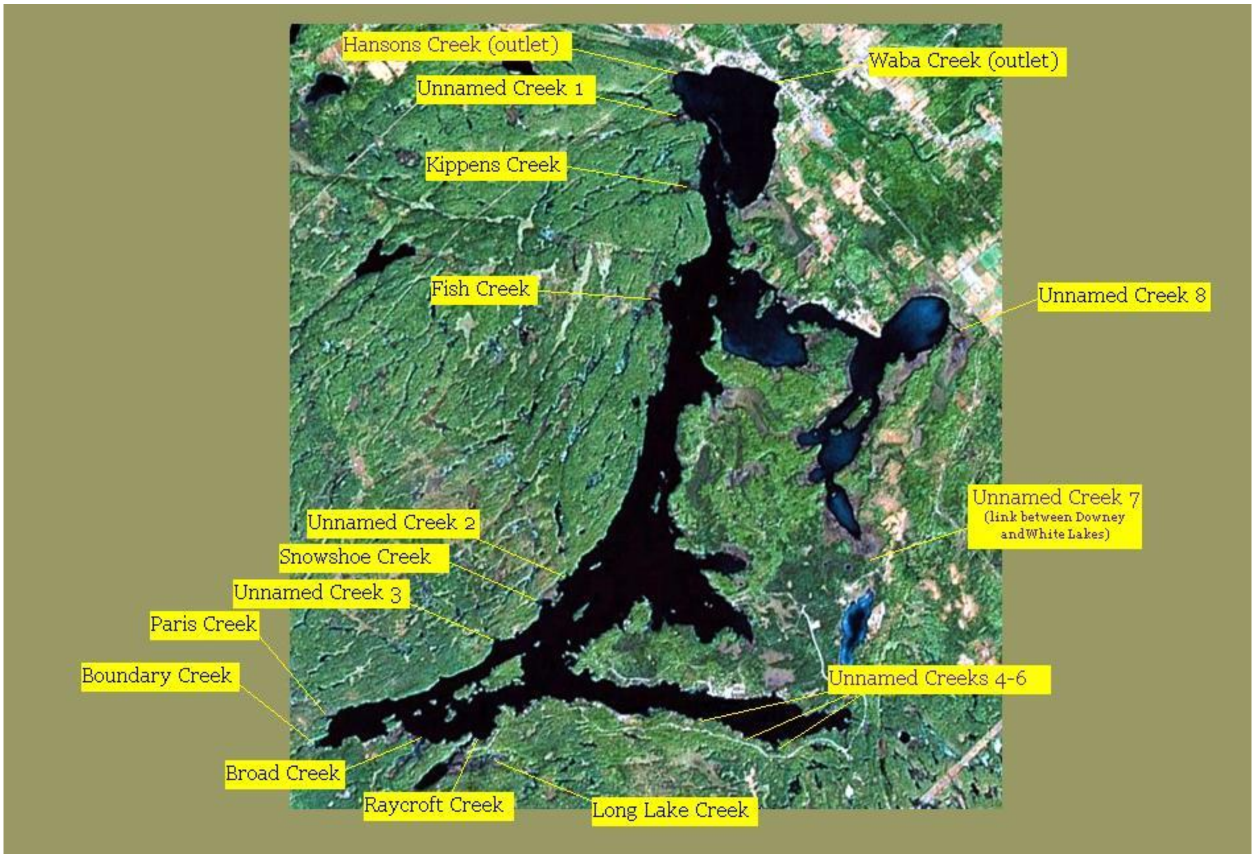
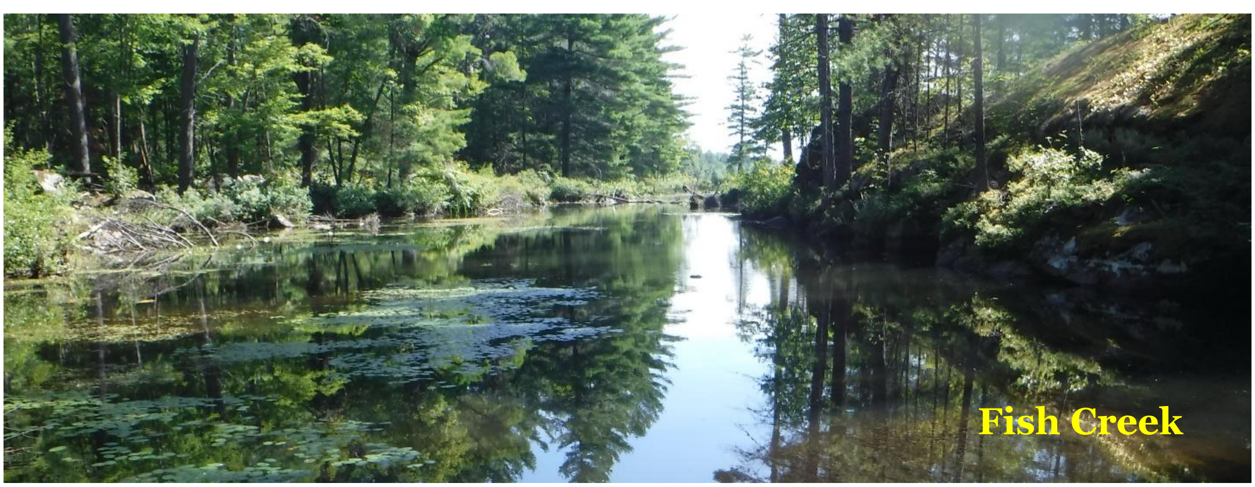
[14] White Lake flushes itself about once per year.
[15] 2017 White Lake Water Quality Monitoring Report, page 71; 2019 White Lake Water Quality Monitoring Report, page 68.
[16] 2018 White Lake Water Quality Monitoring Report, pages 47 to 58.

