WHITE LAKE Property Owners Association Environment Volunteers

REPORT

Water Quality Monitoring Program and Research Activities 2021

WHITE LAKE Property Owners Association Preservation Project

Water Quality Monitoring Program And Research Activities 2021

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Water Quality Monitoring Program Overview and Findings

1.0 2021 Water Quality Monitoring Program and Research Activities

Summary and Highlights

Conrad Grégoire PhD and David Overholt BA

1.1 Introduction

2022 marks the 9th year that we have been monitoring water quality in White Lake. A number of parameters are monitored which are indicative of water quality. This data, as well as reports in the scientific literature, form the basis of annual reports. Data obtained over a period of years is also studied for long and short-term trends. The more data we have the more accurate is our assessment of the state of White Lake

In this Summary Report we provide highlights of our findings for 2021. For a complete referenced account of our work, we ask that you access the White Lake Science and Information Website for full-length Water Quality Monitoring Reports as well as Special Reports on individual topics.

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”.

1.2 The State of White Lake

White Lake is a shallow warm-water lake with high productivity of both plant and animal life. As such, it is very sensitive to nutrient inputs.

One way to asses the impact that nutrient inputs are having on a lake is the number and frequency of algal blooms. Algal blooms are both a sign and a measure of declining water quality.

A recently published report traces the history of algal blooms in White Lake from 1860 to 2021. The detection of algal blooms prior to the construction of the concrete dam at Waba Creek is based on the analysis of sediments using special techniques. Algal blooms to 1977 are reported in the scientific literature and in reports published by the Ministry of the Environment Conservation and Parks. For the period starting in 1977 and ending in 2012 (25 years), no algal blooms were recorded.

Starting in 2013 and to the present, at least one algal bloom occurred in each of these nine years. Four algal blooms were recorded in 2018, two in 2019 and 2020. In 2021, there were 5 algal blooms. In each of these nine years, there was at least one blue-green algal bloom, some of which released toxins into the lake.

Annual algal blooms are a sign that White Lake is under stress and cannot absorb any increase in nutrients or other impacts of human activity, such as shoreline erosion.

Three factors combine to create this situation: lake overuse, invasive species, and climate change.

2.1 Lake Overuse

From 1977 to 2008, the number of cottages, trailers and commercial tourist units on White Lake have increased from 475[1] to 1538, an increase of 324%. Available numbers also show that from 1985 to 2018, permanent homes on White Lake increased by 354% to 209. These trends are continuing today with ever increasing human impact on the lake. More people spending more time using White Lake inevitably means greater amounts of septic system outflow, more and larger boats, etc.

2.2 Invasive Species

The presence of zebra mussels in the lake has changed the way phosphorus is cycled creating a near-shore zone where nutrients concentrate causing algal blooms in the spring and fall. This zone is depicted as the red line in the above figure.

Phragmites is slowly invading our marshlands and could eventually displace cattails and other native plants. Fish and other animals which depend on cattail marshes for reproductive purposes will be harmed. European milfoil is now resident and spreading in White Lake. There are a number of other invasive species including quagga mussels and a number of very harmful plants which could enter the lake soon if nothing is done to stop them.

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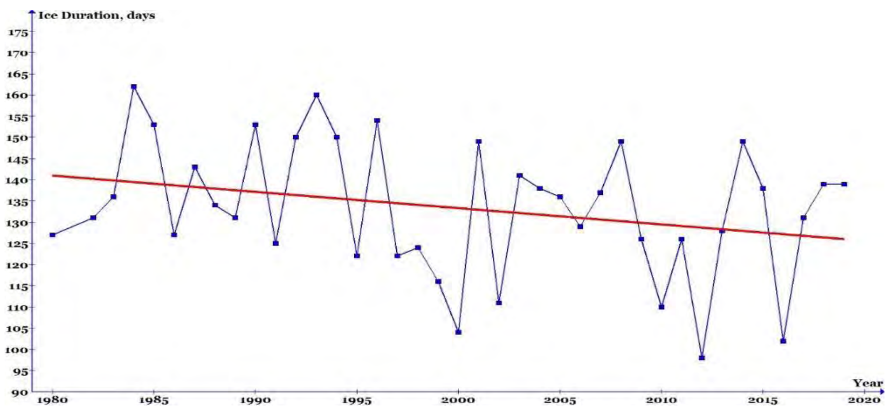
[1] J.P. Ferris, White Lake Integrated Resources Management Plan, Part I, *Ministry of Natural Resources, Lanark and Renfrew Counties, December 1985.*

2.3 Climate Change

Climate change is causing unpredictable and unexpected weather patterns. In recent years White Lake has experienced tornados, a microburst and high wind events causing damage to buildings and infrastructure. Low-snow winters, and prolonged periods of hot weather have resulted in lower water levels and higher water temperatures.

Since 1980, the ice-free season on White Lake has increased by nearly 2 weeks, as shown by the downward sloping redline on the graph to the right. This means that there are now two additional weeks per year for cottagers and residents to be at the lake and to be using the lake for residential and recreational purposes.



3. Algal Blooms - 2021

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.

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

In 2021, White Lake hosted four blue-green algal blooms: each twice and in two locations. These blooms occurred simultaneously in two occasions. The first on September 16, and the second on October 8, 2021. The two types of algal blooms were: Anabaena (now called Dolichospermum), and Microcystis. The Anabaena bloom occurred in the main body of the lake (deepest water), Pickerel Bay and areas along the eastern shoreline. The Microcystis bloom was located mainly in Three Mile Bay and adjacent areas.

The simultaneous occurrence of different types of blue-green algae has never been recorded before in White Lake. Prior to the infestation of White Lake with zebra mussels, only *Anabaena* blue-green algal blooms were recorded. Since the arrival of zebra mussels, only Microcystis blue-green algal blooms were observed. In 2021, we observed five algal blooms which is the largest number ever recorded for White Lake.

The Ministry of the Environment, Conservation and Parks (MOECP) reported that these algal blooms contained toxins at significant but not dangerous levels.

The map on the right shows the location, extent, and nature of the four blue-green algal blooms in White Lake. Other occurrences of these blooms in previous years have shown the same pattern of distribution. It is likely not a coincidence that the blooms are most intense in areas of concentrated lakeshore development such as Three Mile Bay, Pickerel Bay, and adjacent shorelines.

What Can We Do?

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.

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 just want to enjoy the lake.

This is when governments can intervene and take action to preserve White Lake. The people who are charged with managing the lake (with the assistance of the MOECP), are the Councils of the four municipalities sharing White Lake.

Since the Township of Lanark Highlands has both the greatest number of taxpayers of any municipality and the greatest number 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.

4. Total Phosphorus and Water Clarity

4.1 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.

Unfortunately, lower total phosphorus levels were not achieved by any improvement in lake usage, but rather because of a side effect of the presence of zebra mussels. Now, algal blooms occur annually when the total phosphorus level is about 10 parts per billion, which is below the Provincial Objective. The MOECP is now using a different measure in setting its new objective, which for White Lake is now 11 parts per billion. Total phosphorus levels in White Lake currently peak at about 14 parts per billion.

4.1 Water Clarity

Water clarity, as expressed as the Secchi depth, doubled when zebra mussels arrived. 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 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.

5. Loon and Cormorant Counts

2020 was a devasting year for the Common Loon. The overabundance of a species of black fly, which specifically attacks loons, forced them off of their nests. As a result, the number of loons on the lake was reduced by 34% and the number of chicks reduced by 83%.

Unfortunately, the loon population did not recover in 2021 and the numbers of loons, mating pairs and chicks did not change appreciable. We can only hope that the situation improves in 2022.

For the past three years, we have been observing the number of double-crested cormorants calling White Lake home. So far, our observations indicate that the population is growing but at a very small rate. In 2021, we estimate that there are about 4 to 5 nesting pairs on the lake.

6. Invitation

For more information on the above topics and more, the reader is invited to read the full 2021 Water Quality Monitoring Program Report available on the White Lake Science and Information Website. We can be contacted at WhiteLakeScience@gmail.com.

2.0 2021 Gord Rogers Memorial Award Recipient: *David Overholt*

The 2021 Gord Rodgers Memorial Award was presented to David Overholt. This award is given to someone who engages his community, promotes stewardship by example, and goes above and beyond for the benefit of his or her lake community. David is an active member of his local lake association, a member of the Lake Networking Group advisory committee, and has been extremely active in bringing education, awareness, and control to the issue of the invasive phragmites or Common European reed. David 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.

The White Lake Property Owners Association is proud of David's achievements and contributions to lake science and the preservation of White Lake. Congratulations Dave!

3.0 History of White Lake Algal Blooms

3.1 Algal Blooms: 1860 to 1976

From 1860 to 1960[2] the dam at Waba Creek was operated for the benefit of Stewart's sawmill. Floodgates were regularly opened to allow floating logs on the lake to reach the mill. Algal blooms are reported to have occurred during this period as a direct result of logging operations damaging sediments and increasing nutrient runoff into the lake.

In 1968, a new concrete dam was constructed. From that date to 1976, water levels in the lake were kept high at the request of local cottagers and residents. This resulted in the rapid growth of aquatic plants, reduced water clarity and subsequent failure of the walleye fishery. Midsummer algal blooms also appeared[3], leaving green slime on the shores; rock rubble was covered with algae.

There are several factors which at that time resulted in algal blooms. These include:

1. Water Regime – water levels kept too high over the summer months.
2. General use of phosphate detergents and related products.
3. Poor performance of existing septic or other waste disposal systems.
4. Commercial logging in earlier decades contributed to the nutrient load in lake water and lake sediments. This input stimulated large algal blooms, which are recorded in the sediments and revealed by paleolimnological studies of White Lake.

During the 1970s, Canada banned or reduced phosphates in detergents and other products. It is likely that the high-water level regime in place during the time when phosphates were permitted and used widely, contributed to the production of algal

[2] A. Anthers and S.J. Kerr; The Fishery of White Lake, Technical Report TR-107, Southcentral Sciences Section, Ontario Ministry of Natural Resources, Kemptville, ON 31p. 1998.
[3] H. von Rosen; White Lake Fisheries Assessment; Ministry of Natural Resources, Carleton Place District, 1989.

blooms in White Lake. This source of phosphate has been greatly reduced, although still present today.

3.2 Algal Blooms: 1977 to 2021

In 1977, the water level management regime was altered to allow gradual summer drawdowns (0.76 m/yr.) to clean spawning shoals and reduce midsummer algal blooms. Fall and winter water levels were stabilized by mid-late September each year. This resulted in increased walleye spawning activity on traditional spawning sites.

Today the nature and causes of algal blooms in White Lake are quite different. These include the change in phosphorus cycling by zebra mussels, climate change, year-round use of cottages as residences, increased boating effects, shoreline degradation, invasive species, and exposed surface runoff. These issues should now be the subject of our attention.

The data contained in the table below tell the story of more recent algal blooms in White Lake. Prior to 2013 and for a period of at least 25 years, there were no reported algal blooms on White Lake. During that time, however, the number of cottages, trailers and commercial tourist units have increased from 475[4] to 1538 (2018), an increase of 324%. Available numbers also show that from 1985 to 2018, permanent homes on White Lake increased by 354% to 209. These trends are continuing today. The table below indicates that White Lake is no longer capable of absorbing and processing additional nutrients coming from any source. The lake is now experiencing multiple algal blooms every year with a record five blooms in 2021.

The table also shows that the arrival of zebra mussels in White Lake resulted in a change in algal bloom patterns. Prior to their arrival, there were no significant filamentous green algal blooms. However, blue-green algal blooms occurred each year from 2013-2015. All these blooms were *Anabaena* blue-green algae.

Following the arrival of zebra mussels, phosphorus cycling in the lake changed. As a result, White Lake now experienced annual filamentous green algal blooms as well as blue-green algal blooms. However, the blue green algal blooms were now *Microcystis*. In 2021, White Lake experienced blue-green algal blooms from both *Anabaena* and *Microcystis*.

White Lake is a very shallow (average depth of 3.1 m), productive, warm-water lake, and as such is very susceptible to changes in water quality resulting from human activities. When a lake like White Lake is overused, then the rate at which the lake becomes nutrient enriched (eutrophication) is accelerated.

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

White Lake Algal Blooms by Year: 1977 to 2021

Year	Green Algae		Blue-Green Algae	
	Summer	*Fall*	*Summer*	*Fall*
1977 to 2012 (25 years)	-	-	-	-
2013	-	-	-	1
2014	-	-	-	1
2015	-	-	-	1
 Zebra Mussel Infestation				
2016	-	-	1	-
2017	1	-	-	-
2018	2	-	-	2
2019	1	-	-	1
2020	1	-	-	1
2021	1	-	-	4

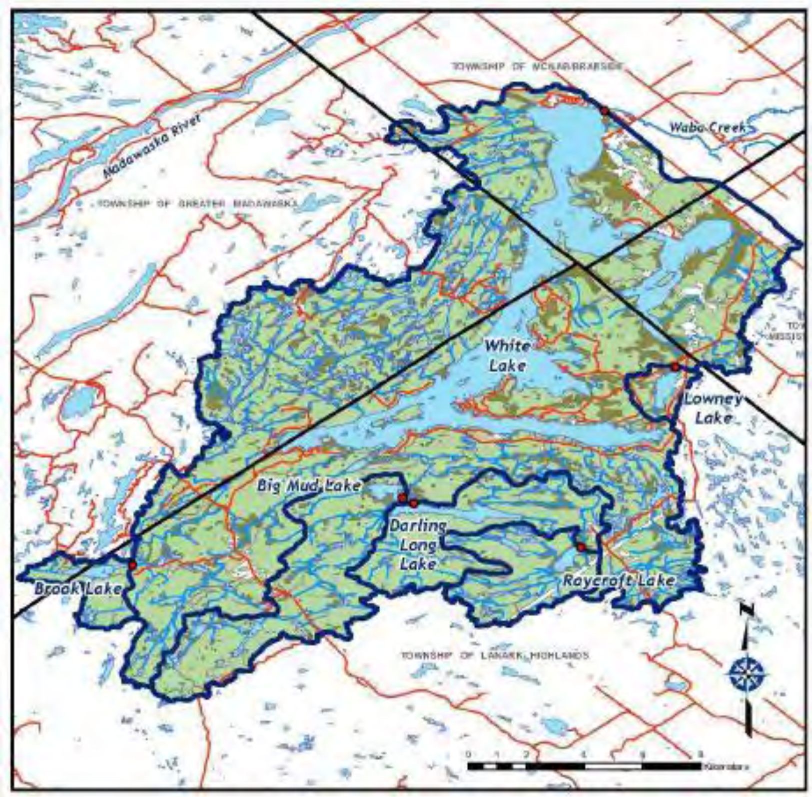
For further reading and to view all photographs and proofs, please read our Special Report entitled *White Lake Algal Blooms: 1860 to 2021* which is currently posted on the White Lake Science and Information Website.

PART II

Water Quality Parameters

4.0 2021 Water Quality Monitoring Program

Introduction and Summary



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

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

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

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

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

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

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

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

Since 2015, the concentration of measured total phosphorus in the lake has declined by about 50%. Total phosphorus levels in 2018, 2019, 2020 and 2021 marginally increased from 2016 and 2017 levels, but not significantly so. The general reduction in total phosphorus levels in no way indicates that there was 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.

In 2021 White Lake experienced at least 3 algal blooms. As predicted by the scientific literature, there were blooms of filamentous green algae. Also predicted was the occurrence of blooms of *microcystis aeruginosa* and *anabaena* blue-green algae. The filamentous green algal bloom was widespread. The blue-green algal blooms were also widespread and peaked twice from mid-September to mid-October. A detailed discussion of the algal blooms can be in this report under the appropriate heading.

We now can show 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.

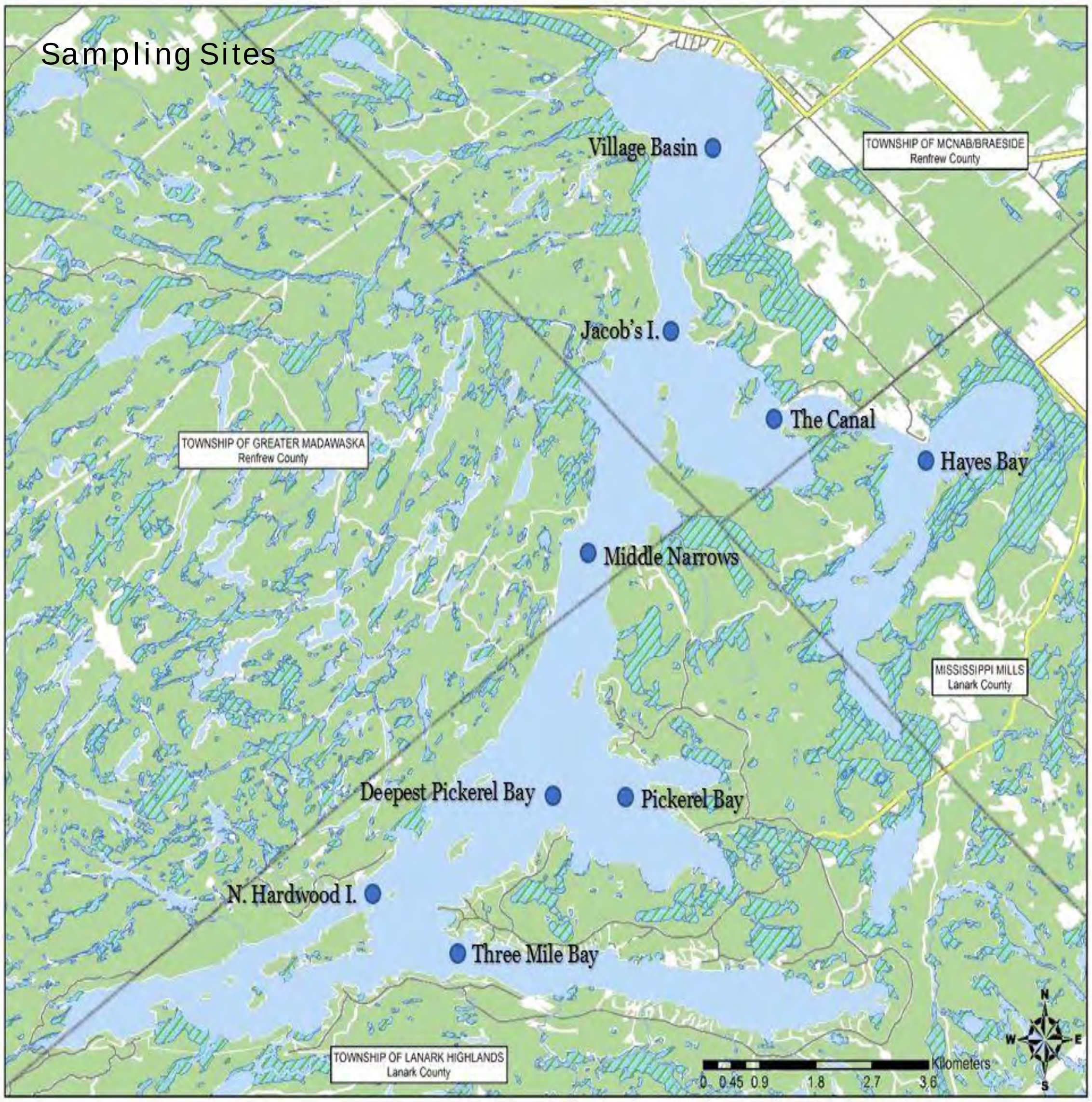
Other Research: In addition to water quality measurements, we have completed a number of research projects aimed at increasing our knowledge of White Lake allowing us to better characterize its nature and processes, such as water flow.

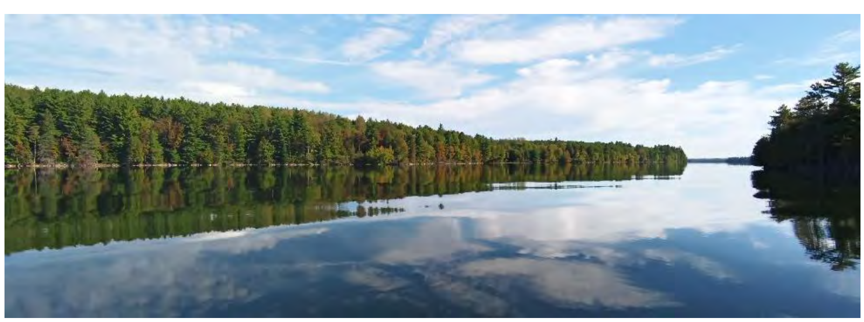
These studies include: 1) Annual Common Loon and Cormorant Surveys; 2) The continued monitoring of the propagation of zebra mussels in White Lake; 3) the assessment of long-term trends in total phosphorus concentrations and its implications in interpreting water quality and lake health.

White Lake Water Quality Monitoring Program

The water quality monitoring program for 2021 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).





Quiet Morning, Western Shore - C. Grégoire

5.0 Algal Blooms – 2021

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

The second type of bloom was from blue-green algae which covered large portions of the lake including Three Mile and Pickerel Bays and extending into the main water body, especially on the eastern side of the lake. These extensive algal blooms consisted of two different taxa in different parts of the lake. The first blue-green bloom was recorded on September 16 and the second on October 8. 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”[5]

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

5.1 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 large patches along the shoreline. Nutrients, such as phosphorus, supporting this alga comes from sediments, and shoreline runoff where shorelines are disturbed, as well as dissolved in lake water.

In 2020, the filamentous green algal bloom was extensive and relatively intense compared to this same type of bloom in 2021. Although there were fewer occurrences than in 2020, the most serious and largest blooms were found immediately adjacent to newly de-treed and landscaped cottage lots, and areas of severely altered shorelines.

Algae bloom when conditions are right for its rapid and uncontrolled growth. These conditions include the presence of excess nutrients (phosphorus), favourable water temperature and clarity, sunlight, and the action of wind and waves. For White Lake, the presence of zebra mussels is an additional factor promoting the growth of filamentous

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[5] 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.

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 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.

In addition to the blooms near altered shorelines, we observed numerous free-floating masses of the algae on the surface of the lake in locations where there were no visible fixed blooms. Many of the blooms occurred in bays or small embayments along the shoreline. During its lifetime, this alga produces gases which become trapped in the fine mesh of the algal mat and serve to raise the bloom from the lake floor to the surface, where it can be affected by the wind.

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.

5.2 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.

