WHITE LAKE PRESERVATION PROJECT

REPORT

Water Quality Monitoring Program And Research Activities 2019

Looking North – Passing Storm

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Water Quality Monitoring Program Overview and Findings

1.0 Highlights

2019 marked the sixth year of systematic sampling of White Lake for water quality parameters. During that time, many changes occurred in the lake and these changes are documented in our annual reports. These reports can be found on our website: http://www.wlpp.ca.

Among the changes which have occurred is the proliferation of two invasive species: zebra mussels and the non-native reed Phragmites. Zebra mussels have spread throughout the lake and several cells of invasive phragmites now occur on Three Mile Bay. Also, beds of aquatic plants have grown denser along the shoreline extending to depths beyond the end of most docks.

Of greater significance, since 2016, are the annual green algal blooms, especially of filamentous algae. Since 2018, three blue-green algal blooms were documented in Three Mile Bay alone, one of these was tested and shown to be toxic.

These changes indicate that the water quality in White Lake is not improving.

The 2019 Water Quality Report contains the usual presentation and analysis of chemical data, including total phosphorus. Also included are a number of interesting articles on zebra mussels, microplastics, algal bloom measurement, and a cormorant and loon count. This year we have added a Q&A section to answer common questions and concerns which have been brought to our attention. Other sections focus on the relevance of older total phosphorus chemical data and its application to defining long term trends. Some important points made in this report are:

- That the quality or quantity of pre-2014 total phosphorus data is inadequate to be used to identify long-term trends in phosphorus concentrations in an off-shield lake like White Lake.
- Only data obtained since 2014 can be used to clearly identify trends in total phosphorus concentrations in White Lake.
- The Provincial total phosphorus limit of 20 ppb no longer applies to White Lake since the arrival of zebra mussels in 2016. After that time, the cycling of phosphorus in White Lake was permanently changed.
- Algal blooms, both green and blue-green now occur at total phosphorus concentrations far below (less than 10 ppb) the Provincial limit of 20 ppb.
- We now need to focus on our observations starting in 2016 and their consequences relative to lake health and management.

- Cottagers, property owners, and business concerns on White Lake must take action to preserve White Lake and to minimize stressors affecting the health of the lake.

2.0 White Lake Q & A

Every year we receive questions from cottagers and others about White Lake. In this section, we answer some of these questions and solicit readers to forward to us any questions they may have. We are happy to answer them.

1. What kind of lake is White Lake? White Lake is a very shallow warm water lake. Scientists refer to lakes like White Lake as wetland lakes because they have so many very shallow bays and lots of marshes. The average depth of White Lake is 3.1 metres or about 10 feet. The deepest spot is 9.1 metres or about 30 feet.

   One of the most important characteristics of White Lake is the chemistry of its waters. The lake sits on top of calcium rich limestone and its entire eastern shore watershed is largely made of the same material. The high calcium and associated high pH values means that there are almost no acid conditions to be found in White Lake. The rocks on the western side of the lake are acidic Precambrian rocks that have little or no influence on the chemistry of White Lake.

   All of this makes White Lake a very productive lake which is good for fish, loons and all of the other creatures that live in and around the lake.

2. What about the surrounding land (watershed) which supplies water to the lake? White Lake has a watershed which is about 10 times the surface area of the lake, which is relatively small. We are very lucky that most of the area draining into White Lake is made up of mainly undisturbed forest and small lakes. There is very little agricultural input. Thus, whatever enters the lake, in the form of any excess nutrients or pollutants, comes from cottagers and lake residents and not from upstream.

3. **What is water quality?......is it the same as the 'health of the lake'?** There are many definitions of water quality, but a good one is: "a measure of the condition of water relative to the requirements of one or more biotic species [fish, etc.] and or to any human need or purpose".

   The health of the lake generally refers to a number of biological, physical, and aesthetic parameters as well as value considerations. To assess the health of White Lake, a multidisciplinary approach is required to collect data and observations so that changes occurring in the lake can be tracked over time.

This means that it is possible to have acceptable water quality for fishing and swimming, while at the same time the health of the lake is deteriorating or becoming more sensitive to stresses imposed on it.

4. Can we assign a single word or letter grade to characterize White Lake water quality? The Ontario Ministry of the Environment uses 20 separate parameters which have to be measured several times during the year in order to assess lake water quality. The final results are obtained using a complex calculation. Conservation Ontario, the body which oversees Conservation Authorities, produce watershed report cards based on at least five measured parameters. The Mississippi Valley Conservation Authority samples 60 of its more than 200 lakes. Individual lakes are not graded, only their host watershed.

   A simplified version of Conservation Ontario's approach has reduced the number of parameters to three: total phosphorus, e-coli and a calculated factor reflecting the diversity and health of invertebrates in stream and lake waters in a watershed. There is no information available on invertebrate species living in the White Lake watershed and no e-coli data has been recorded since 2015. This means that it is not possible to apply this approach to White Lake for two reasons: 1) required data is not available; 2) the scheme can only be applied to a watershed and not a single lake.

   White Lake is not part of any conservation authority, so it is not assessed or graded by any certified body or organization.

5. What is Total Phosphorus? There are many types of phosphorus in White Lake, which can be divided into two categories: phosphorus contained in suspended particles like pollen and plankton, and phosphorus dissolved in the water much like sugar is dissolved in a cup of tea. Total phosphorus is the sum of the two. In White Lake, as in many other lakes, about half of the phosphorus is found in each type. Phosphorus is essential to all life, but too much can cause algal blooms and other problems.

6. Why are we measuring Total Phosphorus in the lake every month rather than just once a year in the spring as is done for most Ontario lakes? Most Ontario lakes are located on Precambrian Shield rocks, and, for those acidic lakes, the highest total phosphorus levels occur in the spring. Levels usually decrease slightly and remain relatively constant through the summer. For these lakes it is appropriate to take average values for interpretation.

   White Lake is not a shield lake, and spring values for total phosphorus are at their lowest annual levels. After that, the total phosphorus can increase by about 300% during the summer and decline again in the fall. For this reason, Provincial and other scientists do not use averages or individual values, but use the ***maximum values*** for interpretation.

For the past 7 years, the Ministry of the Environment's Lake Partner Program has been supporting our work on White Lake by providing the equipment and the chemical analysis of 126 separate water samples for a number of parameters such as total phosphorus, calcium, chloride, etc. Because White Lake is an off-shield lake (see Q1), the Lake Partner Program requires that the lake be sampled monthly so that the maximum value for total phosphorus can be determined. An annual report is submitted to the Ministry as part of the agreement.

7. Is White Lake changing? Is it getting better or worse? White Lake is changing and not for the better. Starting abruptly in 2016, total phosphorus levels dropped by about 50%. This reduction was not because less phosphorus was reaching the lake, but because zebra mussels, which are mostly located along the shoreline, transfer particulate phosphorus (which they eat) from the lake in general to the shoreline zone. Rather than the particulate phosphorus eventually sinking and reaching the bottom of the lake, or being flushed out during the year, now it is now being concentrated via zebra mussel activity in the near shore environment.

   The net result of the action of zebra mussels is to promote the growth of aquatic plants near docks and along shorelines, and at the same time encourages the growth of a specific blue-green algae (*microcystis*) which blooms at total phosphorus levels of less than 10 parts per billion. Another effect is to encourage the growth of filament-like green algae, which is not dangerous but unsightly.

   In the rest of the lake, the amount of the second type of total phosphorus, the dissolved type, remains the same as before the arrival of zebra mussels. Because this is the phosphorus which algae feed on, we still have the possibility, as before, of a lake-wide algal bloom.

8. According to historical records, White Lake has had algal blooms before in the 1940s and 1970s. Why are we concerned about them now? In the past, algal blooms in White Lake were the result of logging activities or water levels being kept artificially too high.