presence of zebra mussels. This may partially explain why the pickerel fishery in White Lake has not been adversely impacted by this invasive species.

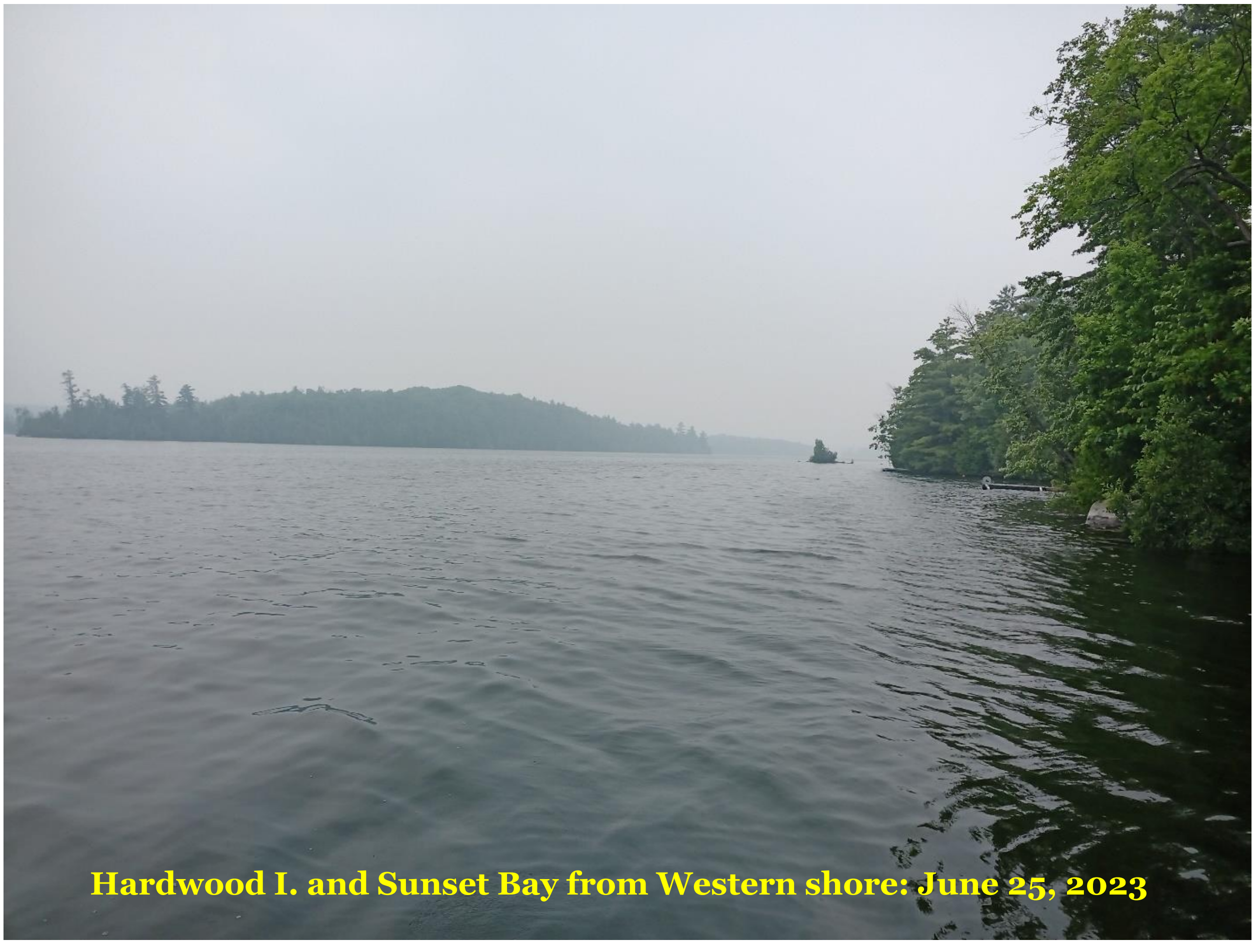


Outlets:

Most are familiar with the single active outlet on White Lake which is at the dam at Waba Creek. But in the past, there were two outlets. The second was Hanson's Creek (upper left on map) which is no longer active since the construction of a dam at Waba Creek.



14.4 Smoke!

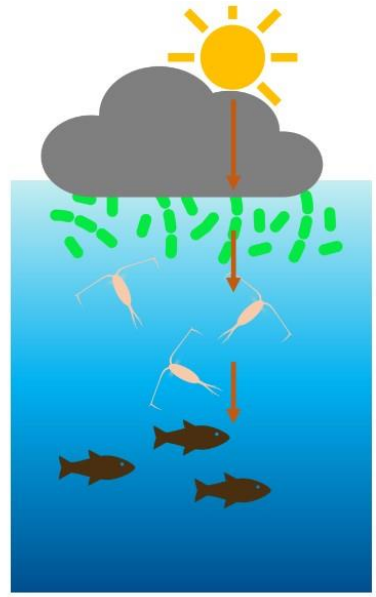

Hardwood I. and Sunset Bay from Western shore: June 25, 2023

Wildfires are a phenomenon which can burn large swaths of forest. They can be started by lightning strikes or human activity. With climate change and global warming taking effect, these fires are becoming more frequent, occurring earlier in the season and burning with greater intensity. Very large fires in remote areas may be impossible to control and can only be extinguished when they run out of fuel or are contained by changing weather conditions, such as rain or wind direction.

A recent forest fire on nearby Centennial Lake highlighted the dangers of these fires in our area, and large persistent fires in Northern Québec have brought high levels of smoke to our region. A reasonable question is how forest fire smoke affects the ecology of a lake such as White Lake.

Wildfire smoke is made of a combination of particles, gaseous pollutants such as carbon monoxide and other irritant compounds both organic and inorganic. If the fire is very close to a lake, then remnants of burned plants and soil can flow into the lake when it rains. Materials swept into the lake in this way can act as 'fertilizer' promoting the growth of aquatic plants including algae.

When only smoke is present, as it is this year at White Lake, effects can be more subtle and dependent on the density and duration of smoke cover. There are few studies published on this topic but they generally agree that the most significant effect is the reduced sunlight reaching the lake.