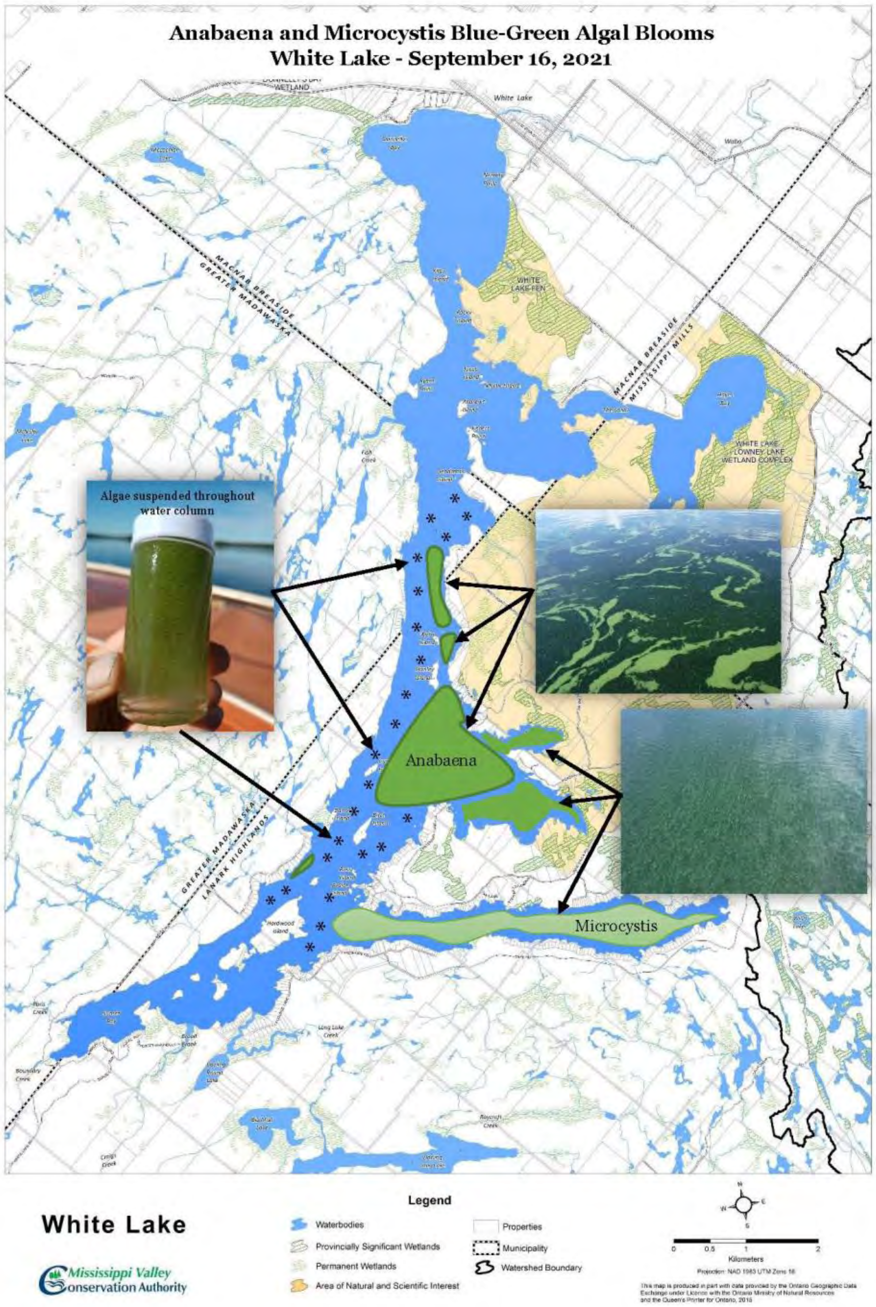
This year, White Lake hosted two different blue-green algal blooms. Each of these blooms simultaneously occurred twice; the first on September 16, and the second on October 8, 2021. The two types of algal blooms were: anabaena (now called Dolichospermum), and microcystis. The anabaena bloom occurred in the main body of the lake (deepest water), Pickerel Bay and areas along the Eastern shoreline going North. The microcystis bloom was located mainly in Three Mile Bay and adjacent areas.

The simultaneous occurrence of different types of blue-green algae has never been recorded before. Prior to the infestation of White Lake with zebra mussels, only anabaena blue-green algal blooms were recorded. Since the arrival of zebra mussels, only microcystis blue-green algal blooms were observed.

It should be noted that both anabaena and microcystis are present in all parts of the lake. During most of the water sampling season, it is possible to observe specimens of both of these algae in the water column, usually at very low concentrations. In 2014 (two years prior to zebra mussel infestation), a lake-wide anabaena blue-green algal bloom occurred in both deep and shallow areas of the lake.

We know from the scientific literature that the presence of zebra mussels favours the propagation of microcystis over anabaena blue-green algae. However, in deeper waters, it may be possible that anabaena could have the advantage over microcystis for two reasons: 1) there are fewer or no zebra mussels present in deeper waters where the lake bottom is muddy; 2) anabaena has the ability to fix nitrogen from the atmosphere; microcystis does not. Both are capable of moving up and down the water column during the day using gas vacuoles. In shallow waters, such as those in Three Mile Bay, the action of wind and waves would effectively mix the water column from the surface to the lake bed. This would allow both types of blue-green algae access to essential nutrients. Mixing would not be as efficient in deeper waters, giving anabaena the advantage over microcystis.

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.



The figure above shows the extent and intensity of the double blue-green algal bloom on White Lake first observed on September 16, 2021. This bloom lasted approximately 10 days, but remerged again on October 8, 2021. The second round of blooms were located in the same parts of the lake as the blooms observed nearly a month earlier, but of lower intensity. Photos of the blooms are included in the figure to give the reader a better appreciation of the appearance of blue-green algal blooms. Also, it is easy to observe that the locations of these algal blooms, as in other years, generally coincide with the most heavily populated and used parts of White Lake.

As noted earlier, blue-green algae are capable of producing toxins called microcystins. In sufficient concentrations these toxins can cause skin irritations as well as serious illness and death. For this reason, the Ministry of the Environment will sample and analyze algal blooms for their content of toxic compounds. For budgetary reasons, the MOE limits each lake to one sampling per year, although they will re-sample if there is believed to be a special need.

This year, only one sampling was done. The water sample was taken from the western shore of the lake in the zone affected by the anabaena blue-green algal blooms. Although other parts of the lake were not sampled, the MOE advises that each bloom, whether tested or not, be considered as toxic in the interest of public and personal safety. The Ministry of the Environment, Conservation and Parks reported the following results for the single sample taken:

As expected, a bloom of blue-green algae (Dolichospermum (formerly Anabaena)) was confirmed. The total microcystin concentration was 0.56 ug/L and the anatoxin-A concentration was below method detection limits of 0.20 ug/L and 0.050 ug/L.

The sample was submitted for microcystin speciation analysis. The microcystin-LR concentration was 0.074 ug/L (Ontario Drinking Water Standard is 1.5 ug/L) and the microcystin-LA concentration was 0.14 ug/L (no provincial standard). All other analyzed species were below method detection limits of 0.050 ug/L.

These results confirm the presence of toxins in the sample taken, but in a concentration not dangerous to human or animal health.

In recent years, an annual pattern of algal blooms on White Lake is emerging. During early summer, we observe widespread nuisance filamentous green algal blooms, and in the fall, we observe blue-green algal blooms in large parts of the lake.

Below is a photo of a wind-driven accumulation of dying or dead ababaena blue-green algae. It is during this phase of the life of blue-green algal that high concentrations of microcystin toxins can be released into the water column.

6.0 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:

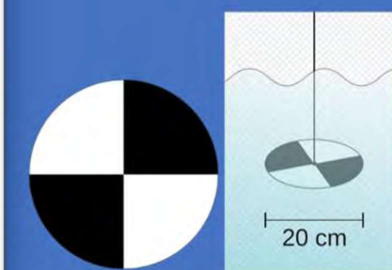
- Aquatic plants will propagate in deeper parts of the lake.
- Aquatic weed beds will thicken in shallow areas where weeds currently exist.
- More zebra mussel habitat will be created on new plant beds.
- Enhanced water clarity means less food for small creatures, including fish.
- The presence of filamentous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

6.1 Secchi Depth Data:

Below is a graph containing the Secchi depth readings for White Lake taken during the 2021 ice-free season.

WHAT IS SECCHI DEPTH AND HOW IS IT MEASURED?

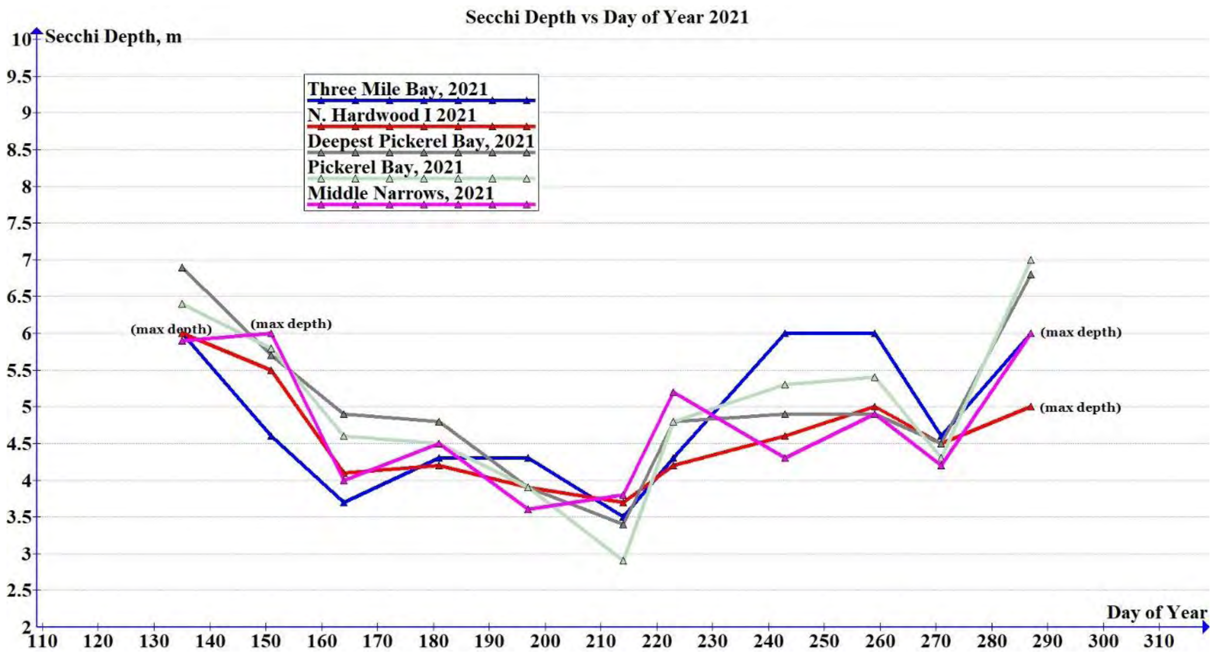
The Secchi depth is a measure of the clarity or transparency of the water. The Secchi disk, named after an Italian scientist, is used to make the measurement. The disk is segmented black and white and 20 cm in diameter:



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.

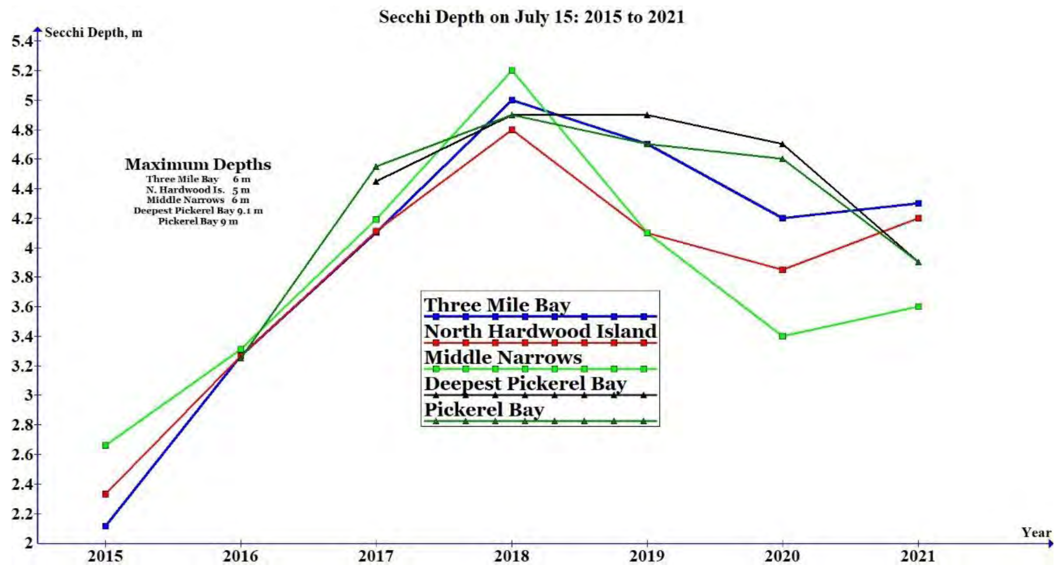
Of the nine sites we sampled, there were only five that had measurable Secchi depths. The remainder of sites were too shallow or the water was too clear at all times. The pattern of Secchi depth readings in 2021 is similar to that of previous years. Secchi depths increase as the lake water column becomes 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 2.8 m (lowest water clarity) were recorded in early-August with a maximum of 7 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 in was prior to the invasion of zebra mussels. One can speculate that this pattern may be related to weather conditions



since it is doubtful that nutrient levels in the lake have changed appreciably in recent years. Alternatively, the presence of reduced numbers of zebra mussels may also have had an effect in decreasing water clarity. Last year there was a significant die-off of zebra mussels, populations of which are now rebounding.

The graph below shows that the water clarity, expressed as Secchi depth, increased significantly during the years 2015 to 2018. 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.



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, water clarity began to again increase, again likely due to fluctuating zebra mussel numbers. To put this in perspective, the Secchi depth for Three Mile Bay in 2021 is still twice the Secchi depth obtained in 2015, and only reduced by 14% from the maximum value obtained in 2018.

6.2 Frequency of Secchi Depth Readings Exceeding Sampling Site Depth

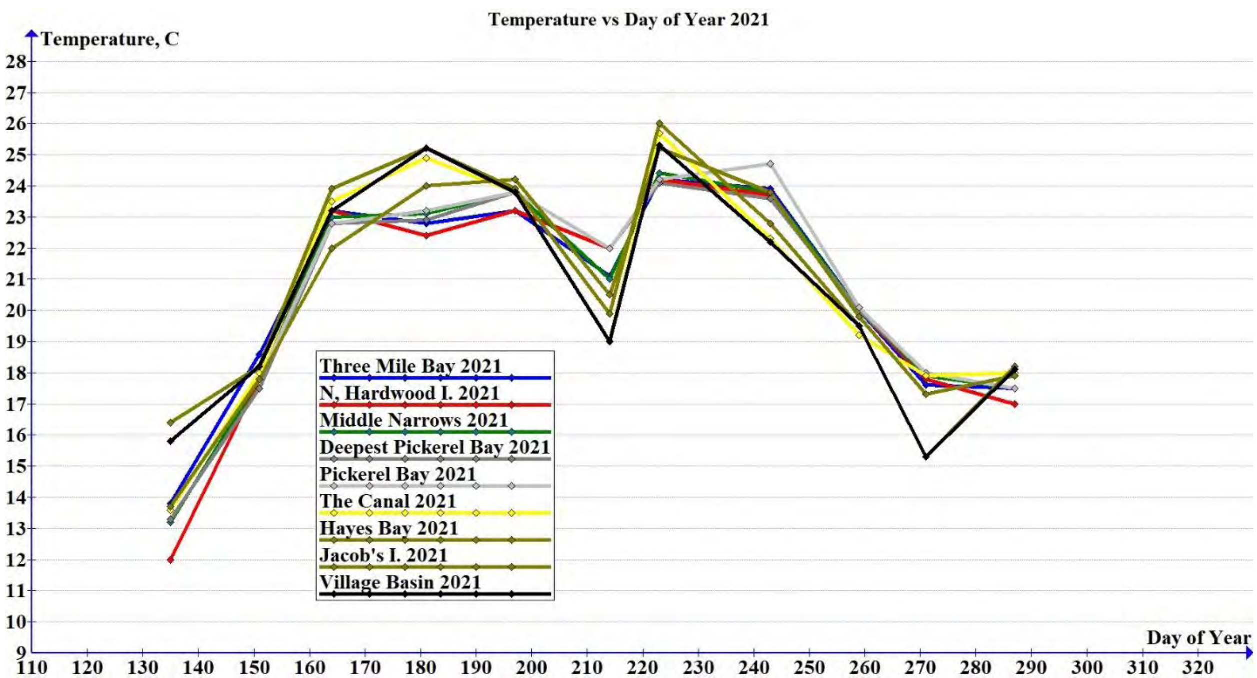
Another way of showing how the clarity of White Lake has been changing in recent years is to consider the number of times the Secchi depth could not be taken because the water was transparent to the bottom of the lake at each of the five deep water sites monitored on a regular basis. The maximum number of measurements made per year is 11*.

Sampling Site	Max. Depth, m	2015	2016	2017	2018	2019	2020	2021
Jacobs I.	4.0	2	8	11*	11	10	11	11
N. Hardwood I.	5.0	1	3	5	5	4	3	3
Middle Narrows	6.0	0	1	2	2	3	2	2
Three Mile Bay	6.0	1	2	5	3	5	4	4
Pickerel Bay	7.5	0	0	1	2	1	0	0
Total		4	14	24	23	23	20	20

These data show that the total number of times the Secchi depth could not be read, because of high water clarity, increased with each year up until 2018 at which time it began to decrease slightly. These data along with above graph indicates that water clarity appears to be reaching equilibrium, which in turn may indicate that the total biomass (i.e., water filtering capability) of zebra mussels is also reaching equilibrium.

7.0 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 would also increase the release of phosphorus (back or internal loading) from sediments into the water column. All temperatures reported in this study were taken at the Secchi depth using a thermometer calibrated against a secondary standard mercury glass thermometer.



The graph above shows the temperature of White Lake water over the course of the 2021 ice-free season.

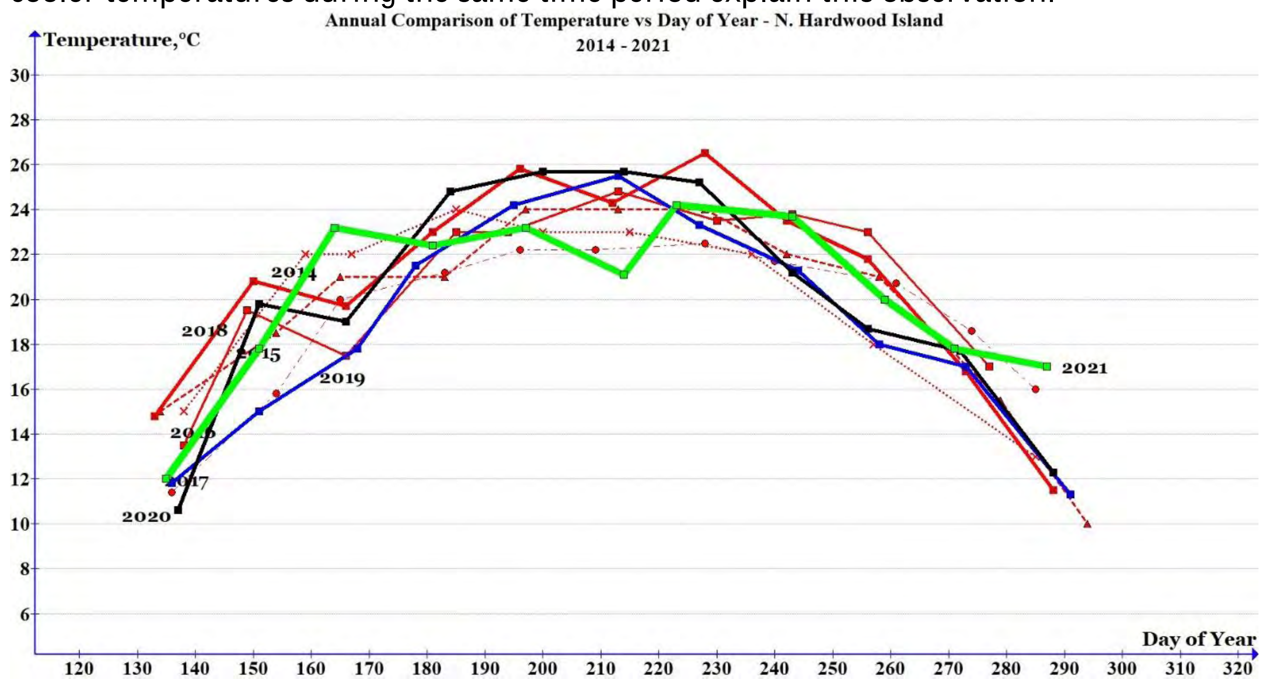
Although there is clearly some variation in measured temperatures depending on the location of the sampling site, the temperature curves follow a trajectory very similar to those observed in previous years. The noticeable 'dips' in temperature which occur from time to time are usually correlated with 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 surface runoff. Because White Lake has such varied bathymetry, there are differences in temperatures at different sampling sites. For the most part, water temperatures for all of the deeper sites were almost the same differing by no more than

0.5 °C. However, temperatures for the shallow sites were at times quite different from those of the deeper sites because they are more susceptible to recent or current weather conditions. A full explanation of this topic can be found in the 2016 and 2019 Water Quality Monitoring Program Reports available on the White Lake Science and Information website.

7.1 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 8 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 2021.

The 2021 data (thick green line) shows that temperatures were generally comparable to other years in both the spring and fall. However, from about July 10 to August 8, water temperatures were relatively low compared to previous years. Depending on weather conditions, the data contained in the above graph shows that temperatures can vary by about 5 degrees over most of the summer.

The table below gives maximum temperatures recorded for White Lake during the past 8 years. 2018 had the highest water temperature recorded to date was 4.1 ◦C higher than the lowest temperature recorded during 2017.

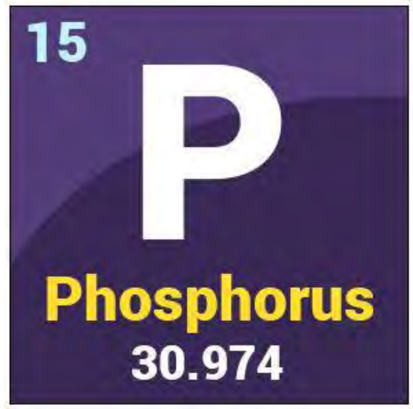
Year	Day of Year	Maximum Temperature, ˚C
2014	199	24.1
2015	217	24.0
2016	223	24.7
2017	216	22.9
2018	196	27.0
2019	213	25.6
2020	214 and 227	26.0
2021	181	25.2

Higher temperatures, especially along shorelines could result in more prolific aquatic plant growth and also encourage propagation of algae, including blue-green algae.

Passing Storm, Birch Island - C. Grégoire

8.0 <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[6] 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

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

phosphorus, dissolved inorganic and organic phosphorus compounds pass through the filter and are measured together as total phosphorus. These are true total phosphorus 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)[7]. 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 2021.