   From 1980 and up to 2013, there are no official records of algal blooms occurring on White Lake. In 2013 White Lake experienced its first ever ***documented*** blue-green algal bloom. Since that time, there have been several more blooms. Some of these were toxic. Before the arrival of zebra mussels, maximum total phosphorus levels frequently exceeded the Provincially recommended limit of 20 parts per billion.

9. Should we worry about a blue-green algal bloom even if no toxins were found when analyzed? The official Provincial policy on this subject is stated in this way: 'The Ministry of the Environment regards any cyanobacterial [blue-green algae] bloom as potentially toxic, whether or not toxins are detected in the water upon testing'. This policy prompted the Peterborough Health Unit to say: 'Even

experts cannot tell which blooms are harmful just by looking at them, *so waterfront residents will have to be cautious anytime that they have any dense algal bloom.'*

10. What can we do to help? One of the main things we can do to maintain or even improve the health of White Lake is to preserve or restore our shorelines to as close to natural conditions as possible. We can ensure that our septic systems are functioning properly. We can work together to demand that the four responsible municipalities enforce their by-laws and encourage the use of well-established best practices when any development projects affect shorelines and nutrient inputs to the lake.

3.0 White Lake: Ours to Protect

The Lake

- White Lake is a wetlands lake. Significant portions of the lake are surrounded by extensive fens and marshes that until 2018 were designated by the Ontario Government as candidate Areas of Scientific Interest.
- White Lake is a headwaters lake. The residents on the lake bear responsibility for the quality of its waters. There is no one upstream to blame!
- White Lake is very shallow. The average depth of White Lake is only 3.1 metres.
- There are many bays, such as Three Mile and Hayes Bays, which have very limited flushing during the year as does the lake in general.
- A significant amount of phosphorous is released from sediments (internal loading).
- These elements make White Lake very sensitive to changes in human use, climate and invasive species.

The People

- White Lake has been a popular tourist destination for generations.
- White Lake supports a lucrative sport fishing industry.
- There are now over 500 cottages on White Lake.
- There are now about 1000 trailer and tent sites on White Lake.
- Cottage conversions and expansions to year-round residences are increasingly popular.
- Power boats are getting larger, faster and more numerous than in previous years.

The Science

- Water quality has slowly been degrading over recent years.
- After a long period with no reported algal blooms, White Lake is now experiencing annual green and blue-green algal blooms. Some of these are toxic.

- Zebra mussels have invaded all parts of White Lake.
- Zebra mussels concentrate harmful nutrients to the near shore; the area around our docks.
- Zebra mussels promote harmful algal blooms at very low total phosphorus concentrations of less than 10 ppb.
- The quality of the near-shore area of White Lake could now be seriously degrading.

The Solution

- Respect approved setbacks and well-known best practices for shoreline development.
- Restore, regenerate or preserve shorelines to their natural state.
- Consider naturalizing lawn areas and avoid the use fertilizers, herbicides, or pesticides.
- Partner with municipal and provincial governments to enforce by-laws and create new laws to protect the lake, such as septic inspections and prevention of the spread of invasive species coming in or out of White Lake.
- Support your local lake organizations and volunteer to help preserve White Lake.
- The solution is US.

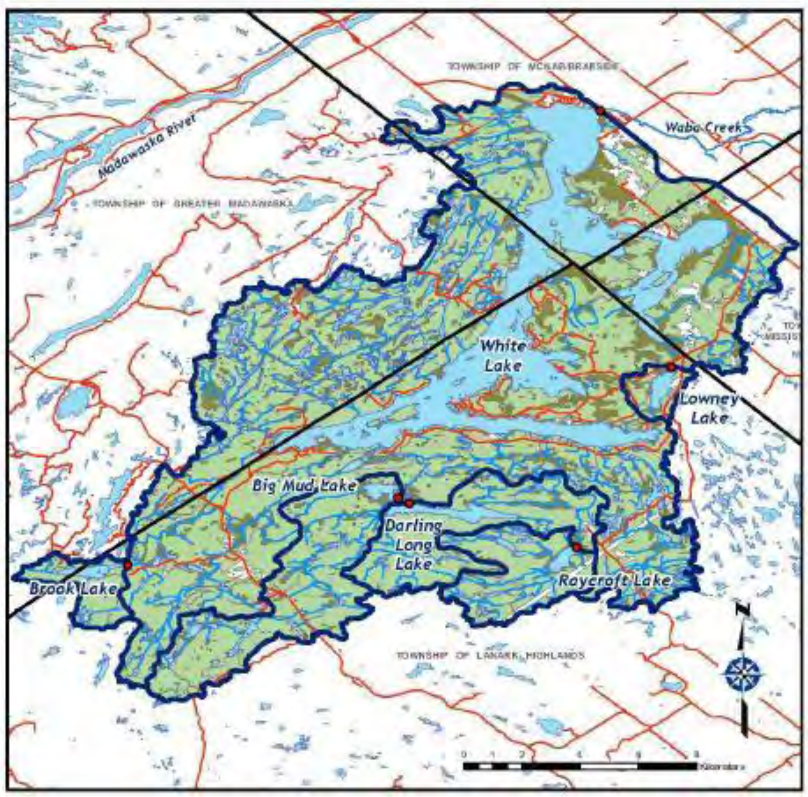

Photo by Sue Munro

WHITE LAKE
PRESERVATION PROJECT

Water Quality Monitoring Program And Research Activities -2019

D. Conrad Grégoire[1], PhD and David Overholt, BS

4.1 Introduction and Summary



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

[1] Head (retired), Analytical Chemistry Research Laboratories and Research Scientist (level 5), Geological Survey of Canada, Ottawa. PhD in Analytical Chemistry, Carleton University, 1978.

An examination of the drainage basin 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. It has been shown that that this terrain does not contribute 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 (up through 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. This is how science works. The word '*Preservation*' looms large in our organizational name because one of our main objectives is to work towards keeping the lake from further degradation and if possible, to 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. The extent of the infestation continued to increase. It will likely take a number of years before an equilibrium is reached and zebra mussels numbers become 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 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 and 2019 marginally increase 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 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 *Synopsis* 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. <u>This means that we can no longer point to lower total phosphorus levels as a positive indicator of lake health</u>.

In 2018, White Lake experienced at least 5 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* blue-green algae. Two blooms, one certified toxic and the other considered toxic (but was not tested), were almost lake wide but concentrated on the north shore of Three Mile Bay. This event was repeated in 2019 with one blue-green algal bloom occurring in Three Mile bay. This part of White Lake has the most populated and altered shoreline of any on the lake.

We can show that White Lake is at capacity. This means 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, as caretakers of White Lake, must do whatever we can to minimize our impact on White Lake ecosystems.

We have to become more vigilant and press our politicians to work with our lake associations and other interested parties to ensure that appropriate 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 activity that erodes and damages shorelines. 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!!

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.