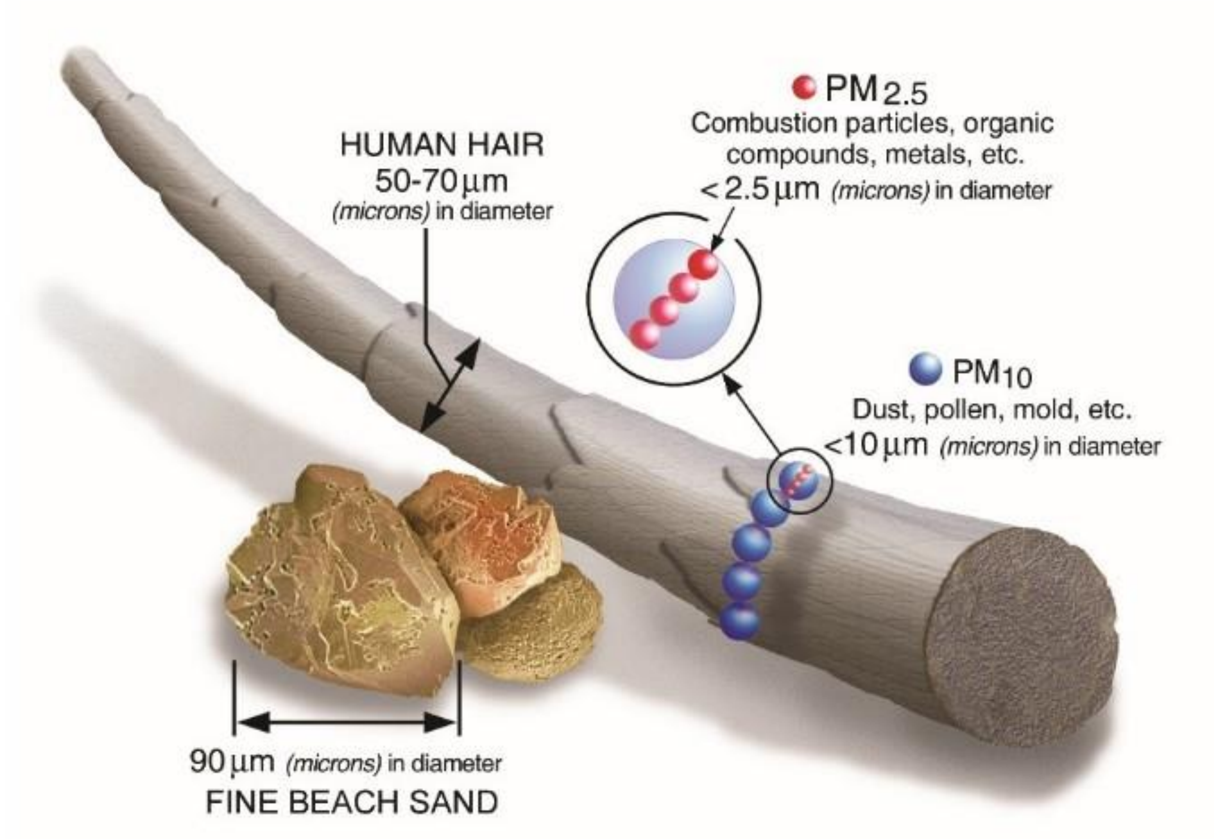
All food comes from the sun which is first used by tiny phytoplankton which are fed upon by zooplankton which are then consumed by increasingly larger insects and fish. The diagram to the right is a simplified depiction of this food chain. The diagram also shows a grey cloud blocking out sunlight.

The main effect of a smoke cloud cover over a lake is to increase the production of phytoplankton in shallow water because of the presence of fertilizing smoke particles. However, phytoplankton production in deeper water is reduced because of floating particles blocking sunlight making photosynthesis more difficult while at the same time reducing the temperature of the lake.

For White Lake this year, the presence of smoke has likely not lasted long enough to result in significant changes in lake ecology. If rain falls through a smoke cloud, however, the suspended particles in the atmosphere will be washed into the lake which may then result in some measurable changes in lake chemistry.

What about us? A smoky atmosphere can be dangerous to wildlife and human health. 90% of fine particles in forest fire smoke is composed of particles less than 2.5 micrometres (millionths of a metre) in size. These particles are also known as $PM_{2.5}$. This group of particles also include ultrafine particles with diameters of less than 0.1 micrometres.

The diagram below compares the size of these particles to more familiar items such as human hair, pollen and fine beach sand.



The danger from the very small particles is that they are so small that once they enter the lungs, they may remain lodged there permanently and may even enter the bloodstream.

External symptoms include a scratchy throat, cough, irritated sinuses, headaches, runny nose and stinging eyes. For those suffering from lung diseases such as asthma or chronic bronchitis as well for older individuals with reduced lung function, exposure may result in a worsening of symptoms and difficulty breathing.

When forest fire smoke is present, stay indoors as much as possible and wear a filter mask when outdoors.

14.5 White Lake Wild Rice

Wild Rice[17] found in White Lake is Northern wild rice (*Zizania palustris*) and is native to the Great Lake region of North America, the aquatic areas of the boreal forest regions of Northern Ontario, Alberta, Saskatchewan, and Manitoba. Although very likely a native species in White Lake, there are anecdotal reports that duck hunters seeded the lake during the 1940s[18] to attract ducks to the lake.