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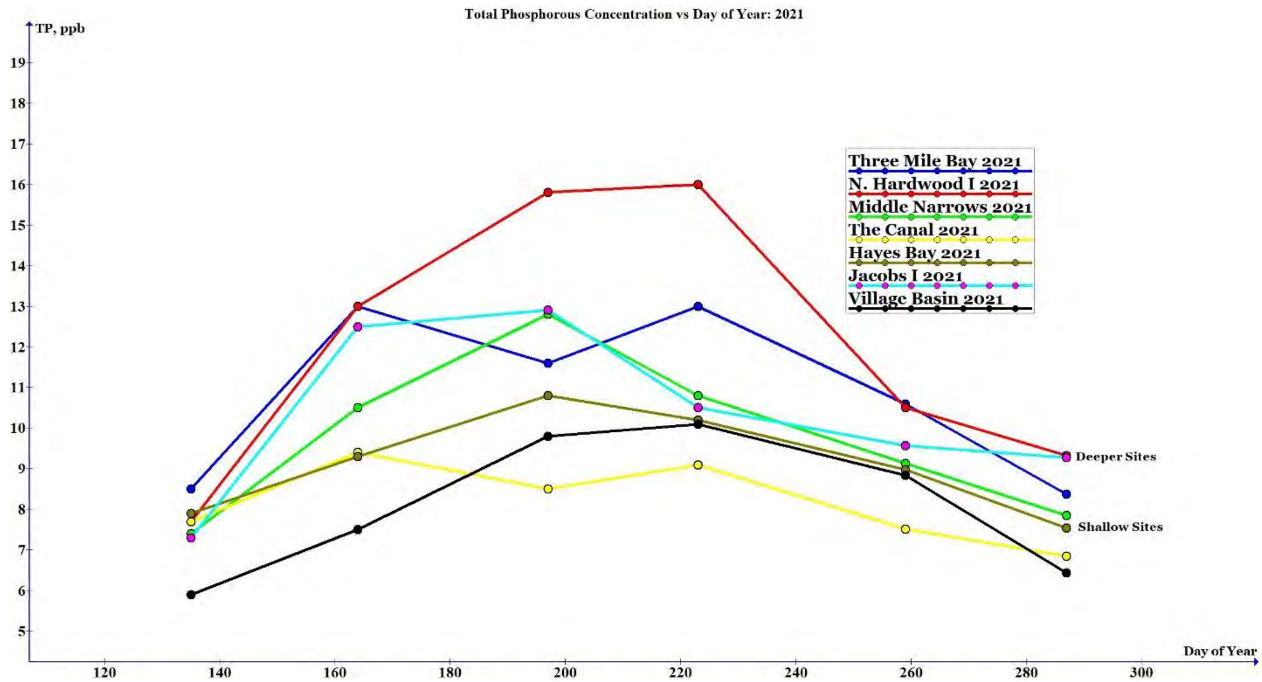
[7] B.J. Clark et al, *Assessing variability in total phosphorus measurements in Ontario lakes*; Lake and Reservoir Management, 26:63-72, 2010.

The graph below shows the change in total phosphorus concentrations during the 2021 ice-free season.



The data for 2021 (above) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in late 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 nearest the N. Hardwood Island and Three Mile Bay sampling sites. These results and trends are in agreement with measurements recorded during the last ten years by government agencies and lake association volunteers. Over the years we have observed that the highest TP values for these two sites sometimes are the same or they could alternate with one site being higher than the other depending on the year. In 2021, the maximum TP for the North Hardwood Island was significantly higher than the maximum TP concentration for Three Mile Bay. This is difficult to explain, but it is possible that the intense infestation of Gypsy moth caterpillars in the forests adjacent to the N. Hardwood I. site may have contributed to increased concentrations. Nutrients contained in caterpillar feces (frass) are readily released during wet periods and may have been flushed into the lake causing hither than expected TP values.

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

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

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

Marl sediments are formed when waters rich in bicarbonate enter from the floor of the lake and upon reaching the surface encounter higher temperatures and lower pressures. Under these conditions, bicarbonate can spontaneously decompose releasing carbon dioxide and leaving behind finely divided (small partical 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[8].

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

We do not have carbonate content values for the organic sediments at the deeper sites, but we do know that these do not react with acid to release carbon dioxide. From this we infer that there is a low concentration of carbonate in these sediments.

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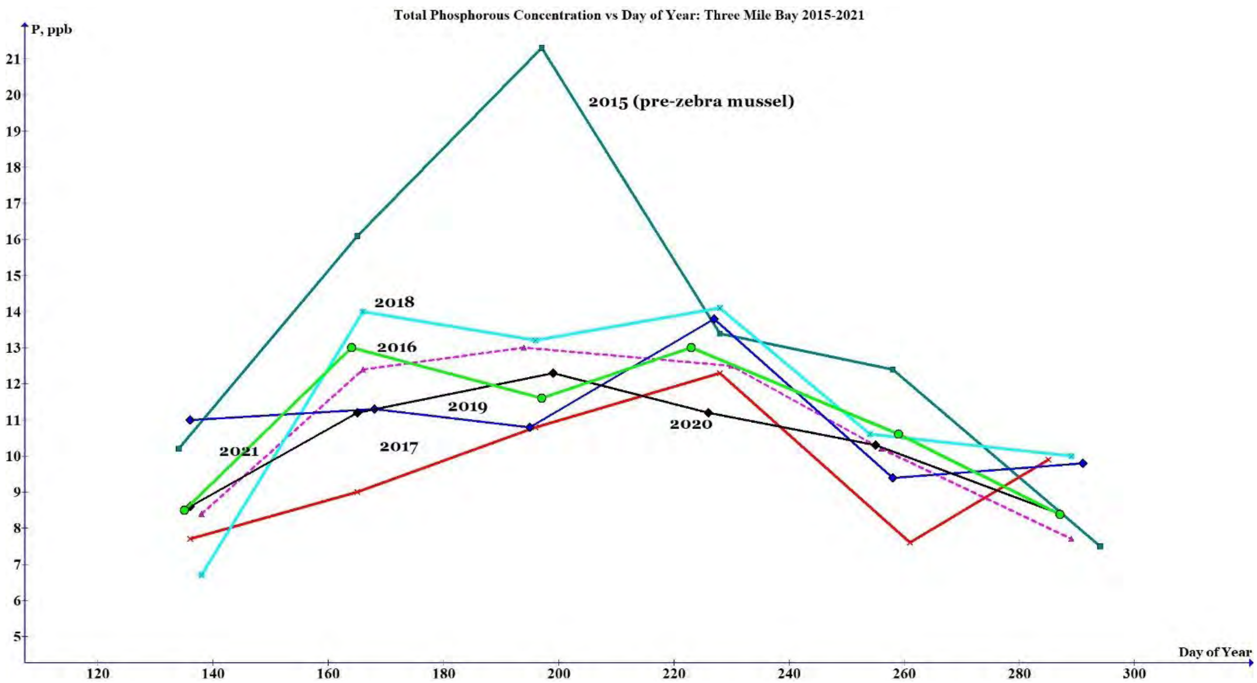
[8] M. Murphy and J. Vermaire, Carleton University, 2019; personal communication.
[9] W.E. Logan, The Geology of Canada, Geological Survey of Canada; 1863, p. 765.

8.1 Annual Trends in Total Phosphorus Concentrations

The figure below shows total phosphorus values for the Three Mile Bay sampling site over a seven-year period.

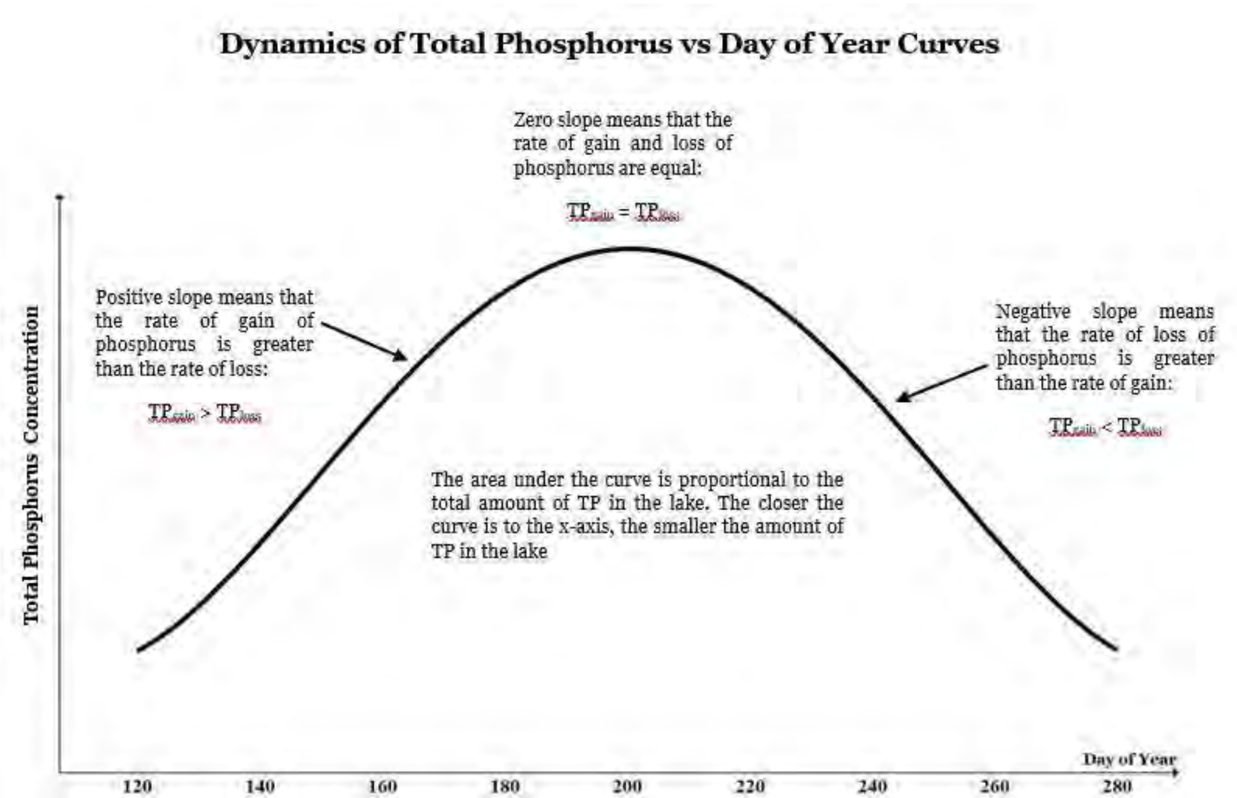


Total phosphorus concentrations declined significantly from those in 2015 and previous years starting in 2016 when the zebra mussel infestation took full effect. Maximum phosphorus concentrations declined by about 50% or more from that date on.

Before continuing with the discussion on phosphorus, it is important to discuss at some length the reason and implications for the actual shape of the total phosphorus vs time curves being discussed so far.

At any given time, phosphorus is entering the lake from a variety of sources including the atmosphere, surface runoff, ground water ingress, sediment back loading, septic systems, etc. At the same time, phosphorus is leaving the water column as it is taken up into living organisms, precipitated as part of an insoluble compound, etc. The total phosphorus concentration measured in lake water at any given time is the balance between the rates of phosphorus entering and leaving the water column. Starting in April and continuing until mid-June or July (depending on the year), the total phosphorus concentration in the lake steadily increases. This, in turn, means that the amount of phosphorus entering the water column exceeds the amount of phosphorus leaving the water column. In mid-June or July, the total phosphorus concentration *reaches a maximum and at that point in time the rate of phosphorus entering the lake water is equal to and balanced by the rate of phosphorus leaving the water column. Beyond mid-July, the total phosphorus concentration in the lake water steadily decreases indicating that the rate of phosphorus input into the lake is less than the rate of loss of phosphorus from the water column.*

This dynamic can be shown graphically:

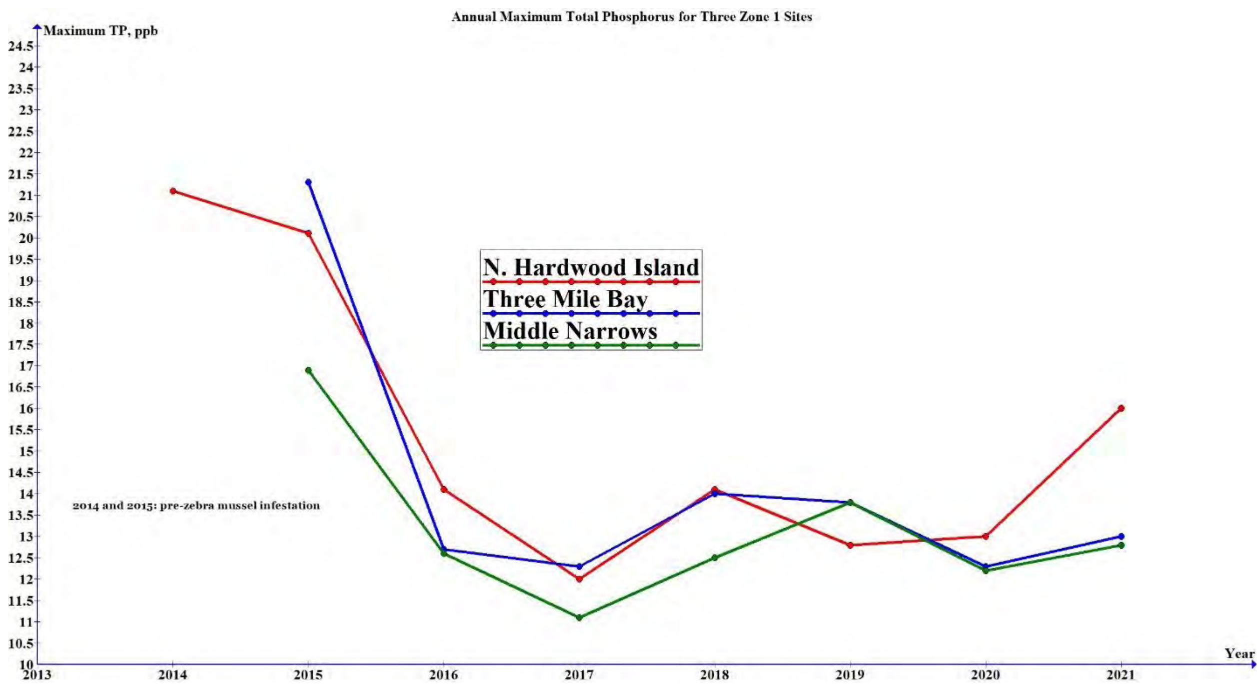


Returning now to the results obtained for total phosphorus from 2016 to 2021: One might be tempted to explain the sudden decrease in total phosphorus levels to lower levels (compared to previous years) as a decrease of <u>input</u> into the lake. Unfortunately, there is no evidence to support this assertion. 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 in the water column.

However, the explosion of zebra mussel populations in White Lake during the 2016 season explains why total phosphorus levels have decreased significantly over previous years. Zebra mussels can remove over 90% of the plankton and other particles normally found in an unaffected lake. Zebra mussels are efficient at removing particulate phosphorus from the water column and transferring it to sediments via feces and pseudo-feces. It is also reported that the concentration of soluble reactive phosphorus remains unchanged allowing for further phytoplankton production. However, it is known that 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 over the past four or five years.

Although shown in another section of this report, it is worth reproducing here the graph of maximum total phosphorus values measured in White Lake for years before (2014 and 2015) and after the invasion of zebra mussels:



It may be useful to remind ourselves of the relative sources of phosphorus entering White Lake[10] and note that not all of the phosphorus is converted to the 'total phosphorus' that we measure every month during the ice-free season.

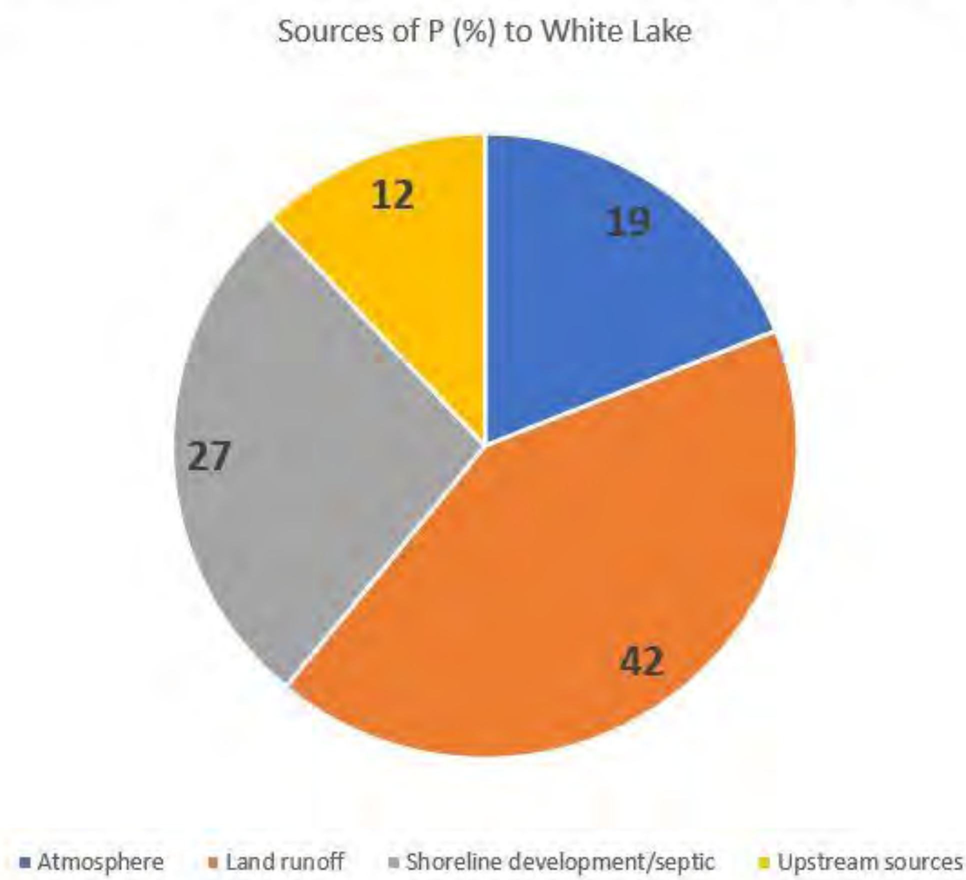
The pie chart below indicates that taken together land run-off, septic systems and shoreline development account for about 70% of the phosphorus entering White Lake.

10 [10] 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 from its inception and both collected research data and contributed to the develop of the Lakeshore Capacity Model used by the Ontario Government.

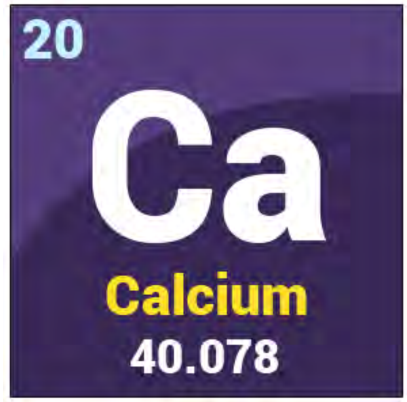
This clearly shows the importance of effective shoreline management to water quality and especially for the control of nuisance and toxic algal blooms which we have been documenting during the past eight years.

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.

Relative Sources of Phosphorus in White Lake



9.0 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 June and July, the concentration of calcium varied from a low of 29.1 ppm to a high of 35.4 ppm. Although the mean values for all individual sites (green) are within one standard deviation of one another, the absolute values for Hayes Bay are somewhat higher. This site, in particular, has a total dissolved solid content which is 20% higher than at all other sampling sites on White Lake.

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.

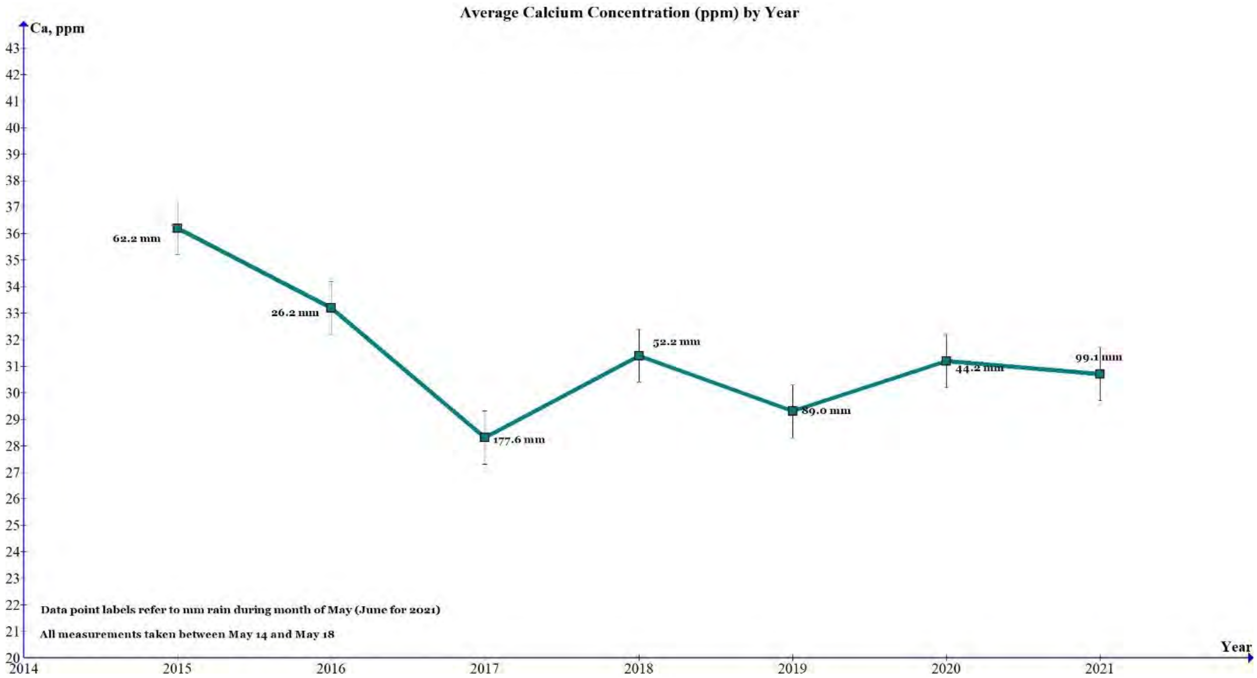
Calcium (ppm) – Sampling Site by Month: 2021

Sampling Site	June	July	Mean
Three Mile Bay	31.1	32.0	31.6
N. Hardwood I.	30.5	32.0	31.3
Middle Narrows	30.7	32.1	31.4
Jacob's Island	31.0	30.0	30.5
The Canal	31.3	29.1	30.2
Hayes Bay	35.4	33.2	34.3
Village Basin	29.8	28.1	29.6
Mean	30.7±.4	30.9±1	

The table below compares calcium concentrations for individual sites over a six-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.

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

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



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

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

These results support the conclusion (see 2017 Water Quality Monitoring Report report) that about 88% of the water entering White Lake is derived from ground water sources with the remainder coming from rain and surface water runoff.