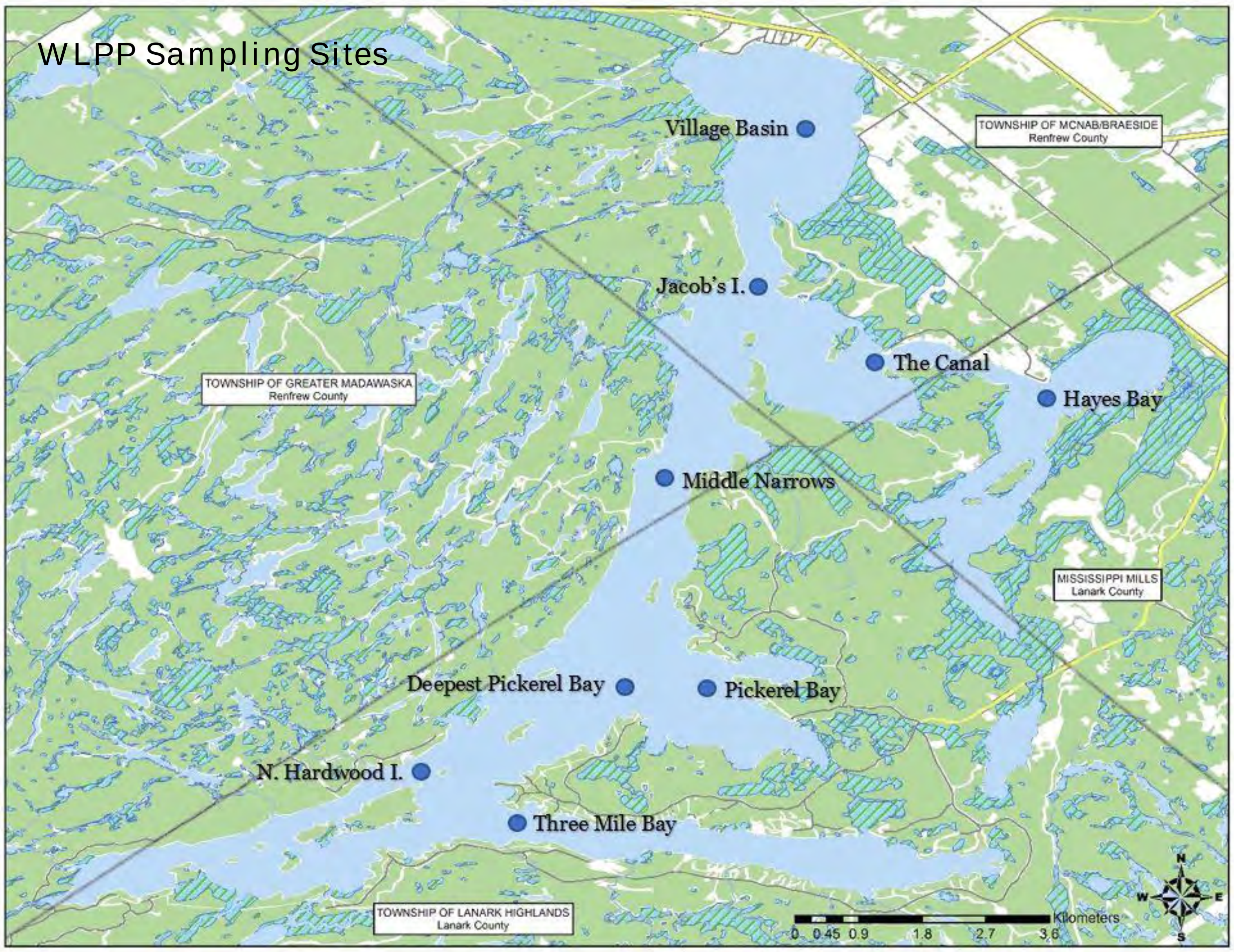
These studies include: 1) Annual Common Loon and Cormorant Surveys; 2) The health of the pickerel fishery; 3) The continued propagation of zebra mussels in White Lake; 4) the presence of micro-plastics in White Lake; 5) Studies on assessing the extent of microcystis blue-green algae in Three Mile bay, and the assessment of long-term trends in total phosphorus concentrations and its implications in interpreting water quality and lake health.

The Science Committee and the WLPP value your opinions and suggestions and welcome any comments or questions you may have concerning this report, its contents or any of our other activities. There is an anonymous suggestions box setup for your convenience on the WLPP website main page at: www.WLPP.ca or you may contact us directly at WLPPmail@gmail.com.

4.2 Water Quality Monitoring Program

The water quality monitoring program for 2019 was carried out by WLPP volunteers and involved the collection of water samples mid-month for 6 months starting in May. We continued to monitor the Deepest Pickerel Bay site so that we would always have a site at which we can measure the Secchi depth, no matter how clear the water becomes as a result of the presence of zebra mussels. This site is located over the deepest spot on the lake at 9.1 m. 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 to remove any large biota such as daphnia which would skew results. The total phosphorus data so obtained includes 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 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 for these parameters. 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).

A second activity involved providing support and participating in research completed by Carleton University. A graduate student has now completed a paleolimnological study of sediments in White Lake. This work involves separating diatoms from sediment layers followed by identifying, classifying and counting them. In this way, the history of nutrient inputs (such as phosphorus) in White Lake can be reconstructed. An MSc thesis has been written and a scientific paper on the research has been accepted for publication in an international research journal. The published paper will be added to the WLPP website.

The scientific literature reports that when a zebra mussel infestation occurs, phytoplankton[2] populations in the water column can be reduced by more than 90%. Since White Lake is a relatively large but very shallow lake. The surface area which zebra mussels can thrive on is large when compared to the total volume of water contained in White Lake. For this reason, it is more likely that phytoplankton populations were significantly reduced as would not be the case for a much smaller and deeper lake.

Section 9.1 in this report on *Water Clarity* shows that since the arrival of zebra mussels, the waters of White Lake have become clearer every year starting in 2015. This trend is expected to continue as the population of zebra mussels increases and eventually reaches equilibrium.

This year we experienced both green and blue-green algal blooms. Action needs to be taken to re-establish disturbed shorelines, respect setbacks, enforce good and well-known environmental practices including septic system inspections. We also need to protect our shorelines from boat wakes which erode shorelines and disturb near-shore sediments.

The changing climate tending towards warmer and longer summers (and longer ice-free periods) means that everyone using the lake, be they cottagers, permanent residents, campers, or casual users need to increase vigilance and care to preserve and protect White Lake.

[2] Phytoplankton are microscopic plants on which small animals (zooplankton) feed. Phytoplankton form the base of the food chain in a lake.

5.0 Historical Trends in Total Phosphorus Concentrations in White Lake 1975 to 2015

Preamble: Our objective in writing this chapter is to show that the quality of pre-2002 total phosphorus data is poor and that it cannot be used to identify long-term trends in phosphorus concentrations. Only data obtained since 2014 can be used to identify such trends. Secondly, the Provincial total phosphorus limit of 20 ppb no longer applies to White Lake. Since the arrival of zebra mussels in 2016, the cycling of phosphorus in White Lake has permanently changed. Algal blooms now occur at very low phosphorus concentrations. We now need to focus on our observations starting in 2016 and their consequences relative to lake health and management.

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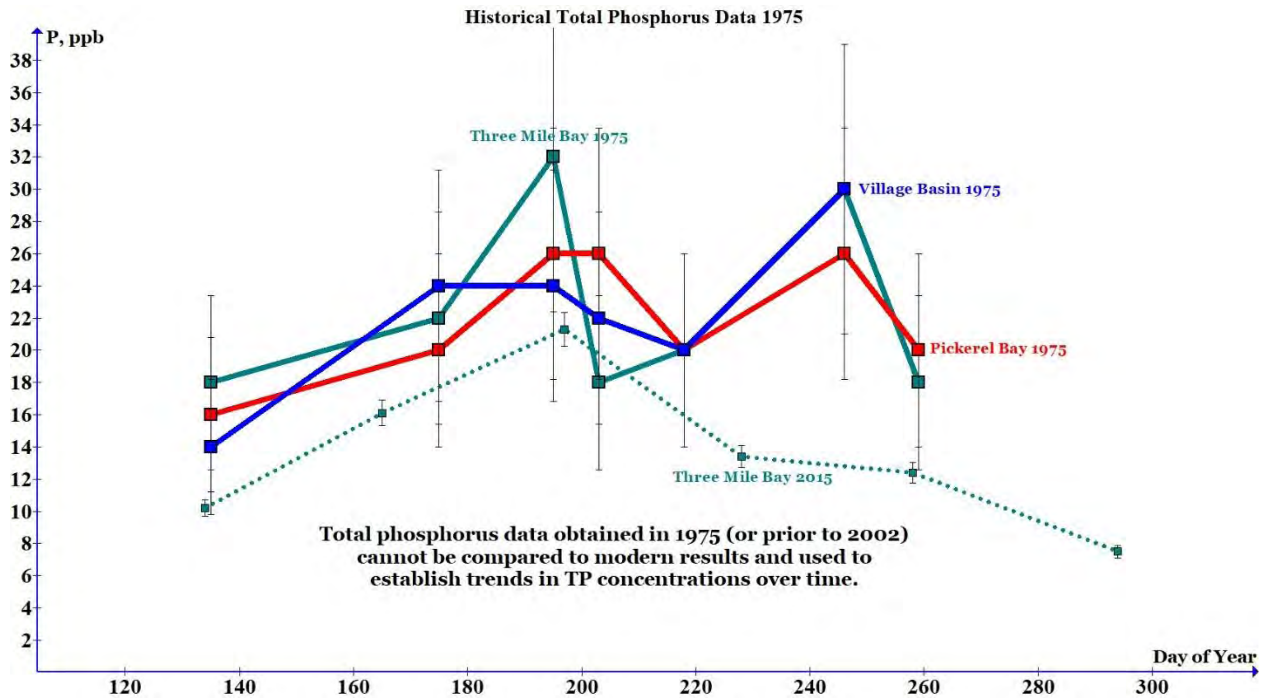
Total phosphorus is one of the most important parameters to monitor when assessing water quality. This is because phosphorus is often the limiting nutrient controlling animal and plant growth. Generally, lower total phosphorus concentrations are beneficial to living organisms while an excess of the element can result in unwanted effects such as algal blooms, some of which can be toxic.