Wild Rice near Hardwood Island

Wild rice is Canada's only native cereal. It is a wild grass that grows from seed annually and produces a very valuable grain that has been used as a food source for thousands of years by the First Nation peoples in parts of North America. In September, during the rice-harvesting season, muskrat, fish, ducks, geese, and migratory birds feed on ripe wild rice seeds. Wild rice filters the waters, binds loose soils, provides protection from high winds and waves along the shorelines, and provides habitat for species at risk, such as least bittern and black terns.

The entire wild rice plant provides food in the summer for herbivores such as Canadian geese, trumpeter swans, muskrats, beavers, white-tailed deer, and moose. In addition to this, rice worms and other insect larvae feed heavily on natural wild rice. These then provide a rich source of food for small marshland birds. The stems of wild rice provide nesting material for such species as common loons and muskrats. Every stage of growth of natural wild rice provides food and habitat for wildlife; as a result, wild rice stands provide exceptional breeding and nesting areas for an abundance of species.

The life cycle for wild rice is simple. In the late summer, the ripened seed drops off the stem and sinks to the sediment, where it remains dormant until the following spring. Low oxygen levels and warmth typically stimulate germination, but some seeds may remain dormant for five years or longer, which allows the rice to survive occasional crop failures. After germination, there are three distinct growth phases that occur. The seed first begins to sprout in early May when the water temperature reaches about 7 °C. For the first three

[17] Abstracted in part from Plenty Canada website: https://www.plentycanada.com/wild-rice--aquatic-ecosystems.html, and Wikipedia.
[18] Doug Tilley, personal communication.

or four weeks of growth, the young plants are under water, which is the defining characteristic of the submerged leaf stage. Then, as the long, thin leaves begin to float on the surface of the water, this becomes the floating leaf stage of growth. Finally, the rice will then grow up out of the water into an upright position to reach the growth stage when it is a mature wild rice plant. Wild rice has a growing season of 106 to 130 days.

White Lake has long supported wild rice beds in many parts of the lake. Over the past several years we have documented the presence of wild rice on the lake. During the summer of 2018, we noticed that wild rice beds in the Village Basin area had increased considerably and now covers a significant area in this basin. This observation led to a complete study of the entire shoreline and shallow areas of White Lake in order to document the areas of wild rice.