10.0 Chloride

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

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

Chloride (ppm) – May, 2015 to 2020

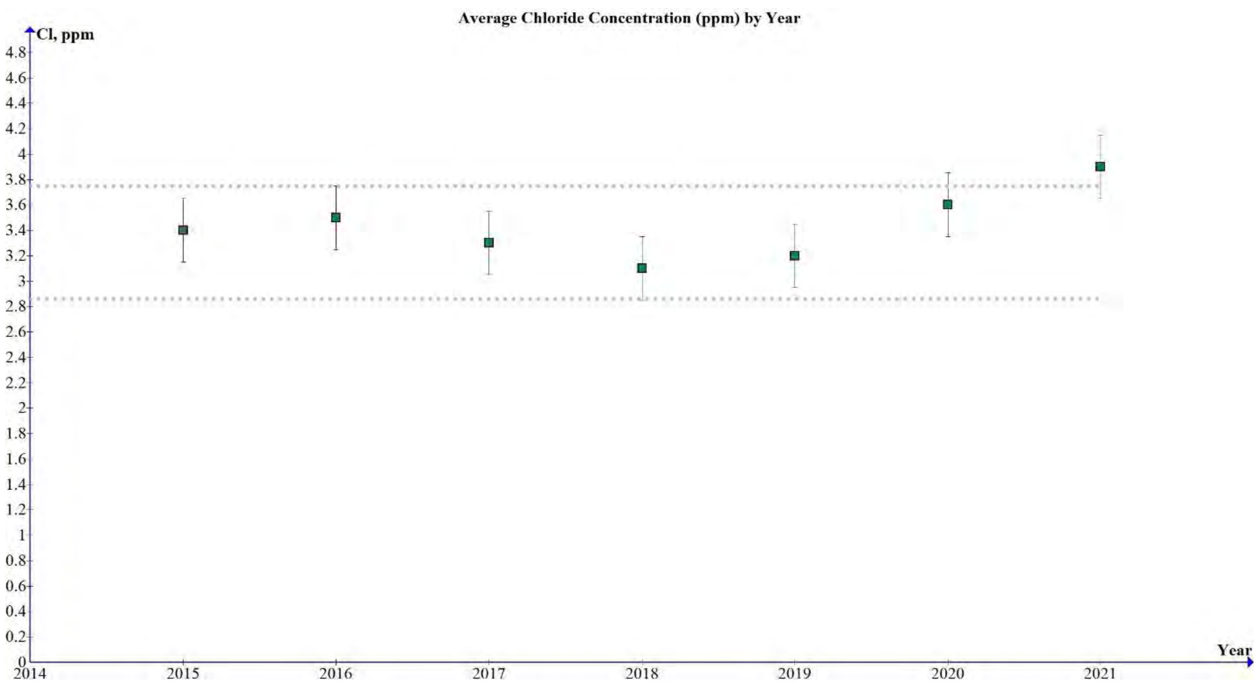
Sampling Site	2021	2020	2019	2018	2017	2016	2015
Three Mile Bay	-	3.4	2.8	2.9	2.8	3.4	3.5
N. Hardwood I.	-	3.4	2.8	2.9	3.1	3.4	3.3
Middle Narrows	3.8	3.5	3.2	3.5	3.3	3.5	3.5
Jacob's Island	3.9	3.7	3.6	3.2	3.7	3.7	3.5
The Canal	4.8	4.7	4.1	4.1	6.2	5.4	3.9
Hayes Bay	9.0	9.0	7.6	8.3	9.5	10.0	-
Village Basin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

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

Average Chloride Concentration (ppm) 2015 to 2021

Year	Average ± SD
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 point that up until 2021, Chloride results were statistically unchanging. Data (2 points only) for 2021 indicate a possible trend towards higher chloride concentrations.



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

The source of the additional chloride in Hayes Bay waters (see table above) could be from the intrusion of road salt from the nearby road. A second possibility is that Hayes Bay receives additional chloride from subterranean brines fed by a spring(s) or aquifer. Road salt may not be the source of the chloride because year over year, the concentration of chloride is not increasing significantly. Also, if road salt were significantly involved, one would expect that the concentration of chloride would rise from a low value (like other sites), rise and fall again, as the source of chloride is diminished. For 2021, chloride values started at 4.0 ppm on May 15, rose to 4.4 ppm on June 30 and fell slightly to 4.1 ppm by July 13. At no time did the concentration of chloride equal the much lower values obtained in other parts of the lake.

11.0 Weather Conditions: 2014 – 2021

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 2021. For this reason, we have included meteorological data from all of these years. The data contained in these tables are those taken at the Ottawa International Airport. Available data from other locations near White Lake (e.g., Pembroke, ON) show similar trends and are not substantially different from those reported below.

An examination of the table below indicates that, with the exception of 2017, total precipitation during the ice-free season for White Lake is generally about 0.5 metres. In that respect, 2021 was an average year for precipitation when compared to values for other years. The number of rain events of greater than 1 mm is about average as well.

Total Precipitation April to October: 2014 to 2021

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

During the six-month period from April to October 2021, White Lake received 586.4 mm of rain and experienced 64 days with precipitation of 1mm or more of rain. Monthly meteorological tables for previous years starting in 2014 can be found in our previous annual reports on White Lake Science and Information website.

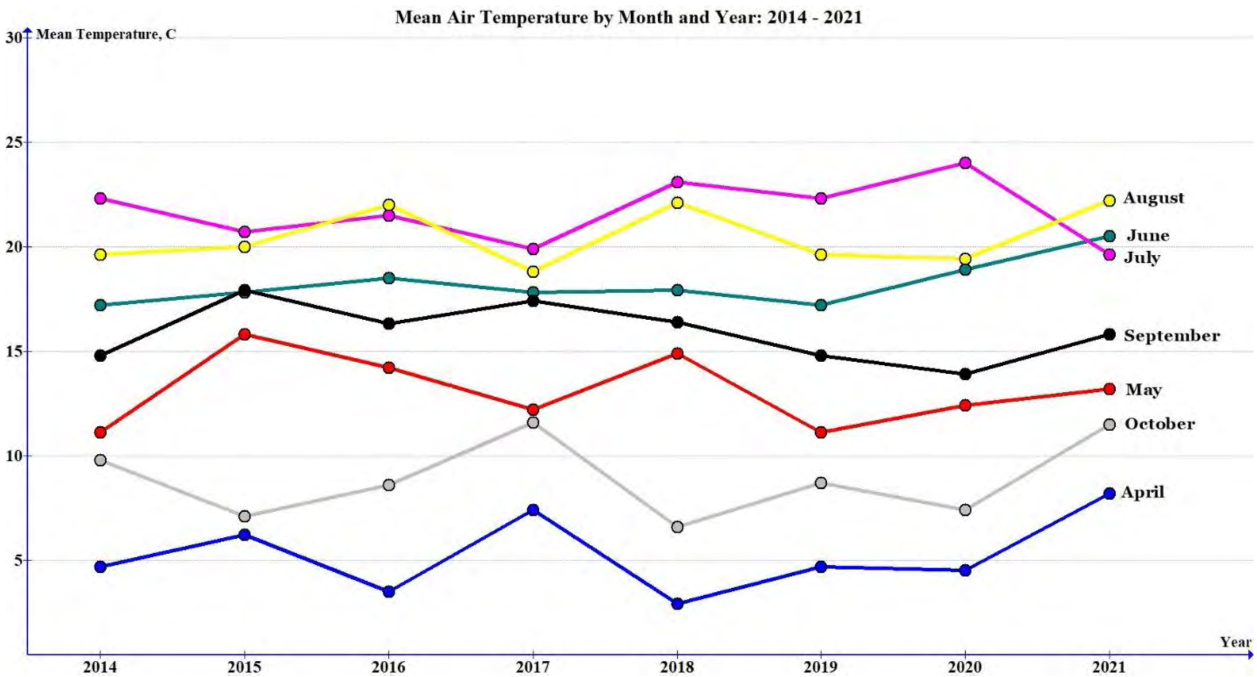
The table below, however does not reveal a year-by-year comparison of monthly temperature values. This data is important, because of the important mechanisms by which White Lake loses water is by evaporation. Prolonged periods of high temperatures with little or no rain could make evaporation the major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

Monthly Meteorological Values – Environment Canada: *2021*

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	8.2	-8.1	24.8	61.7	8
May	13.2	-1.0	32.4	13.5	5
June	20.5	5.9	33.2	99.1	10
July	19.6	8.7	30.8	104.4	10
August	22.2	9.8	32.9	49.0	8
September	15.8	4.7	26.7	118.8	11
October	11.5	-0.5	24.6	139.9	12
Total				**586.4**	**64**

The figure below shows the change in mean air temperature for individual months over the years spanning 2014 to 2021.

Although there is some variation from year to year in water temperatures, there appears to be a trend towards higher temperatures starting in 2019. Because of the uncertainties introduced by climate change, it is possible that this trend will reverse in future years. It is equally possible that temperatures will continue to increase.



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

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.

11.1 Sampling Date Weather Conditions 2021

Date	Day of Year	Weather Conditions
May 15	135	Full sun with an air temperature of 15C; very calm waters with winds at about 5 km/hr.; no rain previous 5 days; water depth unchanged since May 1.
May 31	151	Full sun; no wind; air temperature of 13C; six mm rain fell 10 days prior to sampling; there were several days previous to sampling where temperatures dropped to near or freezing overnight.
June 13	164	Full sun, with no wind. Air temperature from 15 to 17C; no precipitation during prior 2 weeks.
June 30	181	Cloudy with sun or bright overcast; air temp. 23C; Rainy period prior to sampling with about 3mm rain during 5 previous days.
July 16	197	Lightly overcast giving way to sunshine early in sampling period; Air temperature ranging from 17 to 20C; 5 mm rain night before sampling with an additional 10 mm 3 days before sampling.
August 2	214	Full sun; winds ranging from 5 to 10 km/hr; air temperature ranges from 14 to 18C. 10 mm of rain day before sampling and 20 mm three days before sampling.
August 11	223	Full sun; winds less than 5 km/hr; air temperature of 23 to 25C; No rain for previous 5 days; Drought period plus high temperatures of > 30C.
August 31	243	Partially cloudy with some full sun; winds from 5 to 10 km/hr; air temperature of 22 to 25C; 4 mm of rain 36 hours before sampling, preceded by 15 days of high temperature (30+C) with no rain.
September 16	259	Full sun, no wind; 13 to 16 C air temperature; 5 mm rain 48 hours before sampling; Major blue-green algal bloom underway. Microcystis predominant in Three Mile Bay; anabaena predominant in all other parts of Zone 1 except for locations south of mid-Hardwood Island.
September 28	271	Mix of sun and cloud; wind 5 km/hr; Air temperature 9 to 12 C; 60 mm rain fell five days before sampling. White lake is still experiencing blue-green algal blooms although diminished from last sampling date. High population of large phytoplankton contributing to low Secchi disk readings.
October 14	287	Light overcast day; air temp 15 to 18C; no winds very calm; no rain for five days previous to sampling. Algal bloom appears to be over.

12.0 Water Levels – White Lake Dam: 2020

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.

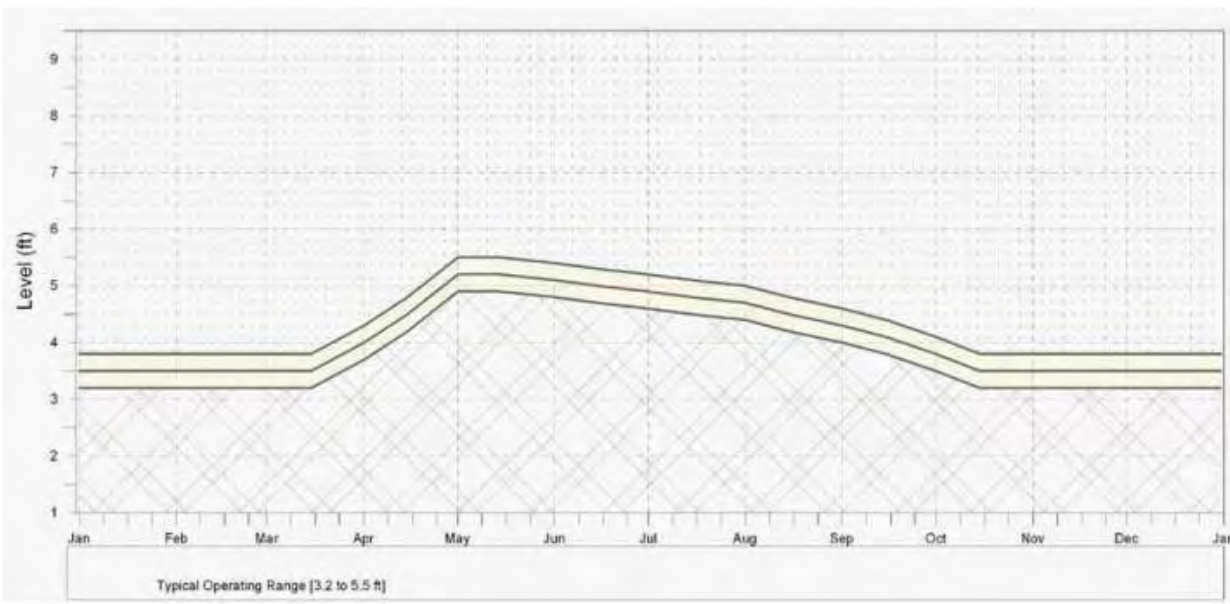
Dates	Target Levels	
	Decimal Feet	cm
January 1 to March 15	3.5	106.7
April 1	4.0	122.0
April 15	4.5	137.2
May 1	5.0	152.4
May 15	5.2	158.5
June 1	4.9	149.4
June 15	4.8	146.3
July 1	4.7	143.3
July 15	4.6	140.2
August 1	4.5	137.2
August 15	4.3	131.1
September 1	4.2	128.1
September 15	4.0	122.0
October 1	3.8	115.9
October 15 to December 31	3.5	106.7

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.

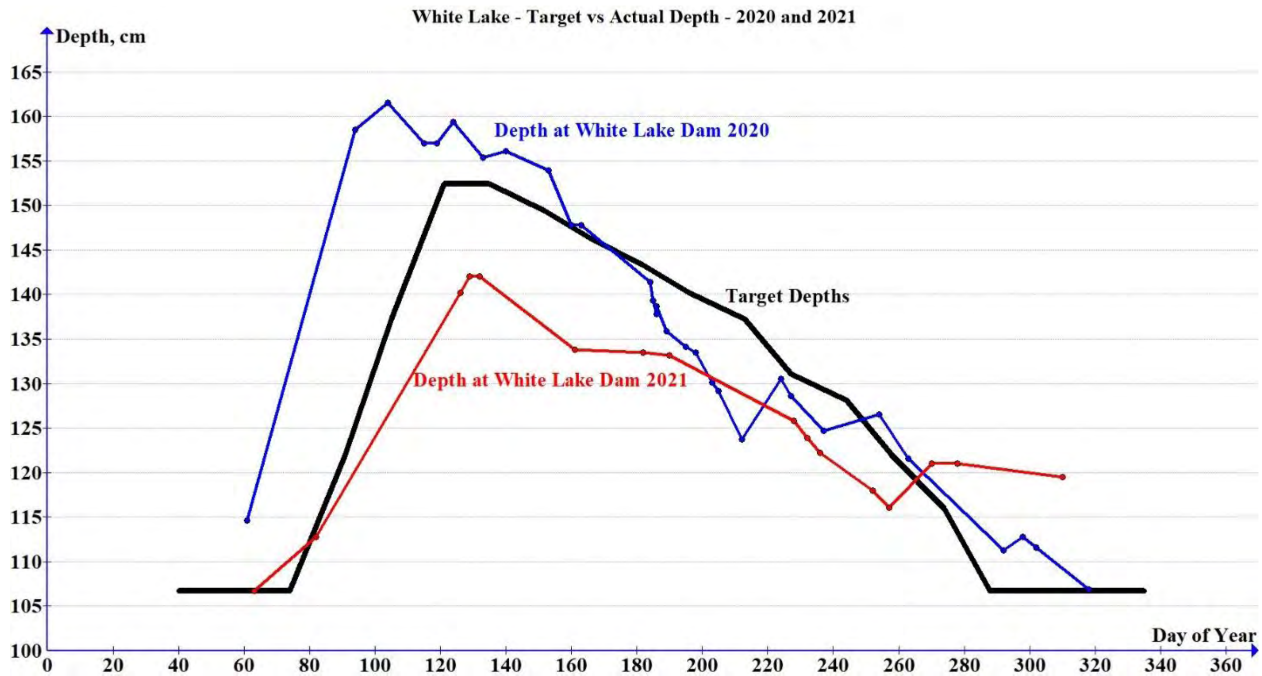
Fall & Winter: The fall/winter holding level is 3.5 feet which should be reached by October 15. If this level is not achieved by November 1, then that recorded level on this date will be considered the fall/winter holding level. Levels throughout the Fall and Winter should be maintained within ± 0.3 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.

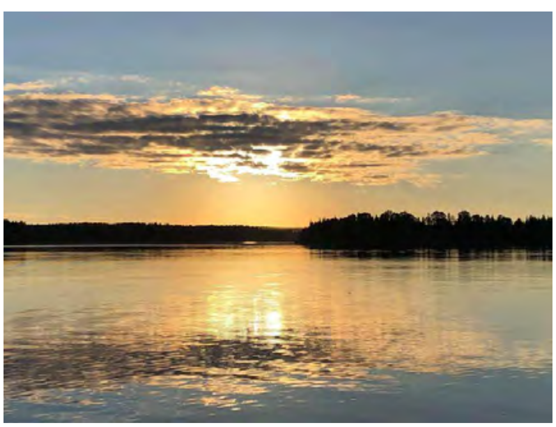
The figure below shows actual depth measurements read at the dam. The red line is for 2021 and the blue line is for 2020 for comparison purposes. The black line is for the target water levels set by the managers of the dam.



It is clear from the graph that for most of 2021 water levels were below those mandated by Madawaska River Management Plan. These much lower water levels were the result of a winter with lower-than-normal snowfalls and periods of warmer weather promoting evaporation from the lake.

It should be noted, that for the during the entire summer, the operators of the dam released the minimum amount of water possible in order to maintain the minimum flow required for Waba creek.

During the summer, the authors observed a lower-than-expected rise in lake water levels following significant rain events. Major input streams such as Boundary and Paris Creeks also did not rise appreciably after heavy rains. This may indicate that a significant portion of precipitation was absorbed directly into the water table rather than flowing into the lake.



October Sunset - Sue Munro

July 23rd Moon - Carolyn Cameron

PART III

Research Activities and Environment Bulletins

WHITE LAKE Property Owners Association Environment Volunteers

David Overholt, BA and Conrad Grégoire, PhD

Special Report

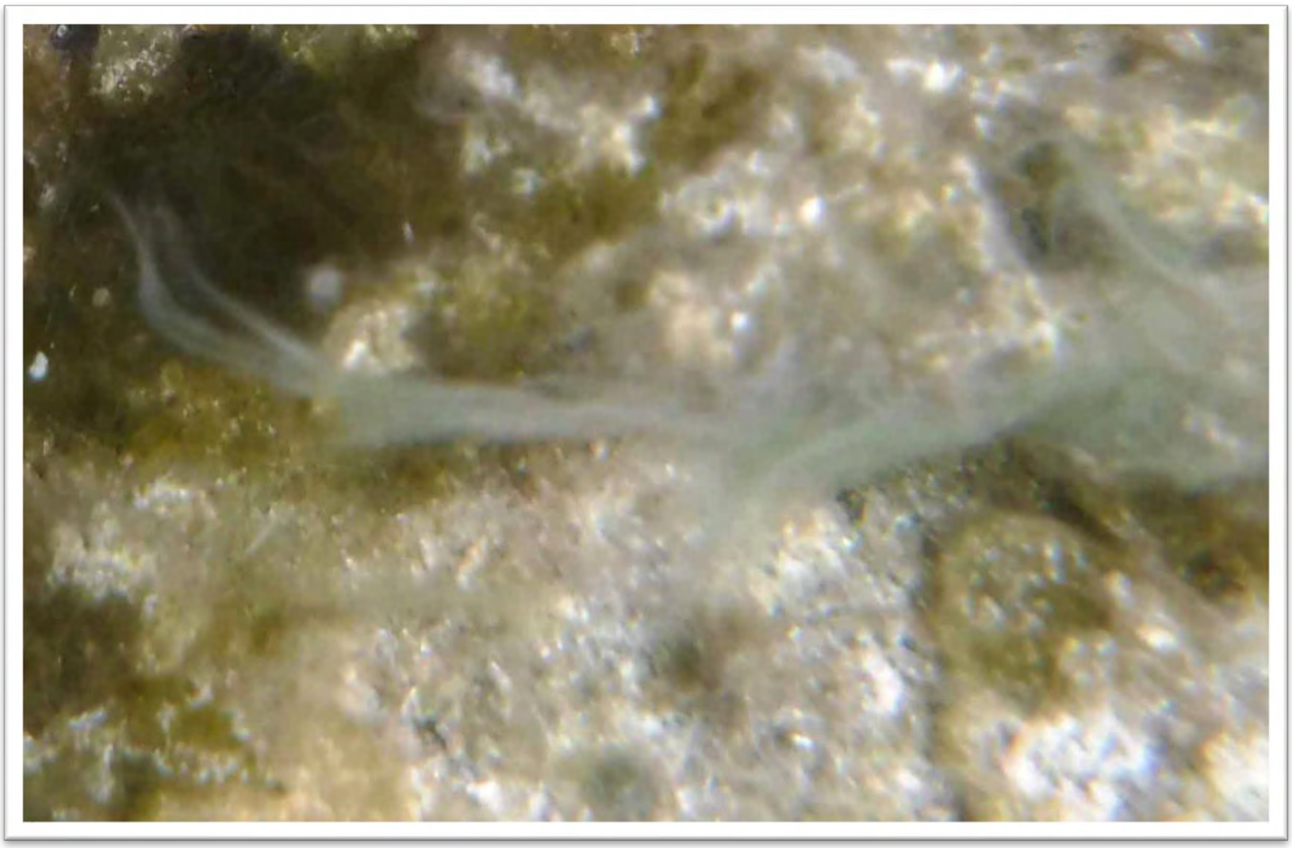
13.0 Propagation of Zebra Mussels in White Lake 2016 to 2021

Introduction

Anyone who maintains a floating dock and removes it in the fall, is intimately aware of the successful reproduction of zebra mussels in White Lake. Last summer, zebra mussels settled onto smooth flat surfaces like the underside of flotation pontoons. By late fall they appeared to be evenly spaced and of a similar size. These are the survivors of the 2021 zebra mussel breeding season. It is known that many zebra mussel shells approach adult length or at least achieve a third of their potential maximum length within the first year of growth.