The collection of total phosphorus data on White Lake has been sporadic over the years making long-term trends difficult to assess. Since 2014, the White Lake Preservation Project (WLPP) has initiated systematic studies that will make it possible to identify long-term trends in total phosphorus concentrations. This makes the identification of long-term trends in Total Phosphorus concentrations difficult to assess.

In 1975, the Ministry of the Environment completed a study of total phosphorus concentrations at three locations on White Lake. Single samples were collected at approximately two-week intervals starting in mid-May and ending in mid-September. Samples were collected at Three Mile Bay, Pickerel Bay and the Village Basin at the North end of the lake.

The graph below is a plot of total phosphorus concentrations vs day of year. For comparison purposes, the bottom 'dashed' line contains total phosphorus data for Three



Mile Bay for samples collected in 2015. Individual points have error bars to better reflect the significance of the data. For the 1975 data, the error bars represent an uncertainty of 30%, which was typical for measurements obtained using a now outdated analytical method[3]. This method had a limit of detection (LOD) of 5 ppb (±100% at the LOD) and for this reason was abandoned by the MOE in 2001. Further, prior to 2002, samples were not filtered allowing unwanted large zooplankton to be accidentally included in samples for analysis. This resulted in abnormally high results which were not representative of the actual total phosphorus present. It also gave erratic results because of the particulate nature of the contamination. The above graph clearly shows both of these effects. For this reason, total phosphorus values obtained prior to 2002 cannot be used for comparison purposes against more accurate and precise results obtained starting in 2002.

The new method now used by the MOE (Lake Partner Program) has an LOD of 0.2 ppb (25 times better than the old method) with a nominal uncertainty of 5% at this concentration. This method was used to obtain the data for 2015 samples represented by the dashed line in the above graph. Data for the year 2015 was used because 2015 was the last year White Lake was free of zebra mussels. In 2016, the lake was infested with the mussels and as a result the cycling of phosphorus in the lake was drastically changed. Data sets from 2016 to the present must now be interpreted differently than data sets obtained prior to the arrival of zebra mussels.

[3] B.J. Clark, Assessing variability in total phosphorus measurements in Ontario Lakes., Land and Reservoir Management, 26:63-72, 2010.

Interpretation of the 1975 data must therefore be done very carefully in order to avoid unjustified conclusions. For this reason, the Lake Partner Program has removed from its website all total phosphorus data produced before 2002.

A cursory examination of the above graphs reveals several interesting features. First, the total phosphorus concentration is relatively low in the spring, increases until mid-July and then decreases. Total phosphorus concentrations rise again in mid-September and then decreases through the fall. Because of the very large error bars on these data points, one can only say that the total phosphorus concentration is not constant during the ice-free season.

The 2015 data (dotted line), which has relatively lower total phosphorus concentrations, follows the same pattern. However, the more accurate and precise 2015 data indicates that the total phosphorus concentrations rose in the spring and reached a maximum in mid-July, after which total phosphorus levels decreased.

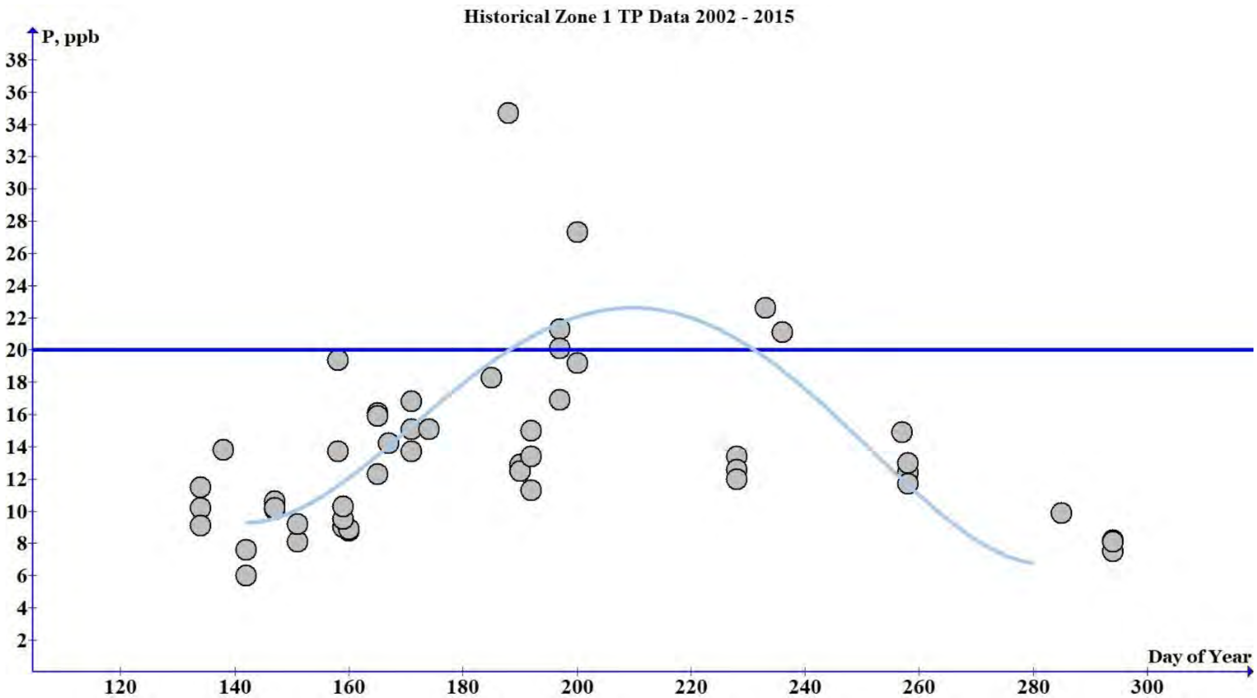
Note: The 1975 data was extracted from a report written by J.P. Ferris[4]. In that report, tabulated total phosphorus results were averaged for the sake of convenience. The reader should be made aware that the practice of averaging total phosphorus results for off-shield lakes like White Lake is no longer accepted practice[5]. For this reason, averaged values are not quoted here.

5.1 Total Phosphorus 2002 to 2015

Since 2002 and up to 2015, the last pre-zebra mussel year, a number of total phosphorus determinations for White Lake were completed. Unfortunately, with the exception of the 2014/5 data, none of the samples were collected in a systematic way, but rather were taken as ‘grab’ samples at various times of the year and at various locations. All of the sampling sites were limited Zone 1, the Main Water Body of White Lake. (See Appendix 1 for Zone Map and descriptions) We know from hundreds of measurements during the last six years, that the total phosphorus values are not identical at all sampling sites in this zone, but are normally no more than a few ppb different from one sample location to another. This data is presented in the graph below where total phosphorus concentrations are plotted by day of year.