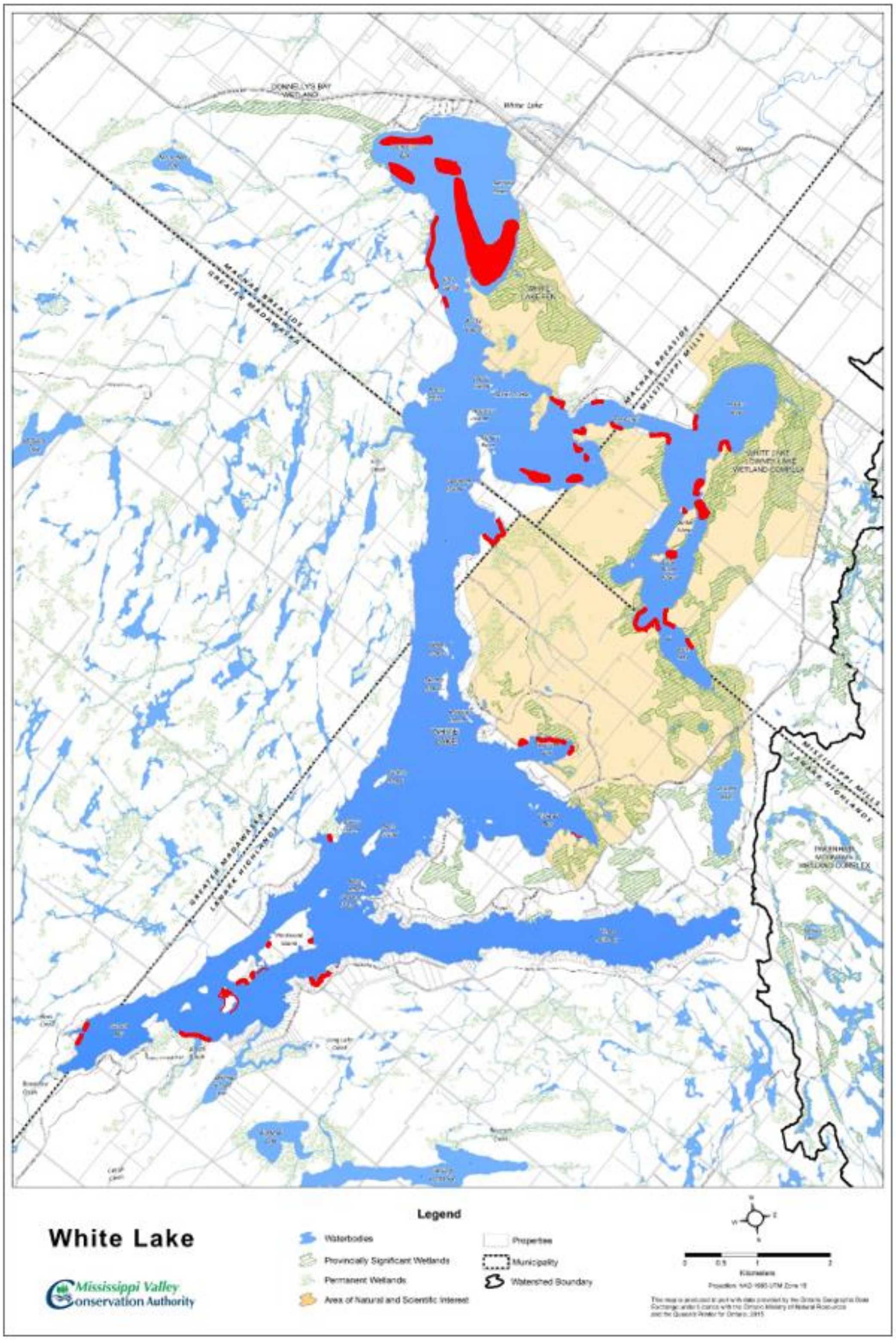
As a result of our survey, we have produced a map showing the locations of wild rice beds.

Wild rice was found in most parts of the lake with the exception of Three Mile Bay and most of the western shore except at Sunset Bay, Barry's Island, and the Village Basin.

Clearly there is not enough rice to harvest in quantity and for this reason, it is best to simply allow local wildlife to enjoy this bounty.

Wild Rice: White Lake Village Basin

Location of Wild Rice Beds on White Lake

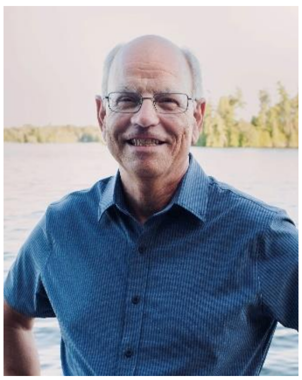


PART IV
Acknowledgements
and
Author Profiles

15.0 <u>Acknowledgements</u>

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 <u>Author Profiles</u>



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 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.