Zebra mussels harvested from a floating pontoon, 2021

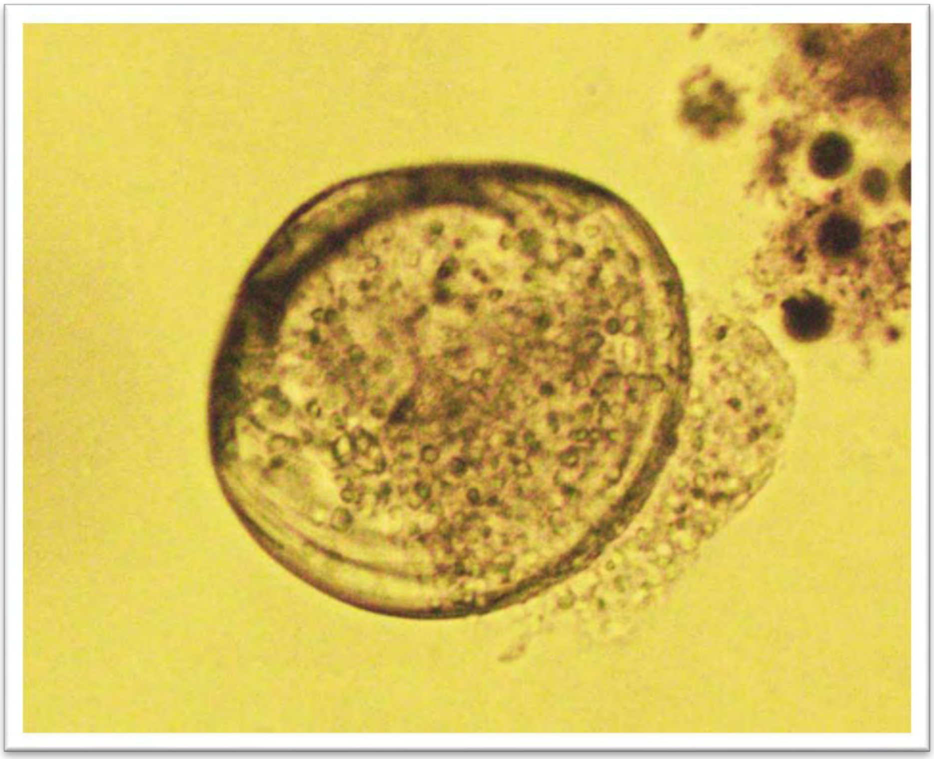
For successful reproduction, male and female zebra mussels must release sperm and eggs into the lake at the same time. This is called synchronicity, a process which depends on the release of a chemical signal between male and female mussels. Zebra mussels are but one of many species that release unfertilized eggs into the open water. Once secreted into the lake, fertilization must happen quickly. This is important to the mussel as any chance for fertilization decreases exponentially with increasing time and distance. The hormone seratonin is thought to act as the trigger. Every year millions of eggs will fail to be fertilized, however our floating docks show this strategy for reproduction works only too well for zebra mussels! The photo below captured what appears to be a spawning event between zebra mussels at Curley's Island.



Spawning event at Curley's Island: 19 August, 2018

White Lake Zebra Mussel Veligers: 2021

In 2021 we followed the cycle of zebra mussel veligers in the open waters of White Lake. Veligers are microscopic free swimming larvae of zebra mussels. For a short period of time they form a significant part of the free swimming plankton community. As planktonic veligers, their challenge is to not be eaten by predators such as fish nor be ingested by adult zebra mussels.



A veliger with the exposed vellum it uses for feeding and swimming

Sampling for Zebra Mussel Veligers

Every two weeks, water samples are taken at nine stations on White Lake as part of the Ministry of the Environment's Lake Partners Program (LPP). At these times, we also take a sample of the water column using a net for our own observations of planktonic life. The 80 micron mesh is the same size as used in the LPP water filters. The sample is taken by either a horizontal or vertical trawl and the length of the sweep is recorded. The filtered material is concentrated to 80 ml or less and allowed to settle for 30 minutes. Veligers are heavier than most other plankton and will settle out quickly. The sample is then examined under a microscope at 40x magnification and any veligers present are counted.

The photo below shows part of the sample count from Three Mile Bay on June 13, 2021. The net sweep of 4 metres represents a volume of 12.5 litres in which 2,784 individuals were found. This result indicates that at least 223 veligers/litre were present at that location on that date.

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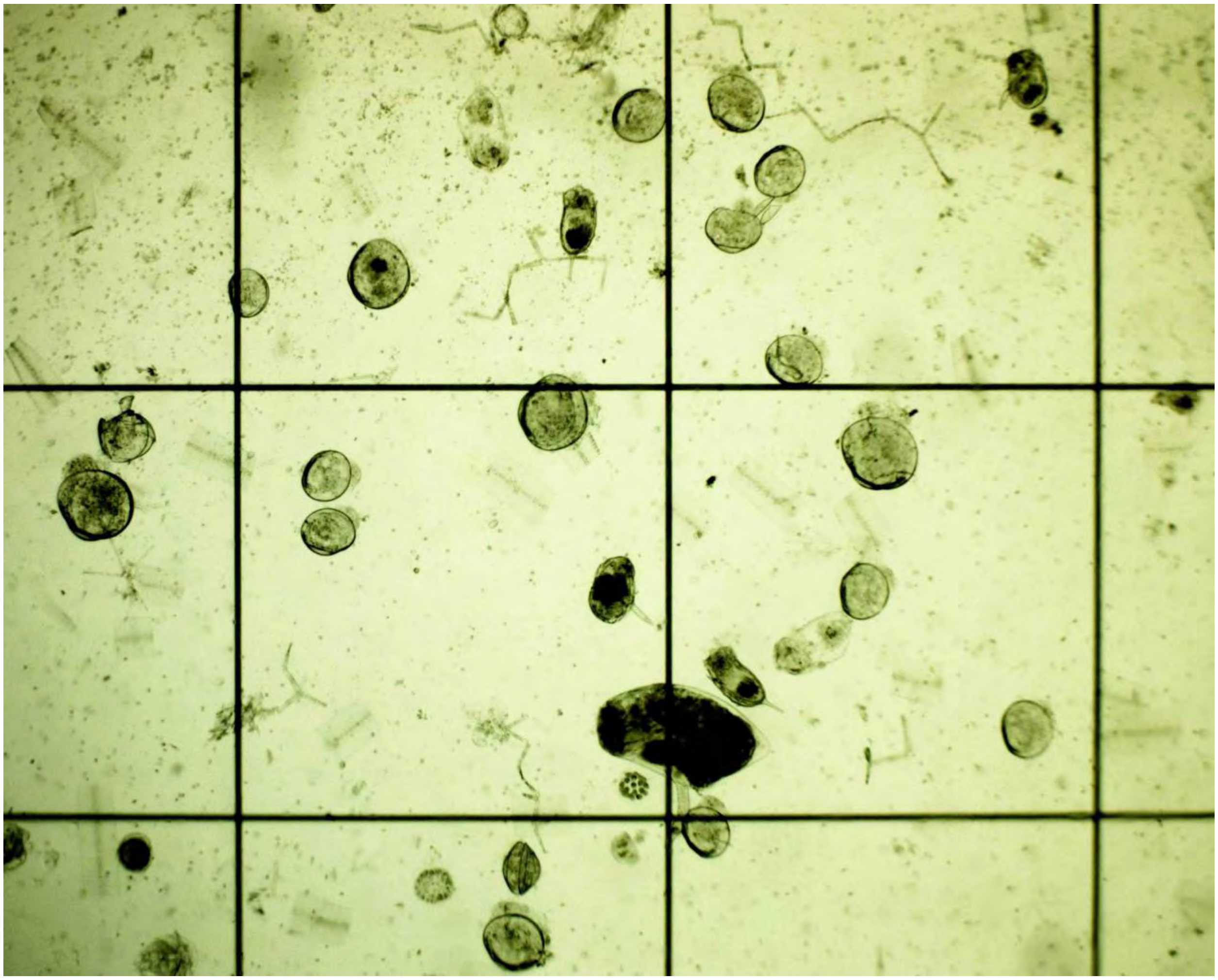
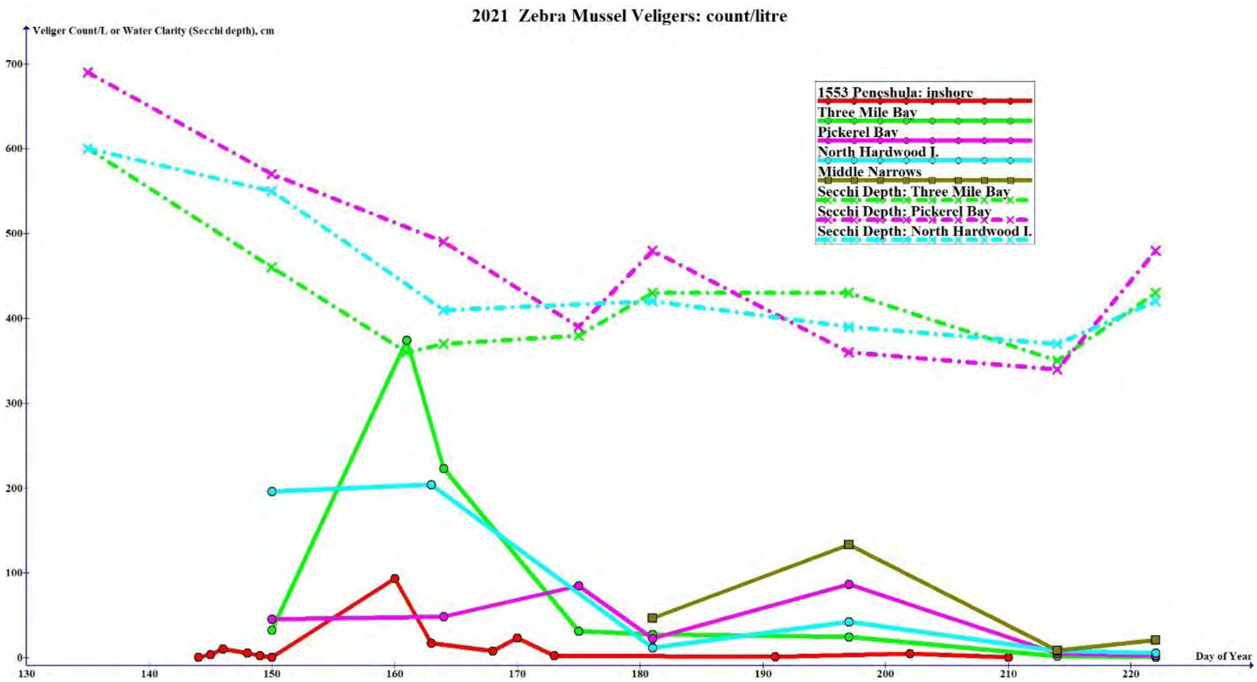


D-shaped veligers in Three Mile Bay   June 13, 2021   Day 164

Frequency of Occurrence of Zebra Mussel Veligers in White Lake: 2021

Results from the veliger survey are displayed in the following graph. Each colour refers to a specific sampling site. Solid coloured lines represent veliger counts at particular sampling stations. Veliger counts are expressed as veligers per litre. The red-dotted line represents an inshore location where depth was less than 2 metres. Secchi depths (water clarity) are represented by the broken coloured lines indicating a Secchi reading at that location on a particular day. Depths are given in centimetres. These Secchi depth readings are the same ones taken for the LPP program.



The above graph reveals a number of facts:

1. Shallow Secchi readings indicate the presence of more suspended material in the water column when compared to other days.

2. At each sampling site, there is a relationship between Secchi depth readings and veliger counts. As veligers increase in number, there is a corresponding decrease in Secchi depths for all sampling sites. Veligers contribute to decreasing Secchi values, but it is the abundant phytoplankton that veligers are feeding on that generates more shallow Secchi readings. As veligers decline in number, Secchi depths and hence water clarity increases.

3. Pickerel Bay (purple line) had a smoother trend with smaller peaks in veliger counts when compared to Three Mile Bay or the North Hardwood Island sites. The Pickerel Bay sampling site is more distant from zebra mussel spawning beds, so it has an averaging effect on the counts as veligers arrive from many different locations and at different times. The exact time of a spawning event occurring in other parts of the lake may not be indicated in these data.

4. Three Mile Bay, North Hardwood Island and the inshore site show major spikes in veliger counts, while Pickerel Bay shows a delayed rise and lower counts.

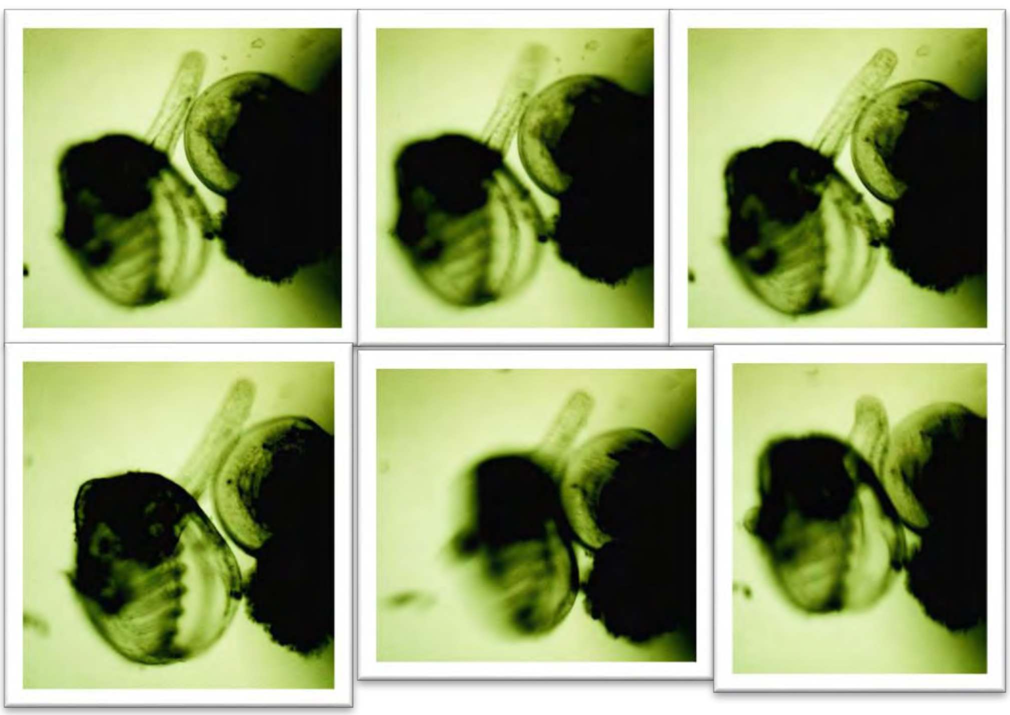
5. The single inshore site is in close proximity to weed beds and a rocky shoreline. These conditions allow for the sampling of a local spawning event which is less subject to influence from more remote locations.

6. The graph also shows that veligers are present thoughout the summer. There is no ‘safe’ period when water can be taken from the lake without the risk it being contaminated by veligers.

Veligers may well be the major cause for the spread of zebra mussels in Ontario lakes. A source for much of the contamination could be from transported bilge water in watercraft. A vessel moored for a few days could attract the settlement of pediveligers which are virtually invisible to the unaided eye. As the name implies, 'pediveliger' refers to the stage in a veliger's development when it has grown a 'foot' which can be used to move around on a solid surface. This is all the more reason for White Lake residents and guests to maintain a clean boat policy whenever watercraft are transported off the lake.

White Lake Pediveligers- Veligers with feet

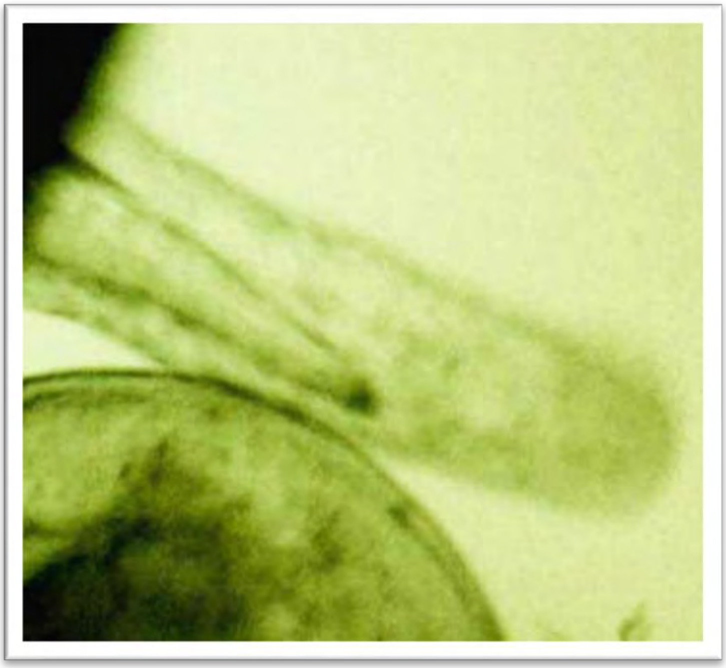
Veligers that survive through the plankton stage face another life challenge. As they grow beyond 0.15 mm in length, they also grow a foot for a future life as adults attached to hard surfaces. But first they must find a secure footing. Foot development continues regardless of whether a suitable hard surface is available. Pediveligers will not survive if they settle into the soft oxygen poor sediment of White Lake. Video images below capture a pediveliger foot in motion.



Pediveliger with extended foot: Three Mile Bay, July 3rd 2021; magnification: 100x.

Pediveligers and juveniles can relocate after they have settled. They will seek out shaded and less exposed surfaces. They also move towards each other to form clusters. Both juveniles and adults retain the ability to crawl with their foot.

Pediveligers secure themselves by a mucous thread that is moulded and extruded by a groove in the base of the foot (see the photo below). These 'byssal threads' are laid down daily and their number will depend on the degree of environmental stress experienced by the zebra mussel.



Zebra mussel foot and groove

The First Year Cohort of Zebra Mussels in White Lake: 2021

To gain an idea of survivorship for the 2021 cohort, we used an aluminum boarding ladder suspended off a floating wharf located 30 feet from the shore. Each of the five steps had a plywood strip attached to it's underside. Steps were separated at one foot intervals. The upper step was emersed 4" below the surface. Steps were left undisturbed from May 17 until October 11, 2021, a period of 145 days. Harvesting involved the complete removal of zebra mussels from both sides of each plywood strip. The photo below illustrates the underside of a step before harvesting.

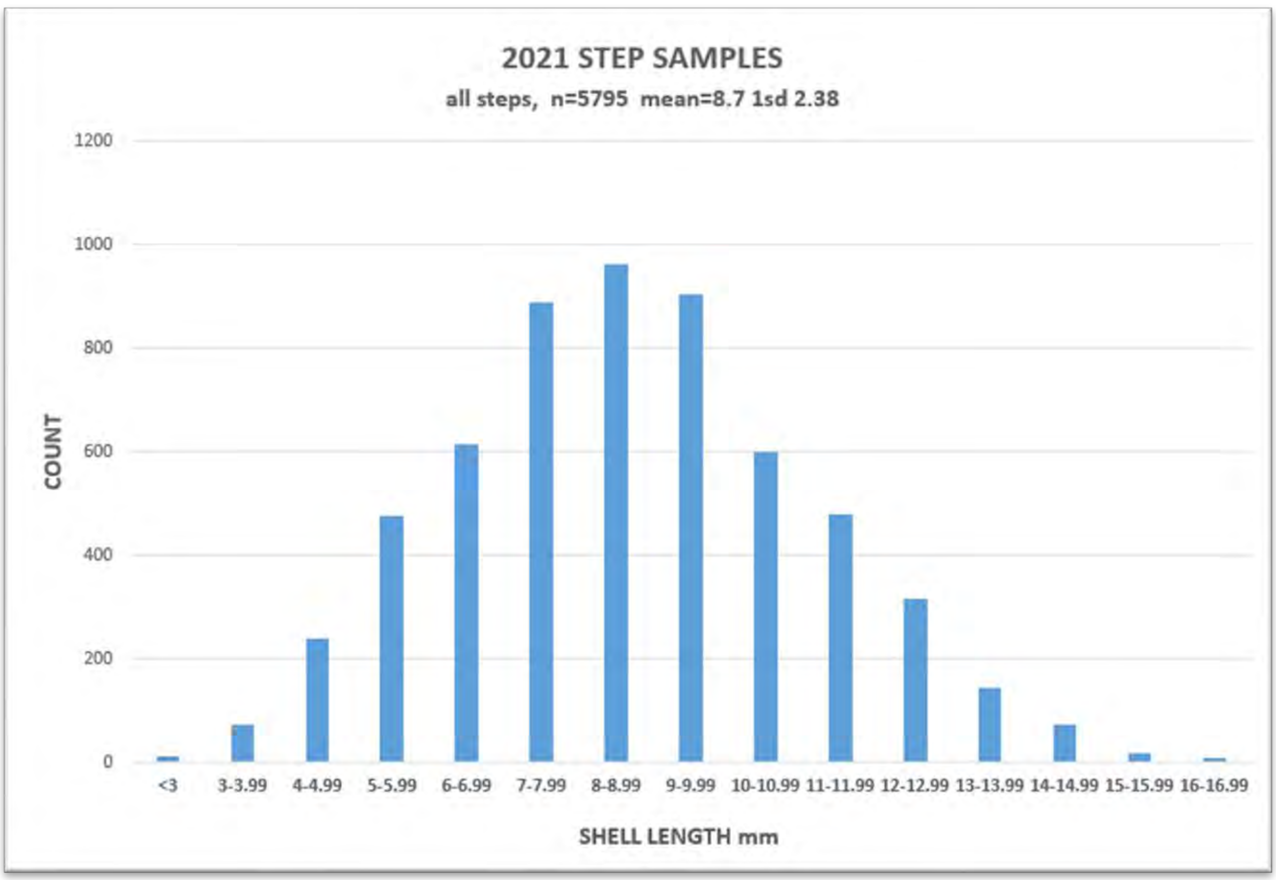
Underside of third step: October 11, 2021

Size measurements were made with a digital micrometer unless individuals were less than 4 mm.