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

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



As was seen in the previous graph, total phosphorus concentrations were low in the spring, increased until mid-July and then decreased to lower levels in the fall. The largest number of points were taken in the spring which, for shield-hosted lakes, would give the highest total phosphorus concentrations. For off shield lakes, like White Lake, better data would be gained if sampling dates had been more evenly distributed over the ice-free season.

The best fit line (light blue) on the graph was calculated using a second order polynomial. This line indicates that statistically, total phosphorus concentrations can be in excess of

- Study of historical total phosphorus levels for White Lake show that for as far back as 1975, total phosphorus concentrations may have exceeded the 20 ppb limit set by the MOE.
- The quality of analytical data has to be taken into account when comparing results from different analytical methods.
- The highest total phosphorus levels were measured in mid-July.
- The use of means or averages for the interpretation of total phosphorus data for an off-shield lake is not accepted practice and leads to erroneous conclusions.
- Until 2014, the quality and quantity of total phosphorus data collected for White Lake were not good enough to be used in determining long-term trends.
- The pre-2014 data does show that maximum total phosphorus values were high and above the 20 ppb Provincial limit.

20 ppb (Provincial limit) from day 188 to day 230 or about 42 days during the ice-free season.

5.2 Changes in Total Phosphorus Levels Since the Arrival of Zebra Mussels: 2016 to the Present

When White Lake became infested with zebra mussels in 2016, the chemistry of the lake changed dramatically. Perhaps the most significant change was in the way phosphorus was cycled in the lake. Rather than being relatively evenly distributed in the volume of the lake and then finding its way to the sediments below at the end of the summer, much of the phosphorus is now consumed by zebra mussels and deposited on and in near-shore sediments. This significant increase in phosphorus in the near shore environment is what is responsible for the explosion of aquatic plants along our shore lines as well as promoting the growth of filamentous green algae.

Total phosphorus is not a single compound, but rather a complex mixture of both particulate (living and dead) and dissolved sources of phosphorus. By definition, total phosphorus is the amount of phosphorus derived from all sources (or species) which will pass through an 80-micron filter.

The easiest way to think of total phosphorus is the sum of: 1) particulate phosphorus; and 2) dissolved phosphorus. The scientific literature on lake chemistry suggests that the two 'types' of phosphorus occur in lakes like White Lake in approximately equal parts. Why is this distinction important?

Zebra mussels are filter feeders and are capable of removing from water all particles as small as one micron (a millionth of a metre). There are literally hundreds of millions of zebra mussels in White Lake and they each can filter 1 to 1.5 litres of water per day. This means that they can together remove most of the phosphorus-containing particles in the lake. In other words, they can remove 50% of the total phosphorus present which corresponds to the fraction of total phosphorus found in lake particulates. This is why the clarity of the lake has more than doubled since the arrival of zebra mussels.

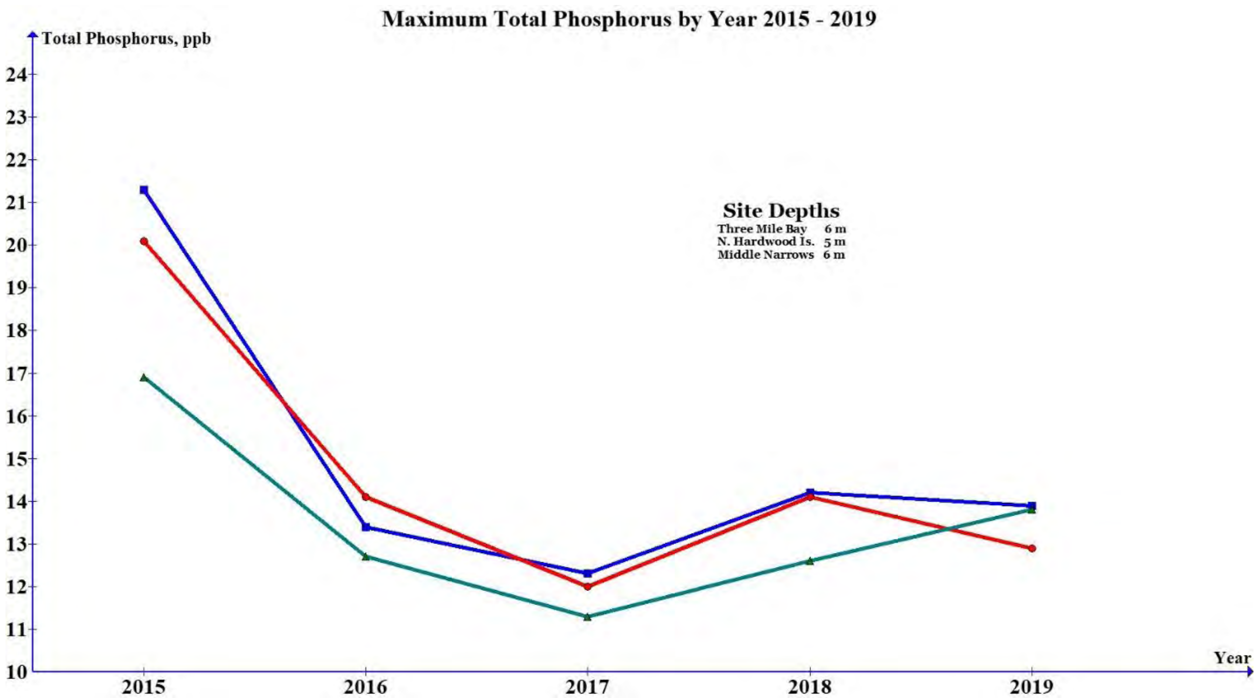
To illustrate this, the table below gives the maximum total phosphorus concentrations for samples taken from three deep water sites in Zone 1 of White Lake, the Main Water Body.

Maximum Total Phosphorus (ppb) by Year: 2015 to 2019

Location	Year					
	2014	2015	2016	2017	2018	2019
Three Mile Bay	-	21.3	13.4	12.3	14.2	13.9
N. Hardwood I.	21.2	20.1	14.1	12.0	14.1	12.9
Middle Narrows	-	16.9	12.7	11.3	12.6	13.8

Shaded areas denote maximum TP in mid-July; unshaded areas denote maximum TP in mid-August.

The data for 2014 and 2015 (pre-zebra mussels) show total phosphorus concentrations ranging from 16.9 to 21.3 ppb. After zebra mussels infested the lake in 2016, the concentrations of total phosphorus decreased by about half and have remained relatively low since that time. The graph below is a dramatic presentation of this change in total phosphorus concentrations.



The shaded area in the table indicates that for these location and dates, the maximum value for total phosphorus occurred in mid-July. Since 2017 and for the unshaded data, these maximum values occurred in mid-August, approximately one month later.

The phosphorus budget for White Lake is complex. White Lake has an internal[6] load meaning that some of the phosphorus found in sediments is released into the water column above. This can happen because of low oxygen or iron levels in the sediment and by increased warming of the sediments as a result of more sunlight reaching the lake floor. This may explain the shift in total phosphorus maxima from mid-July to mid-August since the invasion of zebra mussels.

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[6] D.M. Orihel et al., Internal phosphorus loading in Canadian fresh waters: a critical review and data analysis., Can. J. Fish. Aqat. Sci. 74: 2005-2029 (2017)

The health of the zebra mussels, their numbers and size as well as other parameters can all effect the efficiency of lake water filtration by mussels. Taken together, this may be responsible for shifting the date on which the maximum total phosphorus concentration occurs.