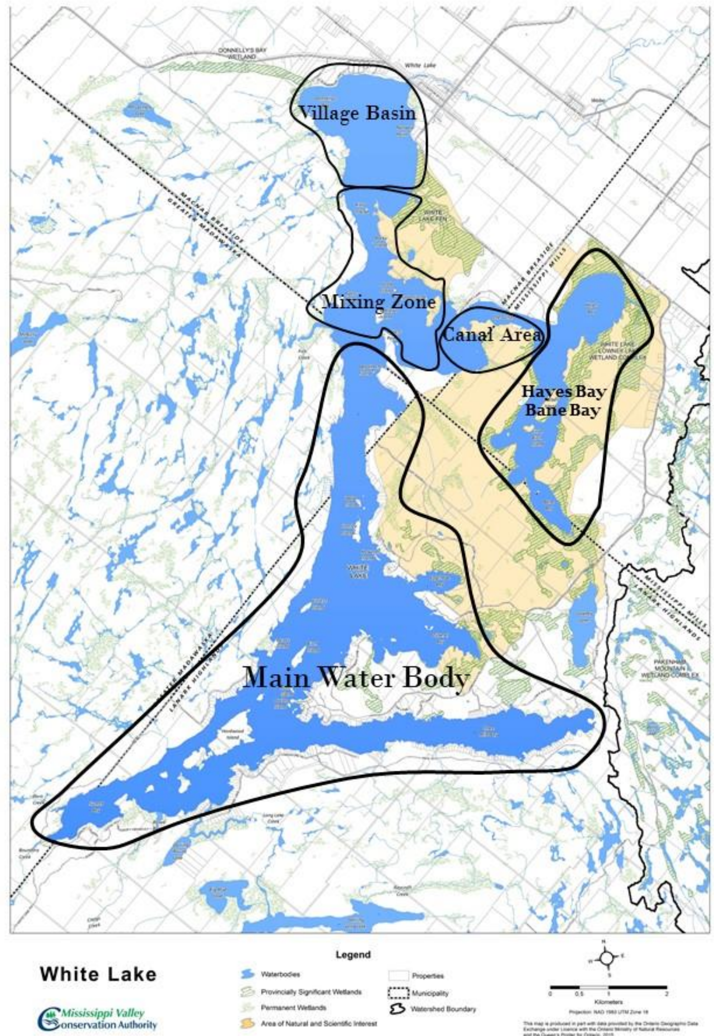
PART V
Appendices

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 – 2023

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

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Total P, ppb	Ca, ppm	Cl, ppm
May 8	9:04	127	4.1	13.2	11.2,12.6 (11.9)	31.8	3.4
June 1	9:09	152	4.6	22.0	-		
June 15	9:03	166	3.2	19.5	12.0,13.2 (12.6)	32.4	3.6
June 30	10:10	181	3.2	22.8	-		
July 14	9:05	195	3.7	23.8	18.3,16.0 (17.2)	32.1	3.6
July 31	9:09	212	2.9	23.2	-		
August 13	9:03	225	4.2	21.8	13.0,12.7 (12.9)	29.5	3.6
September 5	9:14	248	5.1	23.0	-		
September 20	9:03	263	5.4	19.6	10.0, 10.8 (10.4)	26.1	3.7
September 30	9:04	273	>depth	18.4	-		
October 12	9:59	285	>depth	15.2	11.1,11.3 (11.2)	28.7	3.8

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

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Total P, ppb	Ca, ppm	Cl, ppm
May 8	9:18	127	3.7	12.6	12.8,11.6 (12.2)	30.6	3.3
June 1	9:21	152	4.5	21.0	-		
June 15	9:16	166	3.5	19.5	13.3,12.2 (12.8)	31.9	3.6
June 30	10:21	181	3.2	22.9	-		
July 14	9:23	195	3.2	22.9	13.6,14.5 (14.1)	31.9	3.6
July 31	9:23	212	2.9	23.0	-		
August 13	9:21	225	4.3	22.0	13.2,12.9 (13.1)	29.9	3.6
September 5	9:49	248	4.7	23.0	-		
September 20	9:26	263	5.3	19.5	10.5,10.5 (10.5)	26.9	3.7
September 30	9:15	273	>depth	18.5	-		
October 12	10:10	285	>depth	15.5	11.9,12.2 (12.1)	28.7	3.8

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 8	9:37	127	4.1	12.3	-	-	-
June 1	9:39	152	4.8	21.8	-	-	-
June 15	9:36	166	4.7	19.5	-	-	-
June 30	10:36	181	3.4	22.7	-	-	-
July 14	9:38	195	4.9	24.1	-	-	-
July 31	9:32	212	3.0	23.3	-	-	-
August 13	9:37	225	4.9	21.9	-	-	-
September 5	10:04	248	4.0	22.8	-	-	-
September 20	9:40	263	4.8	19.8	-	-	-
September 30	9:26	273	6.2	18.4	-	-	-
October 12	10:20	285	7.4	15.9	-	-	-

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 8	9:41	127	4.4	13.1	-	-	-
June 1	9:48	152	4.1	21.7	-	-	-
June 15	9:45	166	3.9	19.5	-	-	-
June 30	10:46	181	3.7	22.8	-	-	-
July 14	9:50	195	5.1	23.9	-	-	-
July 31	9:37	212	3.1	23.3	-	-	-
August 13	9:48	225	4.7	21.9	-	-	-
September 5	10:12	248	4.0	23.3	-	-	-
September 20	9:52	263	4.7	19.8	-	-	-
September 30	9:53	273	7.1	18.5	-	-	-
October 12	10:21	285	7.5	15.8	-	-	-