Measured lengths were plotted as a frequency distribution which we have done in previous years starting in 2016. (See previous White Lake Water Quality Reports)

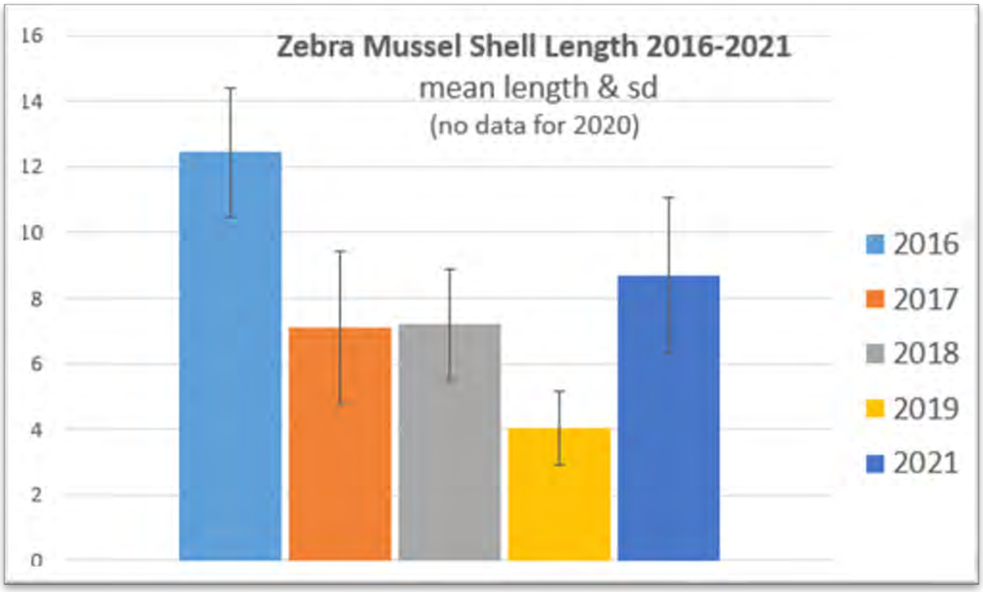
Distribution of Shell Size for the First Year Cohort of 2021

The 2021 frequency graph (below) shows a normal distribution for shell length with a mean value of 8.7 ± 2.38 mm (1 standard deviation). The overall range in size (2.4mm to 16.9 mm) suggest veliger settlements occurred continually throughout the summer. This is in agreement with our veliger count survey. Production diminished significantly for sizes under 4 mm by the fall. It is likely difficult to separate individual spawning events in a headwater lake where veligers are retained and can accumulate in the water column during their free swimming stage and are not flushed downstream.



Changes in Recruitment of Zebra Mussels from 2016 to 2021

The figure below illustrates changes in the recruitment (survival) of first year zebra mussels over the previous 6 years. These data suggest that recruitment is cyclical in



number and size, and reflects the mass die-off of the initial colonizing population. The reported age range of zebra mussels is thought to be about 3 to 5 years. The fourth year (2019) had the lowest harvested count and smallest mean size (4mm). Although we lack data for 2020, the 2021 data indicates zebra mussel recruitment is returning to values similar to those in 2016. We can speculate that this trend will continue in 2022.

A Comparison of zebra mussel populations from 2016 to 2021

	2016	2017	2018	2019	2021
Start Day	July 4	June 12	June 7	June 8	May 14
Retrieval Day	October 15	October 16	October 11	October 17	October 11
Days Immersed	103	126	126	131	145
Harvested Count	1680	5788	9026	3255	5794
Mean Shell Length, mm	12.4 ± 2.0	7.1 ± 2.3	7.2 ± 1.7	4.0 ± 1.1	8.7 ± 2.4
Size Range, mm	6-17	1.1 – 14.59	2.83 - 13.21	1.41 – 8.94	2.4 – 16.86
Wet Weight, g	422	341	161.4	48.5	727
Shell Weight, g	135	86.8	47.7	10.7	253.3

No data available for 2020

The above table shows that differences in shell weight to living wet weight ranged from 22% to 31% during the survey years. The 2019 data with the smallest mean value had the smallest difference in weight (22%). The 2016 and 2021 data show a higher and similar weight range (35% and 31%).

The 2019 data had the second longest immersion period yet shell length achieved at best only 67% of shell lengths from previous years. The small mean size in 2019 suggests a late season start for zebra mussel settlement.

Estimation of Growth Rate of Zebra Mussels: 2016-2021

The following table is somewhat speculative in nature and is based on observations cited in this report. The analysis assumes a constant zebra mussel growth rate, and is based on the maximum length achieved for the maximum days available for growth.

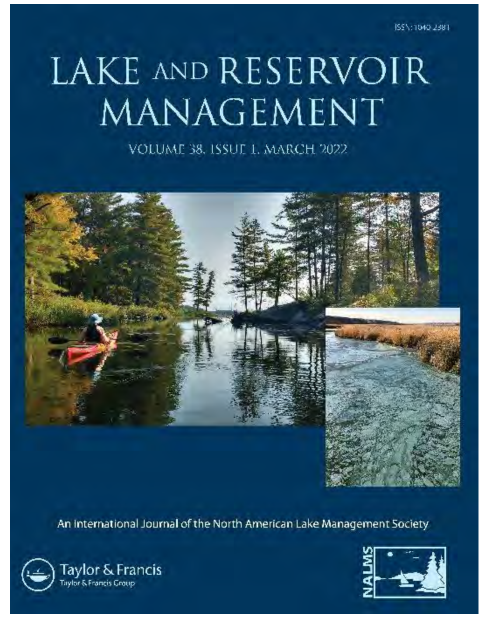
This table suggests the bulk of zebra mussels (~70 %) establish themselves within a 24 to 44 day period. The timing of settlement for the bulk of zebra mussels seems to be shifting to later dates. There is the possibility this reflects a trend to periods of longer maturation and reproduction. Perhaps this trend is facilitated by a warming climate

approximations	2016	2017	2018	2019	2021
shell growth per day	0.165	0.115	0.104	0.068	0.116
days to mean length	75 days	61 days	74 days	58 days	75 days
day of mean length	day 214	day 228	day 210	day 232	day 209
date of mean length	Aug 2nd	Aug 16	July 29	Aug 20	July 28th
day range using 1 SD*	202-226	207-247	199-232	215-248	229-273
date range using 1 SD*	July21-Aug14	July26-Sept4	July18-Aug20	Aug3-Sept5	Aug17-Sept30

*Standard Deviation

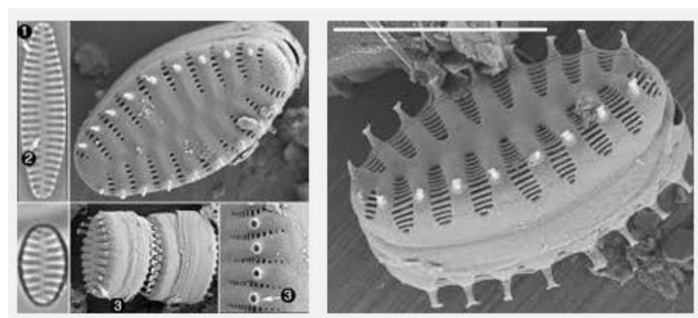
Growth rate (mm/day) = maximum shell length/number of days of immersion
Number of days to reach mean length = mean length/growth rate
Number of days for SD interval = standard deviation values/growth rate
Date estimates = retrieval date – days of growth

14.0 Research Paper on White Lake Water Quality is Published



A research paper on White Lake was recently published in the Journal of Lake and Reservoir Management, which is a highly respected publication read by lake scientists around the world. The paper was entitled '*Assessing the ecological responses of a shallow mesotrophic lake to multiple environmental stressors using paleolimnological techniques*.' The paper was the result of a three-year collaboration between Prof. Jesse Vermaire's research group at Carleton University and White Lake Environment Volunteers, and was co-authored by Michael J. J. Murphy, Branaavan Sivarajah, D. Conrad Grégoire and Jesse C. Vermaire.

Paleolimnological studies involve the study of diatoms in lake sediments in order to gain information about water quality changes over time. Diatoms, like those shown on the right, are the skeletal remains of microscopic plankton. Different species of diatoms thrive in different environments and so the study of these can be used to reveal the history of lake water quality for the last several hundred years or even longer periods.



The findings of the study indicate that White Lake has contained moderate amounts of nutrients for at least the past 200 years. Recorded in the sediments are significant changes in water quality starting in the 1890s when there were logging and land clearance activities. However, the largest single change in the diatom assemblage, and hence water quality of White Lake, was correlated to water level changes resulting from the damming of the lake in 1845 and subsequent alterations to the water level management plan up to the present day.

Prof. Jesse Vermaire and Conrad Grégoire taking a sediment sample for study

The research also revealed increasing amounts of nutrients entering the lake as a result of human activity resulting in a deterioration in water quality. The study also found that impacts of future shoreline development should be assessed while taking into account that there are several co-occurring stressors which together have an amplified impact on water quality. These include climate change and invasive species such as zebra mussels and Eurasian milfoil. A sign of the need for careful management are the annual algal blooms which have occurred in White Lake since 2013.

15.0 White Lake Loon Survey and Wildlife Observations June 26 to July 3rd, 2021

Joyce Benham and Bob Carrière

It was with some apprehension that we started our 2021 loon survey on White Lake. The infestation of a black fly which impacted on nesting loons, resulted in a drop of nesting pairs from 12 to 2 and chick production from 23 to 4 in 2020 when compared to our count for 2019.

We time our loon survey to coincide with the period that loon chicks are fully hatched and in the water with their parents. This makes for the best photography of loons on White Lake. This year, we immediately realized that for some reason, a few nesting loons were still incubating their eggs. Some of these eggs hatched after our survey, however, our report includes most of the new hatchlings as reported to us by others who observed these late nests for us.

Since the arrival of zebra mussels in White Lake, we continue to observe very high-water clarity and the proliferation of aquatic plants. Areas which were easily reached by boat in previous years are now choked with aquatic plants. This year we also observed in many parts of the lake the presence of nuisance filamentous green algae forming large 'clouds' of green just under the surface of the lake and often extending to the lake bed.

Photo Credit: Joyce Benham

Site specific observations:

The specific numbered sites cited below correspond to the numbered sites shown on the map below. Not all sites were occupied by loons in 2021 although they may have been in other years.

Site 1: Single adult loon near the outlet of Broad Brook.
Site 2: One adult loon.
Site 4: Two adult loons.
Site 6: Two adult loons.
Site 9: Two adult loons and one chick.
Site 12: Two adult loons.
Site 13: Four adult loons and one chick.
Site 14: Two adult loons.
Site 15: One adult loon.
Site 19: Two adult loons and one chick.
Site 20: Two adult loons.
Site 23: Two adult loons and one chick in Village Basin.
Site 26: Two adult loons.
Site 28: Two adult loons and one chick.

Summary of Loon observations for 2021:

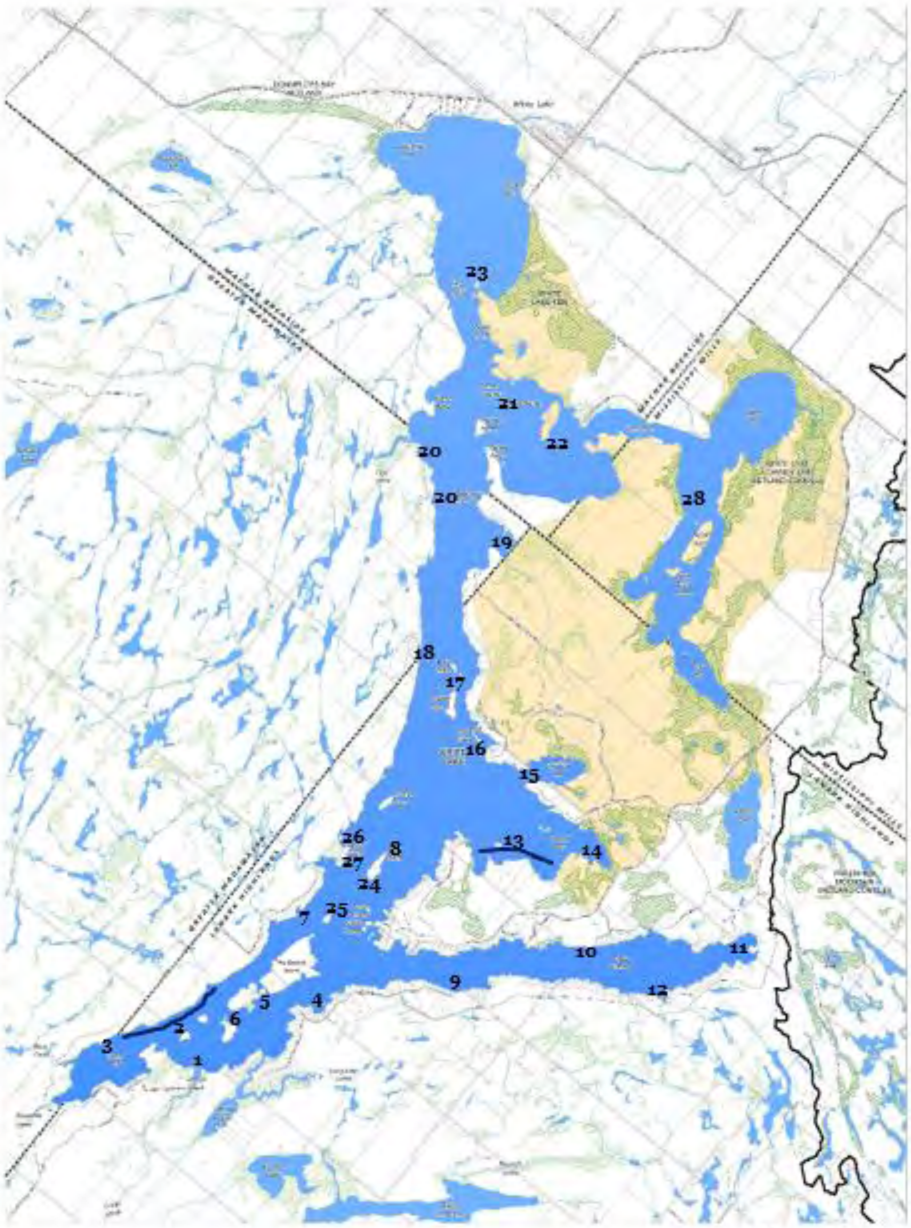
Total number of adult loons: 27
Number of nesting pairs: 5
Total number of chicks: 5

The table below summarizes the results of loon surveys for eight years starting in 2013. It is clear that 2021 was a difficult year for loons. The number of loons returning to the lake did not substantially recover from the low numbers of 2020. Nesting pairs were also very low as were the number of chicks produced.

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

Loon Observation Sites

June 26 – July 3, 2021



Wildlife Observations:

During our stay on White Lake, we made numerous observations of wildlife including bald eagles, ospreys, otters, and great blue herons. Of particular interest was witnessing the mating of two very large snapping turtles. The photo below was taken near the outlet of Broad Brook.

Photo Credit; Joyce Benham

16.0 Double-Crested Cormorant Survey - 2021

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

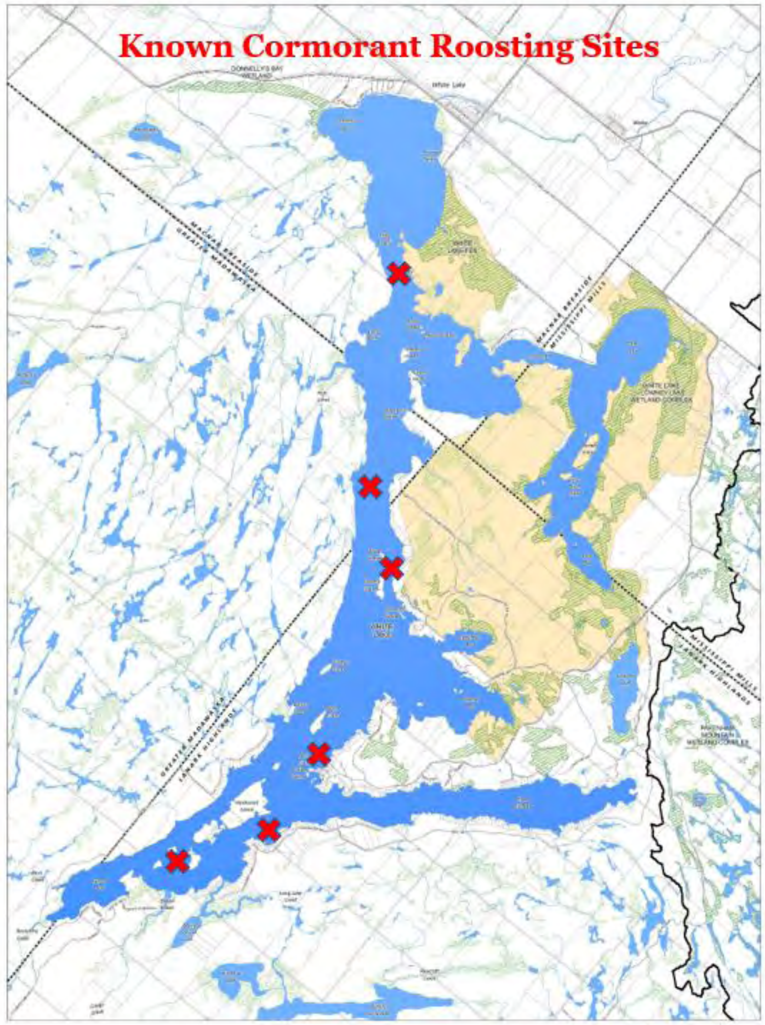
Measuring 70–90 cm (28–35 in) in length, it is an all-black bird which gains a small double crest of black and white feathers in breeding season. It has a bare patch of orange-yellow facial skin. Five subspecies are recognized. It mainly eats fish and catches its prey by swimming and diving. Its feathers,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

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

In fact, the Ontario Federation of Anglers and Hunters (OFAH) web page on cormorants specifically says *"Populations of double-crested cormorants are increasing in number and distribution across Ontario's shorelines. Where cormorant numbers are high, they can negatively affect terrestrial habitats by chemical and physical means through corrosive acidic guano, and stripping/breaking tree branches. In some cases, cormorant colonies have destroyed entire island ecosystems. Many people are also concerned about potential impacts on fish populations and angling opportunities."*

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

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

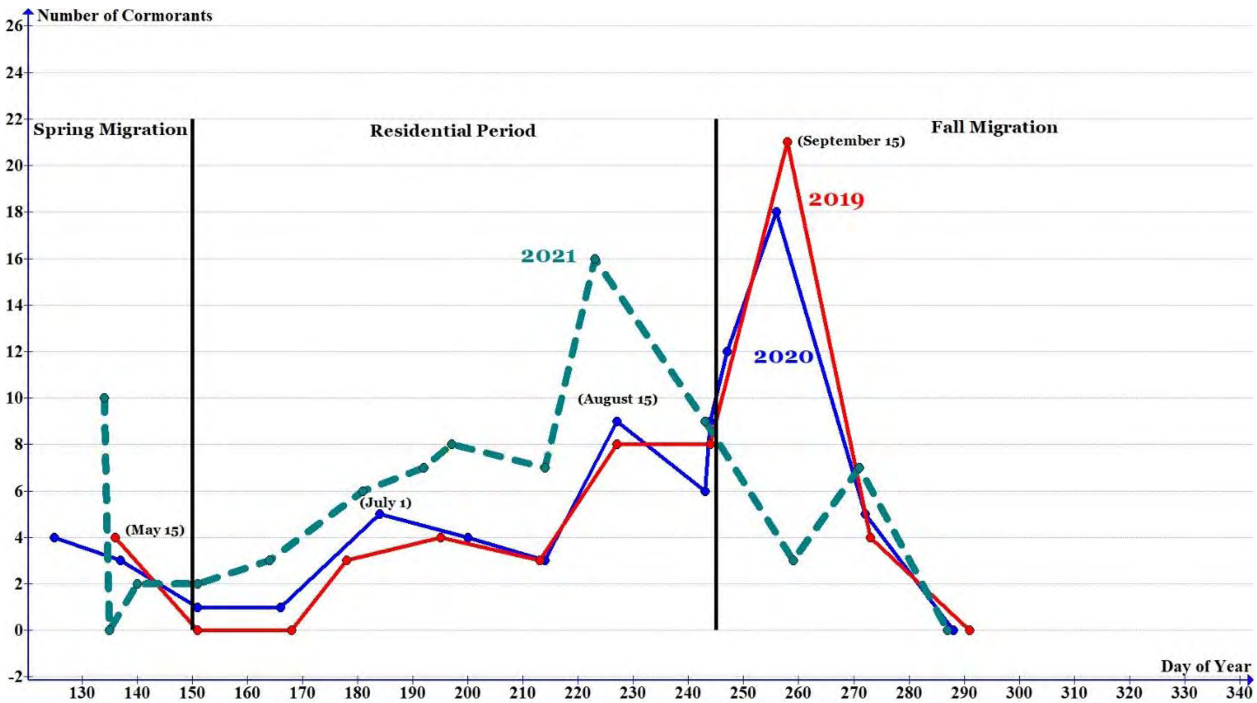


As part of our water quality monitoring program, we decided to start monitoring cormorant numbers on White Lake. Every two weeks we patrol the lake by boat and sample 9 sites in all parts of the lake. Water samples for total phosphorus and plankton counts are collected. Water temperature and clarity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

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

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

The graph is divided into three sections marked by the two vertical black lines. During spring, as well as at the end of summer, larger numbers of cormorants are often observed. Most of these birds are migrating to other sites and only stop and linger at White Lake for a week or so. In 2021, we did not observe the higher numbers usually seen during the fall migration. It is possible that non-resident cormorants did not use White Lake this year, or they arrived and left during the two-week interval between counting dates.



Graph of Cormorant Numbers Observed by Day of Year: 2019 to 2021

Of greater interest are bird counts taken during the residential period. It is interesting that the data curves are very similar, with populations peaking in mid-May, July 1, and mid-August. It is tempting to suggest interpretations for these points. We can speculate that only adult cormorants are seen on the lake up to late July when youngsters join their parents on the lake.

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 from 8 to 10 cormorants making White Lake their home. This translates to a minimum of 4 to 5 nesting pairs producing about 7 to 8 offspring, as reflected in the total cormorant count taken in mid-August.

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

17.0 Selected Environment Bulletins – 2021

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

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

17.1 Water on Ice

One of the joys of winter is taking long walks, snowshoeing or cross-country skiing on the lake. For others, it's snowmobiling or ice fishing which is the main draw.

This winter, these activities have been hampered by the wide-spread occurrence of water on the surface of the ice just beneath the snow. What results is a walk in the slush or a snowmobiling ride that feels more like a bumpy boat ride than anything else.

Although this situation occurs almost every year, it is particularly severe this winter. Why? The reason why water seeps onto the surface of the ice is because of a water pressure increase below the ice. This can be caused by several factors. Ice is flexible, like a sheet of paper and when it snows, the ice tends to sag a bit under the added weight of the snow.

Secondly, water can enter the lake from streams and seepage from land. We noticed that much of the water on the surface of the ice on White Lake is brownish in colour. This is a telltale sign of water coming through soils before entering the lake.

Ice cracks when it expands or contracts allowing water to reach the surface. Holes created by ice fisherman serve the same purpose. But why does the water not freeze instantly once it finds its way onto the ice?

First of all, the temperature of the ice itself is close to zero degrees, especially at the ice-water interface. And, even at very cold temperatures, snow is an excellent insulator. Together these two factors keep water in the liquid state resulting in slush. On a cold day, removal of the snow cover would result in ice surface water turning to ice very quickly.