- Since the arrival of zebra mussels, total phosphorus concentrations in the lake have been reduced by about 50%.
- The reduction in total phosphorus in lake waters is entirely due to the presence of zebra mussels and not from any human remediation.
- In addition to phosphorus entering the lake by other means (pollen, rain, etc.), phosphorus released from sediments is now being transferred to the near shore environment rather than finding its way back to the lake bottom at the end of the season.
- The increased clarity of White Lake is due to the removal of particulate matter in the water column by zebra mussels.

5.3 Zebra Mussels and Algal Blooms: Implications for the 20 PPB Total Phosphorus Provincial Limit

One often repeated goal by lake managers is to take steps to keep total phosphorus levels below the 20 ppb Provincial limit. At total phosphorus concentrations at or above this limit, it is said that the possibility of algal blooms increases significantly. Reaching this limit while experiencing frequent and extensive algal blooms is a clear sign that the lake has reached development capacity.

It is clear from the above discussion that White Lake has frequently exceeded the Provincial limit in years dating back to at least 1975 and is currently still doing so. In addition to this, since at least 2013 White Lake has been experiencing blue-green algal blooms, some of which were toxic. In 2018, there were two extensive blue-green algal blooms in White Lake, one of which was certified toxic and the other presumed to be so[7]. In 2019 a blue-green algal bloom occurred in Three Mile Bay, but again was not tested by the MOE for toxins.

There has been limited anecdotal reporting regarding algal blooms in earlier times with no detail provided regarding the locations, extent or genus of the organisms involved. It was not until 2013 that the first widespread blue green algae bloom was noted, recorded, identified and analyzed for toxins by MOE.

[7] J.G. Winter, A. M. DeSellas et al, Algal blooms in Ontario, Canada: Increases in reports since 1994., *Lake and Reservoir Management,* 27:107-114, 2011

Since 2016, the highest total phosphorus concentration measured in White Lake was 14.2 ppb, well below the Provincial limit. Why should we not be content with this?

As it turns out, the fraction of total phosphorus remaining after zebra mussels have fed is composed of dissolved phosphorus. This is the phosphorus that algae feed upon. This means that the potential to have an algal bloom is undiminished by the activity of zebra mussels. As far as it concerns algae, the phosphorus it can use for growth remains unchanged from the phosphorus that was available before zebra mussels arrived[8].

Now that zebra mussels are present, the proliferation of a species of noxious blue-green algae (cyanobacteria) is favoured: *microcystis aeruginosa*[9,10]. This species of blue-green algae thrives in waters containing low concentrations of phosphorus (<25 ppb) and can successfully compete for other nutrients against other algae present. Additionally, zebra mussels selectively filter out and excrete undigested *microcystis* further adding to its competitive edge against other algae, which the mussels will consume.

In the last two years, White Lake has experienced three significant *microcystis* blooms. At the time when each bloom occurred, the total phosphorus concentration in lake water was less than 10 ppb.

Of great importance is the realization that the Provincial target of 20 ppb total phosphorus <u>no longer applies</u> to lakes which have been invaded by zebra mussels.

Paleolimnological studies[11] of White Lake sediments have shown that White Lake has experienced increased nutrient loads in recent years and is also subject to multiple stressors including invasive species, increased use[12] and climate change.

Simply put, over the passage of time, White Lake has come under stress from changes which are both outside of our influence (climate change) and those which we could do something about on a local level.

The invasion of zebra mussels in White Lake could have been avoided if local and Provincial governments had worked together with cottagers, property owners and other interested parties in setting up effective safeguards against this invasive species. More invasive species will reach the lake if we do not take positive action to prevent their entry.

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[8] T.M. Higgins et al., Effects of recent zebra mussel invasion on water chemistry and phytoplankton production in a small Irish lake, *Aquatic Invasions (2008) Vol 3, Issue 1: 14-20*.
[9] D.F.Raikow et al., Dominance of the noxious cyanobacterium *Microcystis aeruginosa* in low-nutrient lakes is associated with exotic zebra mussels*., Limnology and Oceanography, 49(2), 2004, 482-487*.
[10] L.B. Knoll, et al, Invasive zebra mussels (Dressina polymorpha) increase cyanobacterial toxin concentrations in low-nutrient lakes, *Can. J. Fish. Aquat. Sci., 65: 448-455 (2008).*
[11] M. Murphy, C. Grégoire and J. Vermaire, Ecological response of a shallow mesotrophic lake to multiple environmental stressors: a paleolimnological assessment of White Lake, Ontario, Canada., *Lake and Reservoir Management, in press.*
[12] A. Vandertogt, New blue-green algal bloom confirmed in Muskoka lake., Cottage Life, September 21, 2018.

One of the most effective measures we have at our disposal to protect water quality and lake health is the restoration of our waterfronts. Both municipalities and individuals have an important role to play and we should be working together to preserve the lake for future generations.

- Although the total phosphorus measured in White Lake has been reduced by half by zebra mussels, the amount of soluble phosphorus is unchanged and available for algal blooms to take place.
- The presence of zebra mussels encourages blooms of *microcystis* blue-green algae to take place at very low concentrations of total phosphorus.
- From 1980 to 2013, there were no documented algal bloom on White Lake. We now experience algal blooms annually.
- Since 2018 there have been three extensive *microcystis* blue-green algal blooms on White Lake when the concentration of total phosphorus was less than 10 ppb.
- The Provincial target of 20 ppb total phosphorus does not apply to off-shield lakes, like White Lake, which are infested with zebra mussels.
- Cottagers, property owners, developers, local and provincial governments should be working together to preserve White Lake for future generations.


Ice Out – White Lake

6.0 The Big Picture – What You Should Know About White Lake Today

For the past 6 years the White Lake Preservation Project has been carrying out extensive and systematic water quality studies. We have also worked on a number of projects designed to better describe White Lake and understand how water enters, moves around and leaves the lake during the year. Other work has given us insight into the nature and influence of waters entering the lake from streams as well as springs. We have also studied plankton populations and invasive species such as zebra mussels and how these have changed the lake over time.

We have reported all of our work in a series of annual reports which have been bolstered by accompanying reports from the Mississippi Valley Conservation Authority and Watersheds Canada. Our writing has been enlightened and underpinned by an abundance of published scientific research papers, and all of our reports have been read and vetted by limnologists from government, universities, NGOs, conservation authorities and the private sector.

We now are able to see some trends in the data we collect and are in a position to offer the reader a synopsis of what we have learned and what we believe is in store for White Lake should we, as stewards of the lake, decide to adopt a wait and see attitude. Our long-term goal is to inform and to educate anyone interested in the health of White Lake and to motivate them to take the necessary action to ensure the survival of the lake into the future.

6.1 White Lake

White Lake is a shallow warm water lake. One of its distinguishing characteristics is that it is a wetlands lake surrounded in many places by marshlands. The average depth of White Lake is only 3 metres and the lake is flushed less than once per year. The implication is that nutrients and pollutants entering the lake essentially stay in the lake. Because the lake sits on top of limestone and is bordered on the south by calcium-containing rocks, the waters are an inviting habitat for zebra mussels, which have now found a permanent home in White Lake.

6.2 What About Total Phosphorus?

Recent research has made clear two vital facts related to total phosphorus:

- White Lake is at capacity and cannot handle more nutrient input.
- Zebra mussels have changed the way phosphorus is cycled in White Lake.

The consequences of both of these facts is that we now have and are likely to have more algal blooms; some of these will be toxic.

Total phosphorus levels are currently about half of what they were before zebra mussels arrived. Why are we now having annual algal blooms?

The answer lies in what algae eat and what zebra mussels eat.

Total phosphorus is the sum of a number of different phosphorus-containing components including plankton and other particulate matter plus phosphorus dissolved in water.