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 8	9:55	127	3.9	12.0	10.1,9.8 (10.0)	31.0	3.6
June 1	10:00	152	4.2	21.9	-		
June 15	10:14	166	3.7	19.8	11.1,11.4 (11.3)	31.9	3.7
June 30	11:02	181	3.8	22.5	-		
July 14	10:04	195	5.1	22.2	13.1,15.7 (14.4)	32.1	3.7
July 31	9:49	212	2.9	23.4	-		
August 13	10:02	225	4.2	21.8	13.1,12.4 (12.8)	30.6	3.7
September 5	10:23	248	3.4	22.3	-		
September 20	10:06	263	5.2	19.8	11.1, 10.1 (10.6)	29.0	3.9
September 30	10:06	273	>depth	18.8	-		
October 12	10:44	285	>depth	15.7	10.7,10,9 (10.8)	29.5	4.0

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 8	10:10	127	>depth	14.2	7.8,8.4 (8.1)	30.8	4.5
June 1	10:15	152	>depth	22.4	-		
June 15	10:28	166	>depth	20.3	9.9,10.6 (10.3)	32.4	5.0
June 30	11:19	181	>depth	22.4	-		
July 14	10:27	195	>depth	23.6	10.2,9.8 (10.0)	32.0	5.2
July 31	10:00	212	>depth	22.0	-		
August 13	10:20	225	>depth	21.2	10.1,8.1 (9.1)	28.4	5.9
September 5	10:43	248	>depth	24.4	-		
September 20	10:24	263	>depth	17.5	7.6,8.0 (7.8)	27.0	5.3
September 30	10:19	273	>depth	18.0	-		
October 12	10:55	285	>depth	12.8	9.9,9.6 (9.8)	31.0	4.9

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 8	10:30	127	>depth	14.7	11.8,11.9 (11.9)	32.7	8.4
June 1	10:25	152	>depth	24.1	-		
June 15	10:40	166	>depth	20.5	7.1,6.9 (7.0)	34.6	8.9
June 30	11:27	181	>depth	22.4	-		
July 14	10:36	195	>depth	23.5	9.5,9.4 (9.5)	34.8	9.2
July 31	10:07	212	>depth	21.9	-		
August 13	10:30	225	>depth	21.3	8.2,8.8 (8.5)	32.2	8.8
September 5	10:50	248	>depth	24.4	-		
September 20	10:31	263	>depth	16.5	7.5,6.8 (7.2)	31.1	8.9
September 30	10:29	273	>depth	17.8	-		
October 12	11:01	285	>depth	11.8	7.3,6.8 (7.1)	36.4	9.6

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 8	10:37	127	3.6	11.0	6.9,6.5 (6.7)	31.8	3.7
June 1	10:58	152	>depth	22.1	-		
June 15	11:11	166	3.7	20.1	11.2,10.8 (11.0)	31.4	3.4
June 30	11:43	181	>depth	22.2	-		
July 14	10:53	195	>depth	24.3	14.4,14.2 (14.3)	31.3	3.8
July 31	10:19	212	3.8	23.0	-		
August 13	10:43	225	>depth	21.7	13.2,13.4 (13.3)	28.5	3.8
September 5	11:00	248	>depth	23.2	-		
September 20	10:43	263	>depth	19.5	9.8,9.8 (9.8)	26.4	4.0
September 30	10:47	273	>depth	18.7	-		
October 12	11:19	285	>depth	14.0	9.9,10.7 (10.4)	30.1	4.2

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 8	10:51	127	>depth	13.8	9.3,8.9 (9.1)	28.6	3.6
June 1	11:15	152	>depth	24.0	-		
June 15	11:25	166	>depth	19.9	8.1,8.0 (8.0)	31.4	3.9
June 30	12:00	181	>depth	22.3	-		
July 14	11:04	195	>depth	23.4	10.5,9.6 (10.1)	30.2	4.2
July 31	10:31	212	>depth	21.8	-		
August 13	10:58	225	>depth	21.0	8.2,8.2 (8.2)	27.3	4.0
September 5	11:11	248	>depth	24.2	-		
September 20	10:58	263	>depth	18.5	8.7,8.4 (8.6)	26.4	4.0
September 30	10:55	273	>depth	17.8	-		
October 12	11:30	285	>depth	12.0	8.9,9.6 (9.2)	30.0	4.2

Temperatures taken 1 m from bottom. B= bottom temperature

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.