Although one may associate a slushy ice surface with warm weather, this situation can happen anytime during the winter, even in very cold weather. Snow is really the main culprit because of its weight and insulating properties.

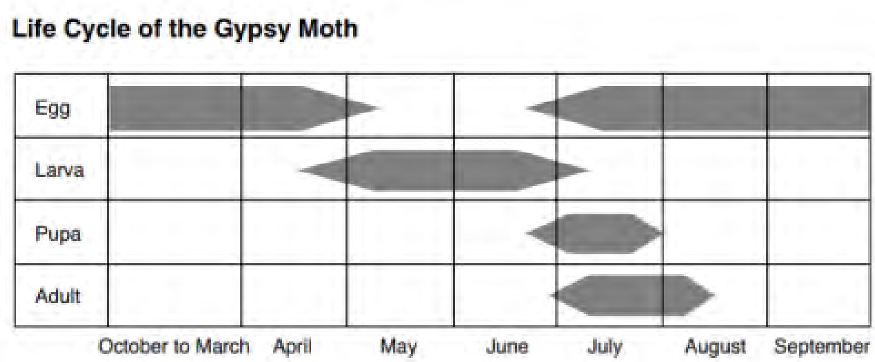
As long as there is sufficient ice thickness, it is not dangerous to walk on a slushy lake, just darned inconvenient!

17.2 Control of Spongy (Gypsy) Moth Infestation

Last year we issued an Environment Bulletin on the current gypsy moth infestation in the forests surrounding White Lake. It is apparent from our observations of trees during the fall and through the winter that the situation may be even worse in 2021. We have found trees hosting as many as 100 egg masses waiting for warm weather to hatch and wreak havoc on emerging foliage. Many trees will not survive two to three years of foliage loss. Coniferous trees are especially vulnerable because these trees retain three years of pine needle growth which can all be lost in a single year from the ravages of gypsy moth caterpillars. These trees can die during a single infestation season.

Gypsy moth numbers rise and fall during an approximately 10-year cycle so they will eventually (almost) disappear and then return in threatening numbers. Cold winter temperatures of below -20C for extended periods can kill a percentage of the eggs waiting to hatch. However, winter has not been severe, and with the effects of climate change steadily changing our seasons, we can expect even more trouble from gypsy months.

Is there anything we can do to prevent the loss of trees on our cottage and home lots? The answer is yes, but a concerted effort is required over more than one year to achieve success. The actions we can take are centered around the life cycle of the gypsy moth as illustrated by the diagram below.



1. From September to late April: *Remove and/or Destroy Egg Masses*.

During this time period, the gypsy month is in the egg stage and masses can be found on tree trunks, branches, buildings, rocks, and even your car. Egg masses are often found at the base of a tree, but also can be found all the way up a tree trunk, especially for badly affected trees. One egg mass contains about 300 eggs.

Scraping egg masses; assemblage of egg masses; single egg mass

The easiest way to eliminate and destroy these eggs is to scrape them off into a container using a narrow putty knife or a small spatula. The collected eggs can be killed by soaking them in a soapy solution for a couple of days. The soap and water combination wets the eggs mass and deprives it of oxygen.

A word of caution: The egg masses are covered with protective hairs and these can irritate your eyes and throat. We recommend wearing glasses and a mask to prevent adverse effects.

A second approach to eliminating egg masses is to use a spray of natural insecticide oil or vegetable oil such as soya oil. By simply mixing one cup of soya oil with one cup of water and a quarter cup of liquid dish soap, one can produce an effective spray that coats egg masses and leaves a layer of asphyxiating oil on the surface of the eggs (see Appendix 1). Shake well before using. This approach can be also be used in concert with scraping as a way to kill eggs tightly lodged into the cracks and crevices of tree bark, especially oak.

Additionally, products as pictured below, can be purchased on the internet by searching their brand names. Any household sprayer which can produce a 'jet' can be used for this purpose.

<u>A third approach</u> cited in the literature is removing egg masses with the use of a vacuum cleaner. Proper disposal of the filter bag is essential to prevent caterpillars from escaping back into the wild.

2. From late April to early May: *Place sticky barriers or bands on the trees.*

Wrap duct tape or other suitable material (sold at hardware stores) around the trunk of a tree about 5 feet off of the ground. This band is then coated with a sticky material called tree tanglefoot which serves to capture hatchling caterpillars as they make their way up the tree trunk from lower down or from areas such as buildings or objects.

Tree tanglefoot is a plant-derived resin which resembles caramel in colour and texture. In order to make spreading of this material easier, especially in cooler weather, the resin can be thinned by adding 25% acetone and applying the mixture using a paint brush. Note that acetone, available at hardware stores, is the only solvent we have found that dissolves tanglefoot. Once applied, the acetone evaporates very quickly.

3. From late May to August: *Replace sticky barriers with burlap bands.*

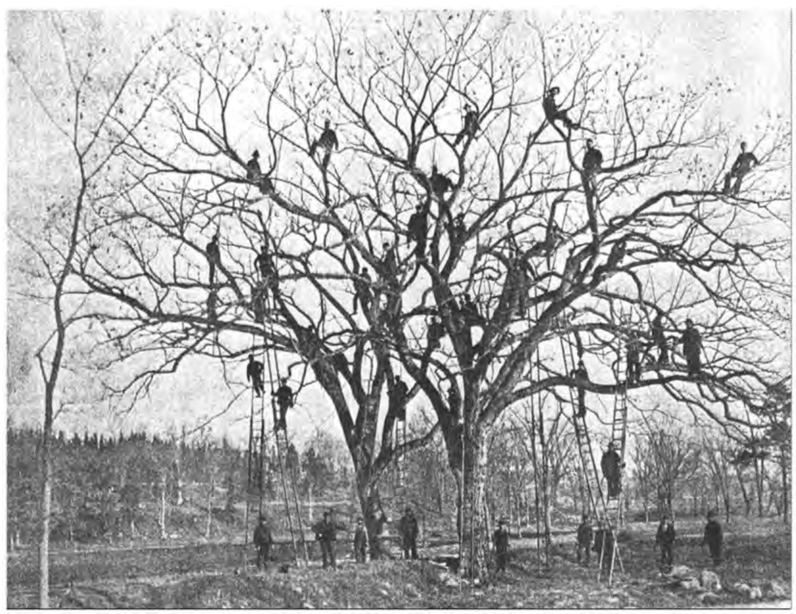
Caterpillars feed at night and hide during the day in places to protect themselves from the heat and predators. In doing this, they often crawl down the trunk of the tree to seek shelter.

At this point, they can be captured by placing burlap cloth bands on the trees as shown below:

Wrap burlap that is about ½ to 1 metre wide around the tree trunk. Tie it at the middle with a length of twine. Then fold the top half of the burlap wrap over the lower half. Simply collect and destroy the caterpillars that emerge from under the burlap. The best time to 'harvest' your catch is during later afternoon before they rouse themselves and crawl back up to the crown of the tree.

From late June to early August, caterpillars will pupate in the same location and can also be harvested. Both caterpillars and pupa can be destroyed by placing them in a soapy solution for a day or two. Your challenge may be finding someone in your family who is willing to do this.

4. Involve your family and your neighbours.



One approach to getting this work done is to make it a family affair. The collection of gypsy eggs, larva and pupa can be a multi-generational activity carried out all year long. Make this year's easter egg hunt of a different kind!

Ridding gypsy moths from your property does not guarantee that caterpillars will not find their way to you from your neighbours. It's a good idea to get them involved as well, and if they are not interested, perhaps they will let you treat the most affected trees on their property and save you work later on.

5. Aerial spraying.

One additional option available to White Lake residents and cottagers is engaging a licensed crop-duster to overfly properties and apply an insecticidal spray. Aerial spraying for gypsy moth is often done using a commercial product called Foray 48B®.

Foray 48B® is a water-based product containing a bacterium called Bacillus thuringiensis variety kurstaki (Btk). Btk is found naturally in the soil and is known to cause illness in many insect larvae when ingested, including caterpillars of pest species such as the gypsy moth. Larvae are most susceptible to Btk when they are in the early developmental stages.

Foray 48B® is not toxic or harmful to people, dogs, cats, fish, birds, reptiles, or insects such as honeybees, beetles, or spiders. Pest control products containing Btk have been registered for use in Canada for about 40 years. It is now the most widely used pest control product in the world.

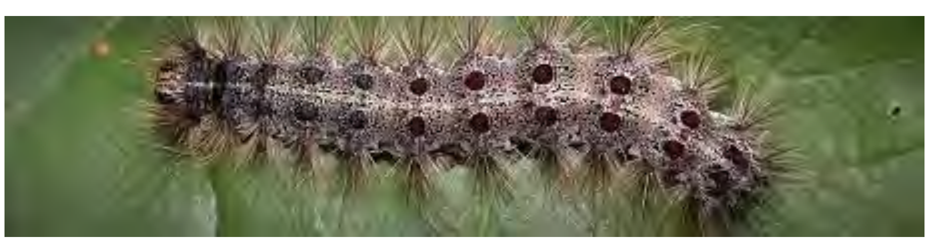
Aerial spraying of Foray 48B® for gypsy moths is usually done in the spring between April and June and takes place between 5:00 a.m. and 7:30 a.m. Three separate applications are done every 7 to 10 days. These applications are usually required to treat the gypsy moth larvae, which hatch during the treatment period.

Depending on the size of the treatment area, the aircraft used and any weather delays, it may take several mornings to complete 1 application.

For aerial spraying to occur, everyone in the area would have to agree to have it done as well as to share in the cost. It is not possible to spray individual properties and so universal buy-in from everyone on a shoreline is required before proceeding. The fact that we cannot spray on public lands, which is only done by the province when warranted, means that the efficacy of spraying only on private land is somewhat compromised by the large pool of moths located on nearby public land.

Suggestion: If you are planning to implement any of the measures outlined above, be sure to buy your supplies early to avoid disappointment.

Female and Male Gypsy Moths



Appendix 1

The efficacy of two different solutions for killing gypsy moth egg masses

An experiment was conducted to determine the efficacy of two different preparations reportedly used to kill gypsy moth eggs. Samples were collected in mid-February by scraping egg masses off of tree trunks. Three separate samples were made by placing 5 egg masses in each of three 250 ml canning jars. A piece of cheese cloth was used rather than the sealing disk to allow oxygen to enter the jars.

The three samples, shown below in the photo were:

1) No treatment
2) Solution made from 10% dish (Sunlight) soap and 90% water by volume.
3) Solution made from 10% dish (Sunlight) soap, 45% vegetable (rapeseed) oil and 45% water, by volume.

After saturating the second and third samples with their respective solutions, the three samples were placed together in front of a south facing window. Eggs hatched in about 14 days.

Results: It is apparent from the photo below that a simple soap solution was not effective in killing gypsy moth eggs. The relative number of newly-hatched caterpillars from untreated eggs appear to be about the same as for those eggs treated only with a soap solution. The third sample, treated with the soap/water/oil emulsion, did not produce any hatchlings. When the egg mass was saturated with a spray of this emulsion, effective control of this pest was achieved.

Gypsy moth 2020

Areas in Ontario where gypsy moth caused defoliation

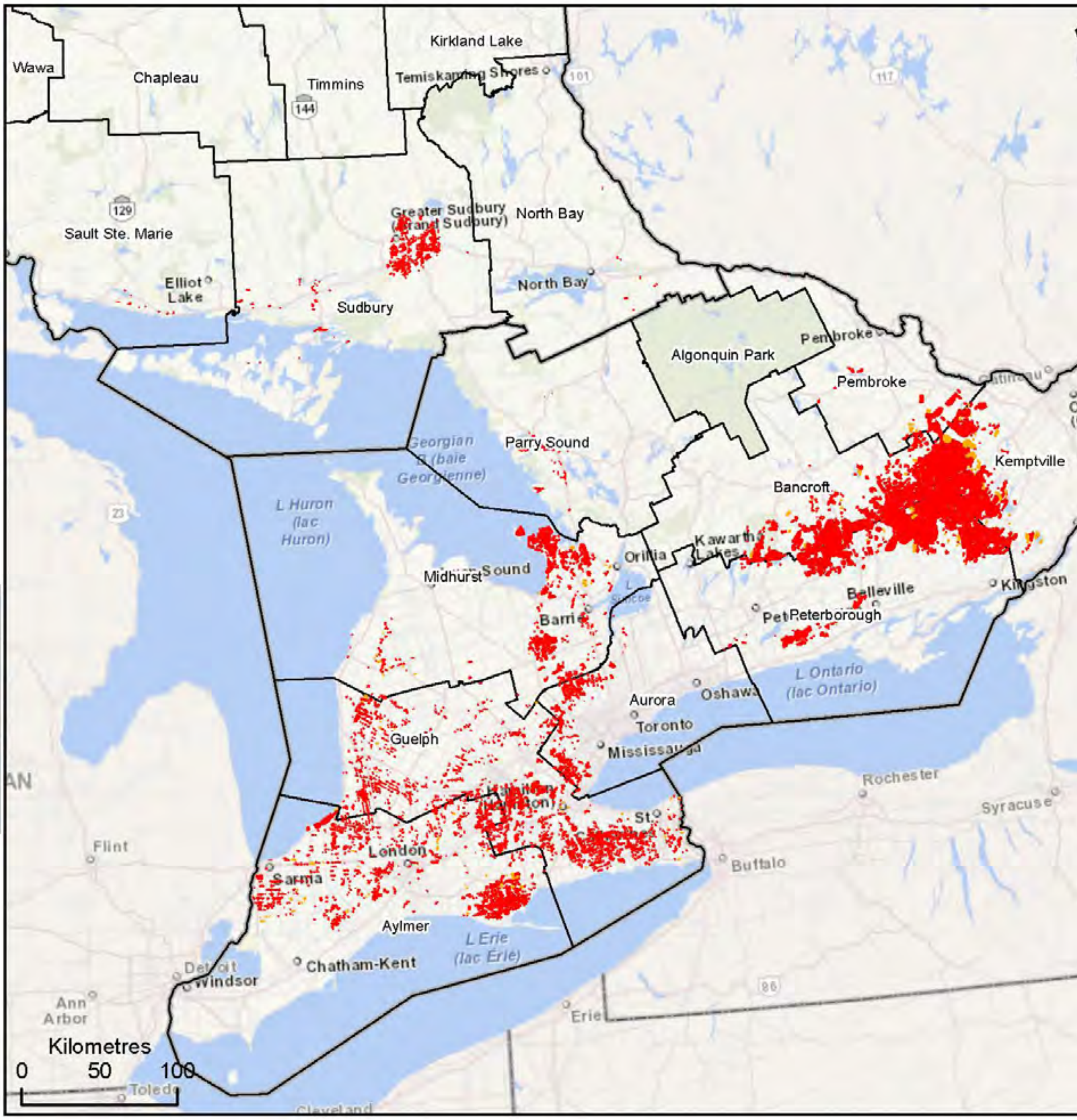
Light = 17,002 ha
Moderate to severe = 569,384 ha

Area of light defoliation

Area of moderate to severe defoliation

Disclaimer:
This map is illustrative only. Do not rely on this map as being a precise indicator of routes, locations of features, nor as a guide to navigation. This map was produced by the Ministry of Natural Resources and Forestry.

Ontario



17.3 Pollen Storm

Every year from mid-May to mid-June, I find myself standing at the end of our dock on the western shore of White Lake looking South. What I see is a yellowish cloud over Sunset Bay which is heading in my direction. Anyone who suffers from allergies has felt the oncoming storm for some time. Dread is in the air!

The oncoming pollen cloud is also a reminder that it is a good time to close the cottage windows and to cover, if possible, any patio furniture.

Much of White Lake is nestled in forests which feature spruce and pine along with deciduous trees such as birch, oak and maple. All of these trees produce pollen in the spring.

The annual pollen storm can be mild or more severe depending on the weather. Cooler temperatures can extend the duration of the storm and rain can function to cleanse the air of pollen and deposit it on land and water.

As far as trees are concerned, one unintended consequence of their reproductive cycle is the loss of huge amounts of pollen to the lake. Some of the pollen ends up floating on the surface of the lake, while most of it slowly sinks to the bottom. On the way down to the sediments, pollen grains become food for small fish and other creatures and also provide added nutrients in support of primary algal growth, the basis of the lake food chain.

What we see on the surface can be easily mistaken as an algal bloom. The wind can act to concentrate the pollen in sometimes very long 'lines' on the surface of the lake, in much the say way we see lake foam lines developing in the fall.

Eventually, the floating mass of pollen will begin to decompose giving off foul odours in the process.

Once pollen sinks and becomes part of the sediments at the bottom of the lake, some of it will decompose and release nutrients, including phosphorus. It has been reported that for some lakes, as much as 10% of the phosphorus entering the lake ecosystem is derived from pollen.

Because there is usually a lack of oxygen in sediments, some of the pollen will be preserved in the sediment. In fact, sediments thousands of years old can be recovered by coring.

These cores can be divided into slices of one centimetre or less. The slices can be precisely dated using radiocarbon dating techniques, and analyzed for their preserved pollen content. Scientists (Paleolimnologists) can then use this information to reconstruct the forest cover and even the climate over thousands of years.

A recent study of sediment cores from White Lake, which we participated in, found that the lake is 'filling in' at the rate of about 1 millimetre per year. This means that in about 3,000 years, you will be able to take a walk across Three Mile Bay, in the summer, without getting wet!

17.4 White Lake: Myths and Maps

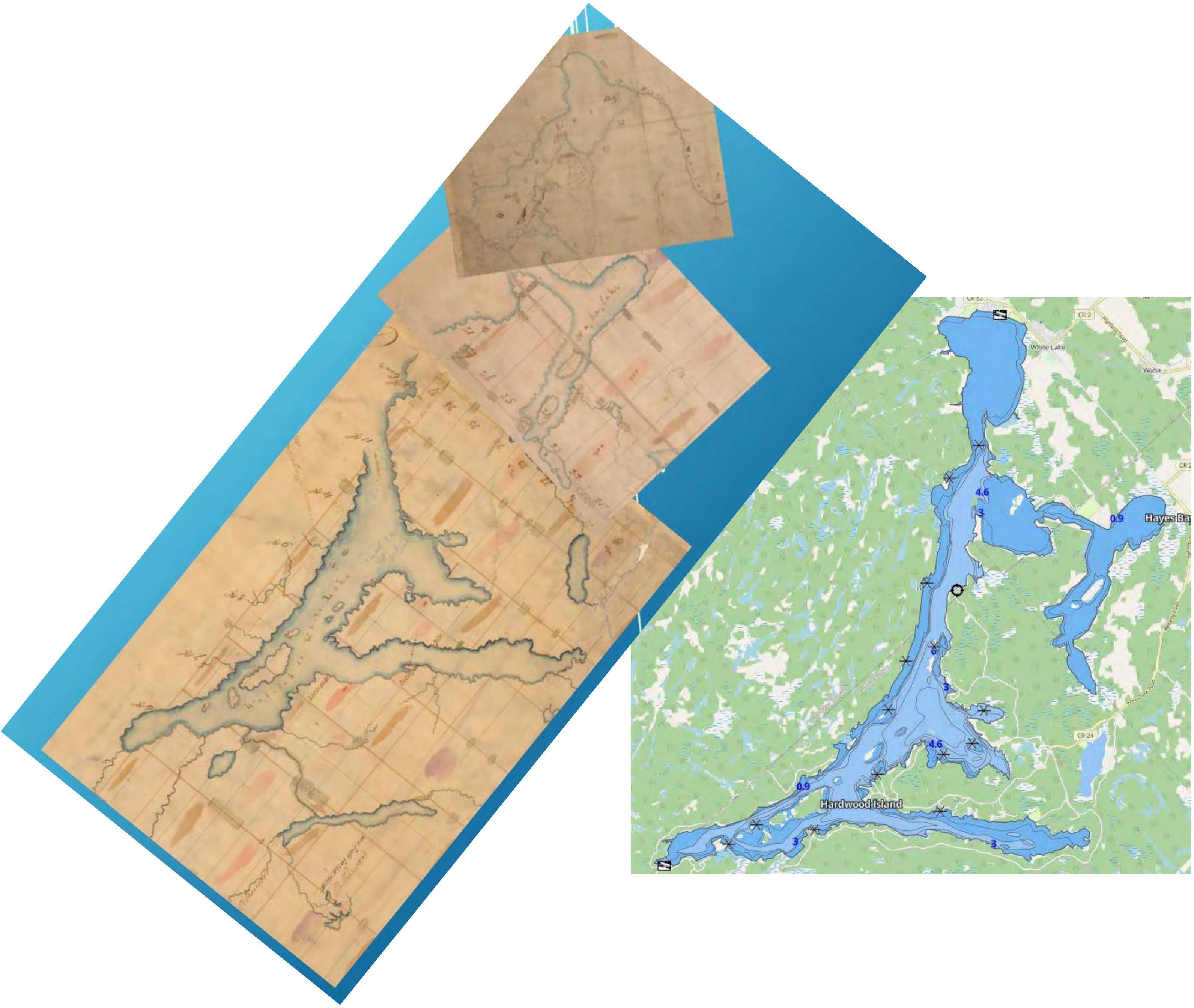
Over the years we have heard cottagers and residents of White Lake bristle at the suggestion that the lake is artificial, created when the first dam was built in 1845. In one publication[11], the author states that "*when a dam on Waba Creek was constructed it resulted in the water levels increasing in three previously small interconnected water bodies*", and thus forming the lake as we see it now.

We do not have a picture of the dam as it was in 1845, however the photo below shows the condition of the dam in 1919. This dam was rebuilt in 1948 and was changed to the present-day concrete structure in 1968.

What if we had a map of the lake both before and after the first dam was built? Then we could compare the outlines of the lake, and see just how the dam affected its contours.

[11] V.R. Brownell; *A Biological Inventory and Evaluation of the White Lake Study Area, Eastern Ontario;* Ontario Ministry of Natural Resources, Kemptville Ontario District Office; 2001

As it turns out, we can do just that. On the left is a composite of the hand-drawn maps of White Lake created in 1822 by surveyor Reuben Sherwood[12]. On the right is a present-day satellite map of the lake.



The two maps above clearly show that the contour and shorelines of the lake are essentially identical before and after the construction of the original and replacement dams at Waba Creek.

[12] Province of Ontario Archives

So, as the current dam raised water levels in the lake by about 1.5 metres, why are the lake contours on both maps essentially the same? If there were three interconnected ponds before the dam was built, why are they not evident on the 1822 map?

The answer to these questions lies in the fact White Lake is a wetlands lake. About 25% of the lake surface area is made up of marshes and very shallow (≈ 1.5 to 2 m) waters.

Lake Contours: When Reuben Sherwood surveyed the lake, he included the extent of wetlands as part of the natural contour of the lake. In his 1985 paper, Ferris[13] said that "*Although there are seasonal fluctuations, there has been very little change in water levels since 1823. Water levels have not increased by more than 20 cm vertical and 9.1 m horizontally*".