The diagram below shows the two categories of phosphorus which added together gives <u>total</u> phosphorus:

Total Phosphorus =	Plankton and particles containing phosphorus This fraction is about 50% of total phosphorus This is what zebra mussels eat!....about 90% of what is in the lake. Result: <u>Clear water!</u>	+	Dissolved phosphorus from septics, shoreline runoff, sediments This fraction is about 50% of total phosphorus This is what algae eat! Result: <u>Algal Blooms!</u>

Zebra mussels effectively transfer most of the phosphorus in the blue box above to the shoreline where they live. This phosphorus would normally end up in sediments in the middle of the lake.

In the end, the amount of phosphorus available for algae to grow has not changed even though the total phosphorus concentration we measure in water samples has been reduced by 50%!

6.3 What Happens to All of That New Phosphorus Input at the Shoreline?

Zebra mussels are filter feeders and they very efficiently filter out all of the particles containing phosphorus (green box above). They then excrete most of it to the sediments just below them.

The result of adding all of that extra nutrient load on the sediments is to encourage the growth of green algae such as the filamentous green algae which is now common. It also encourages the growth of blue-green algae, especially one called *Microcystis* which does form toxic algal blooms. We have had two such toxic blooms in 2018 and one in 2019.

Let’s review how zebra mussels have changed White Lake:

Zebra mussels change the way phosphorus is cycled in the lake.

Zebra mussels transfer phosphorus from open lake water to near-shore waters and sediments.

Zebra mussels also change the composition and chemistry of near-shore sediments.

Zebra mussels do not remove the type of phosphorus responsible for algal blooms in the rest of the lake.

Zebra mussels promote growth of green and blue-green algae along shoreline.

Filamentous green algae along White Lake shoreline

What does the scientific literature predict would happen to White Lake once zebra mussels invaded it?

Published Literature Predicts	White Lake Observations
Marked decrease in total phosphorus levels	Decrease in TP by about 50%
Significant increase in water clarity	Water clarity more than doubled
Density and extent of aquatic plants along shoreline will increase	Marked increase in density of aquatic plants along shoreline
Shoreline water will become very clear especially in calm weather (no waves)	Where zebra mussels are present, water becomes crystal clear along shoreline
Microcystis blue green algae favoured over *Anabaena* blue green algae	2018 White Lake experiences first two recorded *Microcystis* algal bloom
Toxic algal blooms will occur at relatively low TP concentrations	2018 toxic (25 ppb toxins)* algal bloom in Sept. when TP was <10 ppb
Filamentous green algae will increase significantly	Filamentous green algae blooms are now common and extensive

*Drinking water limit: 1.5 ppb; Recreational limit: 20 ppb

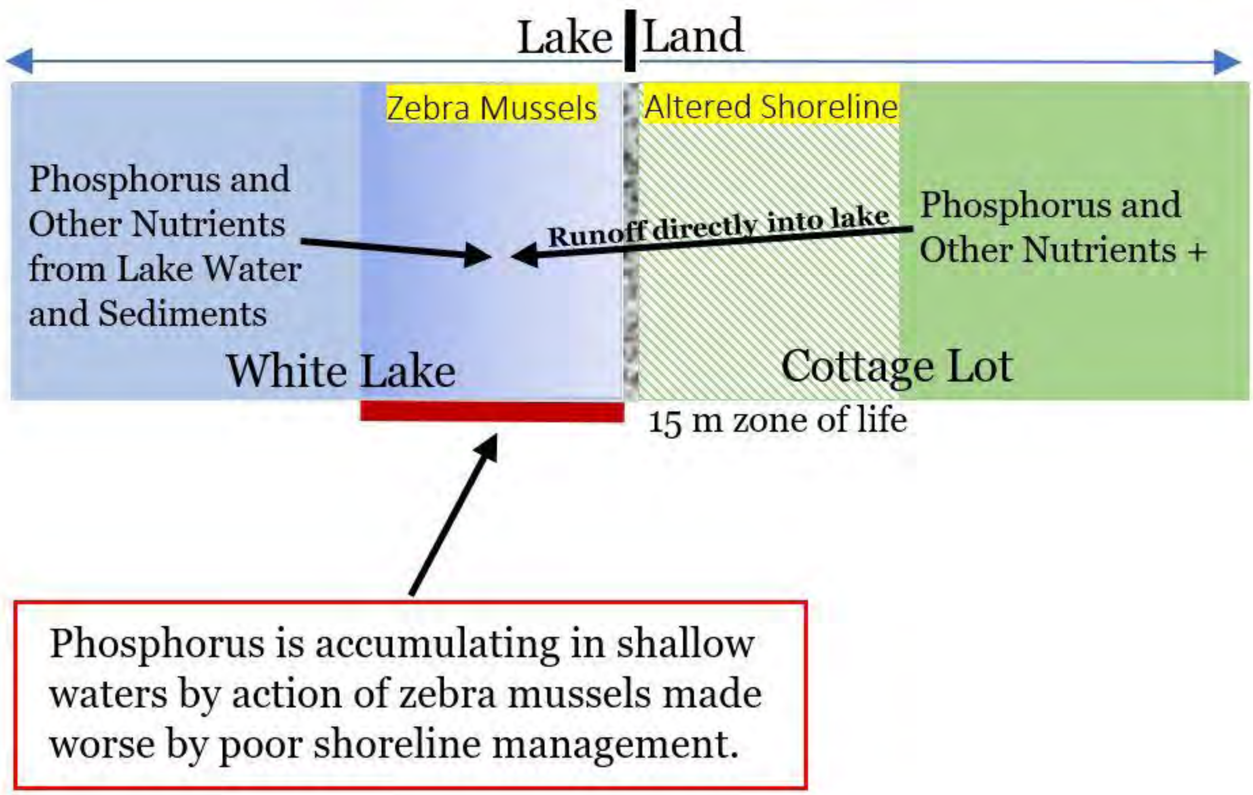
6.4 What is Happening Now to White Lake?

White Lake is currently under stress not only from the various pressures placed on it by human activities, but also by other factors including climate change and invasive species such as the zebra mussel. Some of these pressures are incremental like cottage conversions to permanent homes and some of these pressures are more dramatic as is the case of zebra mussels.

Below is a diagram which attempts to summarize the net effects of many of the factors discussed above. The blue square on the left represents White Lake and the lighter blue portion represents the near-shore environment where we generally have our docks, swim, fish, etc.

The green square on the right represents a typical cottage lot and the cross-hatched green portion the area of the shoreline sometimes referred to as the 15 metre zone of life.