What Ferris is saying here is that the MAXIMUM level of the lake has not changed since pre-dam times. Before the construction of the dam, White Lake water levels rose during the spring melt and early summer and then slowly receded. Flooded wetland areas were drained with some areas drying up and others turning into shallow swamps.

What the dam achieved, however, was raising the MINIMUM level of the lake by about 1.5 metres. This explains why the contours of White Lake appear to be the same in the two maps above.

Three interconnected water bodies: How do we explain the assertion by some that the lake was a series of three interconnected ponds before the dam was built? Is there any basis in fact supporting this?

Using bathymetric (depth) data and figuratively 'draining' away 1.5 metres of water from the lake, could these three interconnected water bodies be revealed?

The map below shows in light blue the extent of White Lake at low-water prior to the construction of the dam. This is what the lake would have looked like in late August. The darker blue areas would have been flooded at high-water in the spring and early summer.

It appears from this map that there remained only a single water body and there were no other areas of open water at low-water in late summer.

However, we know from present day observations that there are parts of the lake which do not support the growth of aquatic plants because the sediments there are composed of marl, a calcium mineral. These areas are shallow (≈2 m) and circled on the map below. It is possible that at low water levels, prior to the construction of the dam, these parts of the lake appeared as open water perhaps only .5 metres deep.

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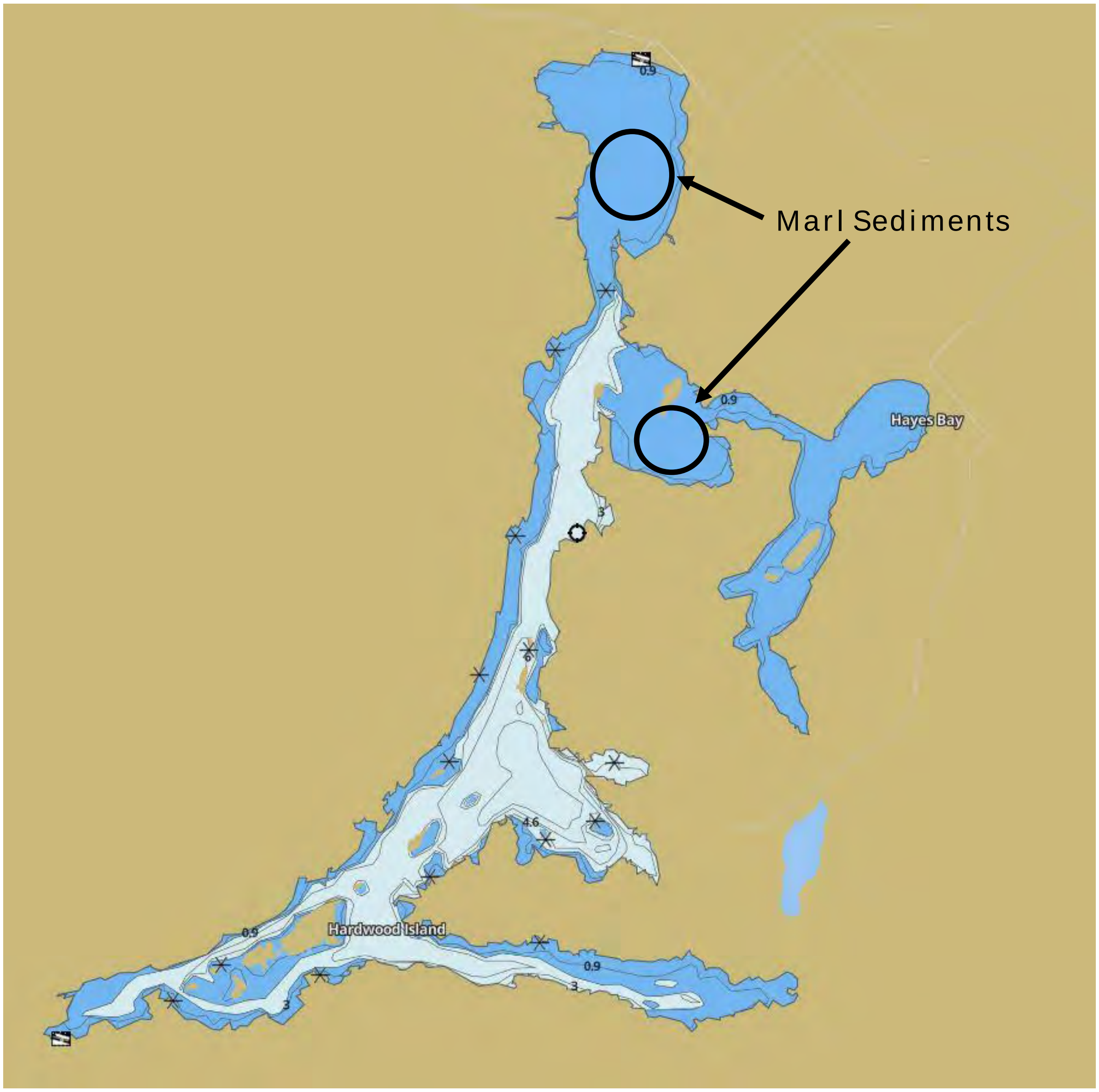
[13] J.P. Ferris, White Lake Integrated Resources Management Plan, Part I, *Ministry of Natural Resources, Lanark and Renfrew Counties, December, 1985.*

In the end, all theories appear to be correct. We can have an unchanging lake contour at high water before and after dam construction as well as several interconnected open water bodies during seasonal low water conditions.

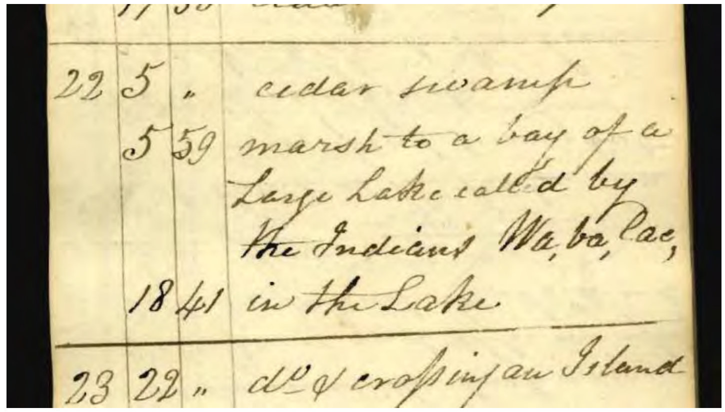
The secret to understanding all of this is that the dam increased low water levels while not substantially changing high water levels.



*Joan Gregoire is thanked for her sharp-eyed editing of this and all other Environment Bulletins.

17.5 **White Lake: What's in a Name?**

The first published report including the name of the lake we know today as White Lake, was that of surveyor Reuben Sherman. An excerpt from his 1823 field notes (shown to the right) reads "*cedar swamp marsh to a bay of a large lake called by the Indians Wa,ba,lac*". A hand drawn map (below) of the area resulting from this survey labels the lake as 'Wa,ba,lak'.



White Lake is a translation from the Algonquin name 'Wàbà Sagaigun'[14]. Taking onto consideration that the final letter of the name of the lake found in the field notes was a 'c' and on the map a 'k', one can speculate which European group first re-named the lake. It could have been either the French (lac) or the British (lake). The first recorded Europeans, however, who explored this area were French; Étienne Brûlé (1610) and Samuel de Champlain (1613).

Today, it is not obvious to anyone boating the lake, why it should be called White Lake. Everywhere you go, the lake water ranges in colour from clear to brownish. The sediments are essentially black and quite muddy. Yet, for First Nation Peoples, it was obvious to them that the lake was exceptional and named it Waba (white) for its defining property.

The installation of a dam on White Lake in 1845 started a process resulting in the covering up of the existing lake bed (especially at the Northern end of the lake) with black sediments which are today about 15 cm thick. Below these sediments is a layer of white marl[15]. The Southern, and deeper part of the lake, already had from 3 to 5 m of black sediments dating back to nearly the end of the last ice age.

The very first description of marl in White Lake was by William Logan[16], who founded the Geological Survey of Canada in 1842 and for whom Mt. Logan, Canada's highest peak, is named. He described White Lake marl in this way: 'In the lower part of White Lake about seven hundred acres are covered with marl, which was found to have a depth of from five

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[14] Hessel, Peter (1987). *The Algonkin Tribe, The Algonkins of the Ottawa Valley: An Historical Outline*. Kichesippi Books. ISBN 0-921082-01-0.
[15] Marl in Ontario, G.R. Guillet, Industrial Mineral Report 28, 1969, Ontario Department of Mines.
[16] W.E. Logan, The Geology of Canada, Geological Survey of Canada; 1863, p. 765.

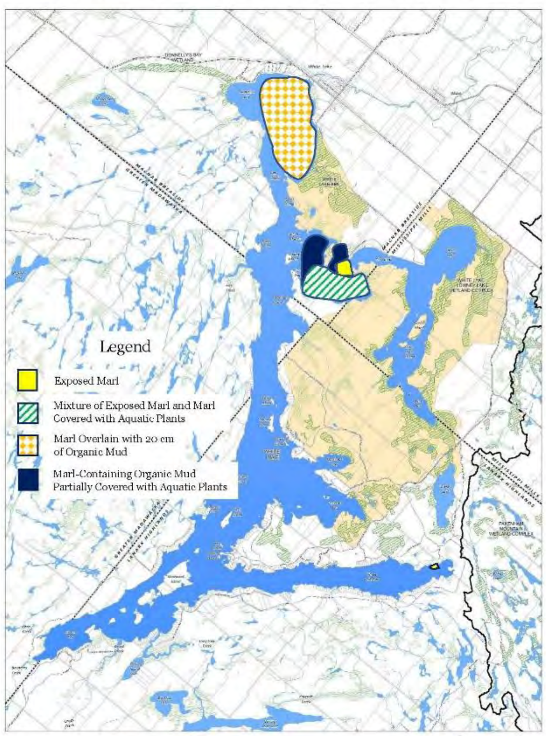
to seven feet, and was covered by not more than two or three feet of water'. The location on the lake he was referring to is off of Norway Point on the White Lake Village basin.

Marl is a calcium-rich sediment formed by the precipitation of calcium carbonate from mineral-rich spring waters entering the lake.

It is also formed by the accumulation of snail and small clam shells.

Both of these are white in colour, as shown in the photo on the right of marl sediments recovered from near Norway Point in the Village Basin.

Areas of White Marl on White Lake



The map on the left show areas on White Lake where there are marl deposits. Anyone arriving at White Lake at any time prior to the construction of the dam would have seen large very shallow areas of the lake that appeared to be white in colour.

It could be that when First Nations peoples arrived on its shores and looked out over the water, they would have pointed towards the lake and said 'Wàbà Sagaigun'.

PART IV
Acknowledgements and Author Profiles

18.0 Acknowledgements

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

19.0 Author Profiles

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

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

Joyce Benham is an accomplished nature photographer and along with husband Robert Carrière, spends one week in July of each year photographing and documenting wildlife sightings on White Lake. The naturalist couple from Hammond, Ontario documents the number and location of adult loons and chicks and from file photos can recognize individual loons. Monitored annually, loon populations can be used to measure habitat health as well as threats from wave action, boat traffic and other factors contributing to changing loon populations.

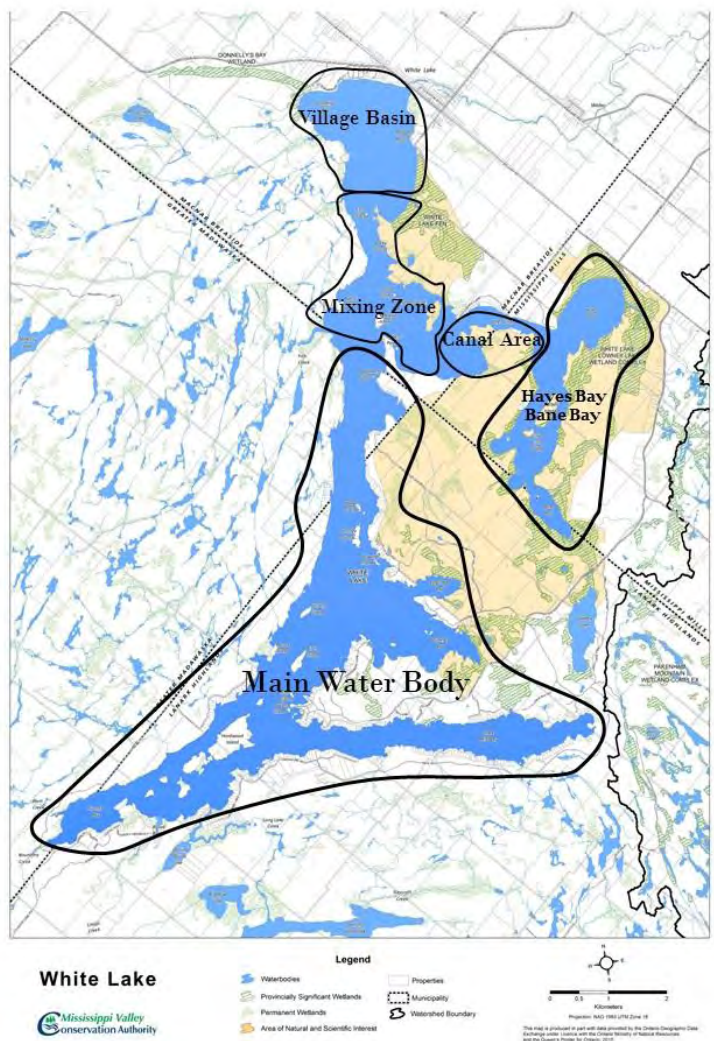
PART V
Appendices

Appendix 1: White Lake Zone Map

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 – 2021

Three Mile Bay N. 45⁰ 15.767'; W. 076⁰ 32.521 Depth: 6.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 15	8:58	135	>depth	13.8	8.6,8.4 (8.5)		
May 31	9:03	151	4.6	18.6	-		
June 13	8:58	164	3.7	23.2	13.0,13.0 (13.0)	31.1	3.4
June 30	10:07	181	4.3	22.8	-		
July 16	9:02	197	4.3	23.2	11.2,11.9 (11.6)	32.0	3.0
August 2	9:27	214	3.5	21.1	-		
August 11	9:00	223	4.3	24.2	13.0,13.0 (13.0)		
August 31	9:01	243	>depth	23.9	-		
September 16	9:15	259	>depth	20.0	10.5,10.7 (10.6)		
September 28	10:13	271	4.6	17.6	-		
October 14	9:00	287	>depth	17.5	8.3,8.4 (8.4)		

North Hardwood Island N. 45⁰ 16.162'; W. 076⁰ 33.203' Depth: 5.0 M

Date	Time	Day of Year	Secchi Depth, M	Temp, ºC	Total P, ppb	Ca, ppm	Cl, ppm
May 15	9:14	135	>depth	12.0	7.3,8.1 (7.7)		
May 31	9:24	151	5.5	17.8	-		
June 13	9:15	164	4.1	23.2	13.0,13.0 (13.0)	30.5	3.4
June 30	10:20	181	4.2	22.4	-		
July 16	9:21	197	3.9	23.2	17.7,14.1 (15.8)	32.0	4.0
August 2	9:15	214	3.7	22.0	-		
August 11	9:19	223	4.2	24.2	15.4,16.6 (16.0)		
August 31	9:22	243	4.6	23.7	-		
September 16	9:45	259	>depth	20.0	10.2,10.8 (10.5)		
September 28	10:18	271	4.5	17.8	-		
October 14	9:23	287	>depth	17.0	9.0,9.7 (9.4)		

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 15	9:35	135	6.9	13.3	-	-	-
May 31	9:41	151	5.7	17.5	-	-	-
June 13	9:26	164	4.9	22.8	-	-	-
June 30	10:30	181	4.8	22.9	-	-	-
July 16	9:42	197	3.9	23.8	-	-	-
August 2	10:01	214	3.4	22.0	-	-	-
August 11	9:37	223	4.8	24.1	-	-	-
August 31	9:42	243	4.9	23.6	-	-	-
September 16	10:11	259	4.9	20.0	-	-	-
September 28	11:00	271	4.5	20.0	-	-	-
October 14	9:41	287	6.8	17.5	-	-	-

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 15	9:47	135	6.4	13.7	-	-	-
May 31	9:52	151	5.8	17.8	-	-	-
June 13	9:38	164	4.6	22.8	-	-	-
June 30	10:42	181	4.5	23.2	-	-	-
July 16	9:53	197	3.9	23.8	-	-	-
August 2	10:11	214	2.9	22.0	-	-	-
August 11	9:46	223	4.8	24.3	-	-	-
August 31	9:52	243	5.3	24.7	-	-	-
September 16	10:21	259	5.4	20.1	-	-	-
September 28	11:18	271	4.3	18.0	-	-	-
October 14	9:47	287	7.0	17.5	-	-	-

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 15	10:02	135	5.9	13.2	7.1,7.7 (7.4)		3.8
May 31	10:03	151	>depth	17.8	-		
June 13	9:52	164	4.0	23.0	10.0,11.0 (10.5)	30.7	3.4
June 30	10:54	181	4.5	23.1	-		
July 16	10:05	197	3.6	23.8	11.0,14.5 (12.8)	32.1	4.2
August 2	10:26	214	3.8	21.0	-		
August 11	10:04	223	5.2	24.4	10.8,10.8 (10.8)		
August 31	10:15	243	4.3	23.8	-		
September 16	10:47	259	4.9	20.0	9.7,8.6 (9.1)		
September 28	11:36	271	4.2	17.9	-		
October 14	10:00	287	>depth	17.5	8.0,7.7 (7.9)		

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 15	10:23	135	>depth	13.6	7.6,7.8 (7.7)	-	4.8
May 31	10:16	151	>depth	18.0	-		
June 13	10:05	164	>depth	23.5	9.3,9.5 (9.4)	31.3	5.0
June 30	11:15	181	>depth	24.9	-		
July 16	10:15	197	>depth	23.8	8.2,8.7 (8.5)	29.1	4.6
August 2	10:37	214	>depth	19.0	-		
August 11	10:15	223	>depth	25.7	9.1,9.0 (9.1)		
August 31	10:18	243	>depth	22.3	-		
September 16	11:00	259	>depth	19.2	7.5,7.6 (7.6)		
September 28	11:51	271	>depth	15.2	-		
October 14	10:10	287	>depth	18.0	7.0,6.7 (6.9)		

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 15	10:35	135	>depth	16.4	8.3,7.4 (7.9)		9.0
May 31	10:27	151	>depth	18.2	-		
June 13	10:15	164	>depth	23.9	9.2,9.3 (9.3)	35.4	9.5
June 30	11:25	181	>depth	25.2	-		
July 16	10:27	197	>depth	23.9	10.9,10.6 (10.8)	33.2	9.7
August 2	10:43	214	>depth	19.9	-		
August 11	10:25	223	>depth	26.0	10.1,10.3 (10.2)		
August 31	10:27	243	>depth	22.8	-		
September 16	11:19	259	>depth	19.5	8.9,9.0 (9.0)		
September 28	12:02	271	>depth	15.3	-		
October 14	10:21	287	>depth	18.2	7.6,7.5 (7.6)		

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 15	10:53	135	>depth	13.7	7.2,7.3 (7.3)		3.9
May 31	10:39	151	>depth	17.8	-		
June 13	10:25	164	>depth	22.0	12.0,13.0 (12.5)	31.0	4.1
June 30	11:36	181	>depth	24.0	-		
July 16	10:37	197	>depth	24.2	12.8,12.9 (12.9)	30.0	4.4
August 2	10:54	214	>depth	20.5	-		
August 11	10:38	223	>depth	25.2	10.0,10.9 (10.5)		
August 31	10:43	243	>depth	23.8	-		
September 16	11:30	259	>depth	19.8	9.5,9.6 (9.6)		
September 28	12:14	271	>depth	17.3	-		
October 14	10:40	287	>depth	17.9	9.6,9.0 (9.3)		

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 15	11:16	135	>depth	15.8	6.5,5.3 (5.9)		4.0
May 31	10:55	151	>depth	18.2	-		
June 13	10:45	164	>depth	23.2	7.2,7.8 (7.5)	29.8	4.4
June 30	11:49	181	>depth	25.2	-		
July 16	10:53	197	>depth	23.8	9.9,9.7 (9.8)	28.1	4.1
August 2	11.07	214	>depth	19.0	-		
August 11	10:47	223	>depth	25.3	9.7,10.4 (10.1)		
August 31	10:57	243	>depth	22.2	-		
September 16	11:45	259	>depth	19.5	8.9,9.1 (8.8)		
September 28	12:25	271	>depth	15.3	-		
October 14	10:50	287	>depth	18.1	6.6,6.3 (6.4)		

Temperatures taken 1 m from bottom. B= bottom temperature

Weather Conditions 2021

Date	Day of Year	Weather Conditions
May 15	135	Full sun with an air temperature of 15C; very calm waters with winds at about 5 km/hr.; no rain previous 5 days; water depth unchanged since May 1.
May 31	151	Full sun; no wind; air temperature of 13C; six mm rain fell 10 days prior to sampling; there were several days previous to sampling where temperatures dropped to near or freezing overnight.
June 13	164	Full sun, with no wind. Air temperature from 15 to 17C; no precipitation during prior 2 weeks.
June 30	181	Cloudy with sun or bright overcast; air temp. 23C; Rainy period prior to sampling with about 3mm rain during 5 previous days.
July 16	197	Lightly overcast giving way to sunshine early in sampling period; Air temperature ranging from 17 to 20C; 5 mm rain night before sampling with an additional 10 mm 3 days before sampling.
August 2	214	Full sun; winds ranging from 5 to 10 km/hr; air temperature ranges from 14 to 18C. 10 mm of rain day before sampling and 20 mm three days before sampling.
August 11	223	Full sun; winds less than 5 km/hr; air temperature of 23 to 25C; No rain for previous 5 days; Drought period plus high temperatures of > 30C.
August 31	243	Partially cloudy with some full sun; winds from 5 to 10 km/hr; air temperature of 22 to 25C; 4 mm of rain 36 hours before sampling, preceded by 15 days of high temperature (30+C) with no rain.
September 16	259	Full sun, no wind; 13 to 16 C air temperature; 5 mm rain 48 hours before sampling; Major blue-green algal bloom underway. Microcystis predominant in Three Mile Bay; anabaena predominant in all other parts of Zone 1 except for locations south of mid-Hardwood Island.
September 28	271	Mix of sun and cloud; wind 5 km/hr; Air temperature 9 to 12 C; 60 mm rain fell five days before sampling. White lake is still experiencing blue-green algal blooms although diminished from last sampling date. High population of large phytoplankton contributing to low Secchi disk readings.
October 14	287	Light overcast day; air temp 15 to 18C; no winds very calm; no rain for five days previous to sampling. Algal bloom appears to be over.

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.