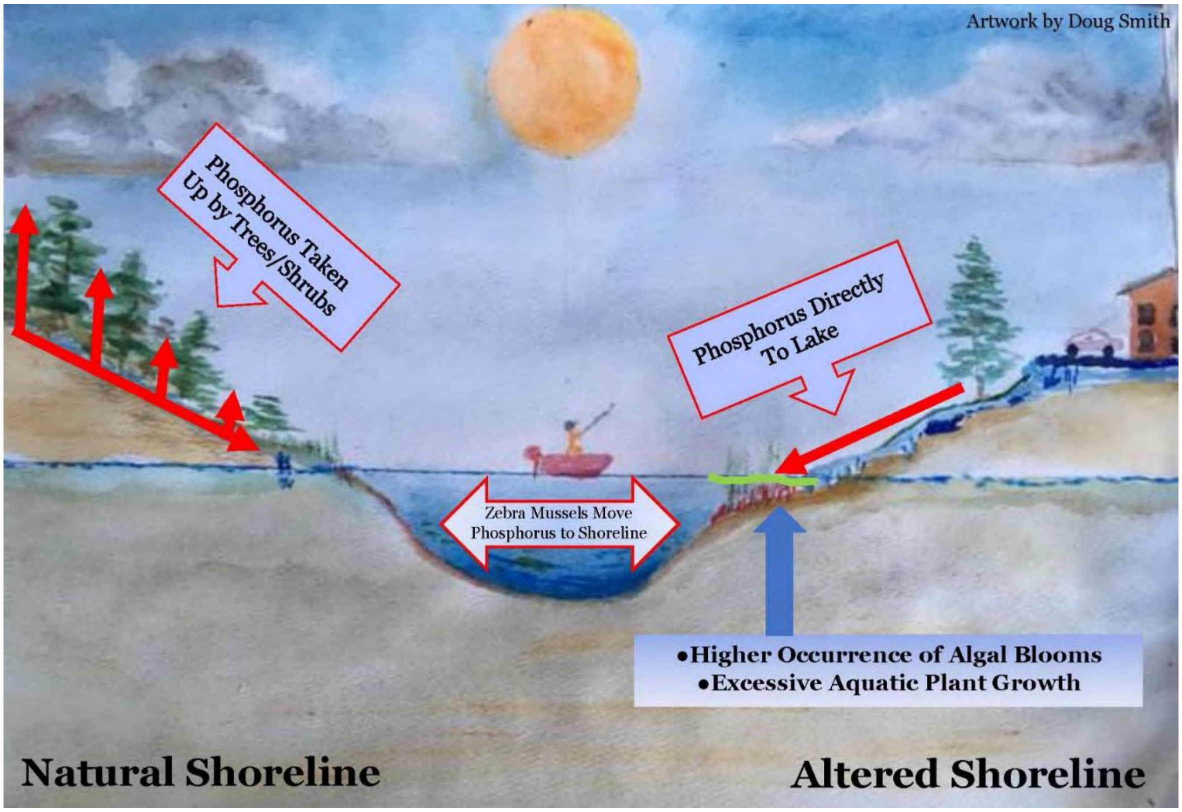
What the diagram shows is that one very important nutrient input to the near-shore environment that we can control is the maintenance of a healthy shoreline. Ignoring setbacks, clearing trees in favour of lawns, etc. all increase nutrient runoff into the lake.



6.5 What Do We Have to Lose?

This year we experienced two toxic blue-green algal blooms centered on altered shorelines. It is difficult to predict if we will have more next year or the year after that. What we do know is that as White Lake becomes more stressed, the probability of more blooms will increase.

The diagram below shows in a simplified way what happens when we alter a shoreline and interfere with nature's way of handling phosphorus and other nutrients. On the left we have a natural undisturbed shoreline showing phosphorus taken up by trees and other vegetation, preventing it from reaching the lake. On the right we have an altered shoreline providing no buffer for phosphorus and other nutrients allowing these to reach the lake unimpeded. The results are plain to see: more aquatic plants and algal blooms!



If we choose to ignore the signs, we could be headed for: 1) Higher frequency of algal blooms; 2) Earlier occurrence of algal blooms; 3) Greater extent of algal blooms; 4) Longer duration of algal blooms; 5) The release of massive quantities of phosphorus from lake sediments resulting in permanent algal blooms, loss of recreational use, lower property values and tax revenues.

The choice is ours to act and protect White Lake for ourselves and future generations.

WHITE LAKE PRESERVATION PROJECT

7.0 Five Years in Review: 2014-2019

Water Quality Studies & Environmental Outreach Programs on White Lake

The White Lake Preservation Project (WLPP) and the White Lake Property Owners Association (WLPOA) have just announced that we now share one group of volunteers to carry out our water quality programs. Starting in 2019/2020 Dr. Conrad Grégoire and Dave Overholt will be responsible for the joint program. There will be one water quality report each year. We will also be looking into jointly planning Environmental Science and Outreach programs. Described below are those offered to date by the WLPP.

Water Quality Programs

(WLPP Committee member Dave Overholt examines plankton

Water Sampling and Analysis

Going forward starting in 2020, there will be one comprehensive water sampling program carried out jointly by the WLPP and the WLPOA under the auspices of the *Lake Partner Program of the Ministry of the Environment, Conservation and Parks (MECP)*.

This is a continuation of the joint WLPP/Ontario government program and includes: monthly sampling during ice-free months for total phosphorous, calcium, and chloride. With the agreement of MECP, sampling has been expanded to 7 standard locations. There are also readings twice a month of Secchi depth and lake water temperature in a total of 9 sites. The monthly program of sampling for total phosphorous, designed and approved by MECP, is specific to off-shield lakes like White Lake.

In 2015 and 2016, the Mississippi Valley Conservation Authority *(MVCA)* partnered with the WLPP to facilitate additional lake monitoring focusing on depth profiling studies of dissolved oxygen, temperature, conductivity and chlorophyll-a. Reports were published by MVCA as a part of the Watershed Watch program. In 2017 *Watersheds Canada* carried on the work of the MVCA, partnering with WLPP to measure the same parameters. On-lake studies on the calibration of environmental monitoring equipment was carried out with Water Rangers Ottawa, and a detailed survey and mapping of wild rice occurrences was completed in collaboration with Plenty Canada.

Water Quality Monitoring Program and Research Activities Reports

Since 2014, the White Lake Preservation Project has published over 400 pages of scientific reports and bulletins. These reports contain data and data analysis of a number of key water quality parameters including total phosphorus, water clarity, pH, conductivity, temperature, dissolved oxygen and eight chemical elements. These reports document algal blooms, loon and cormorant populations, zebra mussel propagation and effects, fisheries, plankton activity, aquatic plants such as wild rice and tape grass, and invasive species. Water levels are also monitored.

Paleolimnology

Paleolimnology is the study of sediments to track changes in lake conditions over time. The first study of White Lake was completed in collaboration with WLPP scientists in 2014 by Prof. Jesse Vermaire of Carleton University. The study found that nutrient levels in White Lake have been increasing in recent decades. The second collaborative study, completed in 2019, assessed water quality changes in White Lake over the past 130 years and documented the recent history of poor water quality due to water level changes, nutrient loading and invasive species.


Dr. Conrad Grégoire (left) and Prof. Jesse Vermaire

A paper (co-authored by C. Grégoire with M. Murphy and J. Vermaire) entitled "Ecological response of a shallow mesotrophic lake to multiple environmental stressors: a paleolimnological assessment of White Lake Ontario" will be published in the *Journal of Lake and Reservoir Management*.

Initiatives in Environmental Science and Outreach

In addition to the activities described above, the broader membership of the WLPP has initiated programs and environment-related activities focusing on outreach and participation of lake residents, businesses and visitors. Going forward, WLPOA and WLPP will jointly plan these kinds of activities. *The programs described below have been fully or partially funded by lake volunteers and the Gottlieb Foundation.*

The White Lake Preservation Project website: Conrad Grégoire

The website www.WLPP.ca is a comprehensive site containing all documents and information available on White Lake. Published works dating from the 1950s to the present are referenced and archived. It is the only website that brings together published scientific work from both Federal and Provincial agencies as well as academia.

The site also contains information on the physical, chemical and biological aspects of the lake including the geological setting, fisheries, algal blooms, loon populations, endangered and invasive species, the White Lake Fen and conservation areas.

All current studies done on the lake by the WLPP as well as those completed in collaboration with the provincial government, the Mississippi Valley Conservation Authority, Watersheds Canada and Carleton University are posted on the site. WLPP Water Quality Monitoring Reports from 2014 to 2018, newsletters and bulletins are also posted on the website along with announcements of upcoming events. Additionally, there is a sign-up opportunity for those wishing to stay current with activities or to volunteer to help.

Walleye spawning bed project at Paris

2015: White Lake Spawning Bed Project *Watersheds Canada, Melissa Dakers, Janet Taylor, Adam Pugh, Conrad Grégoire*

This project was a true community effort. It was led by Watersheds Canada and the Lanark County Stewardship Council, with active participation of the WLPP and the Lanark & District Fish & Game Conservation Club.

The program received funding from Fisheries and Oceans Canada. Two local contractors (Lou Laventure Construction Ltd, M. Sullivan & Son Ltd) provided the heavy equipment and crew members necessary to deliver the rock to the spawning sites. Volunteers helped place brush bundles to act as shelter for fry at certain underwater sites on the Lake.

2016: BioBlitz *Janet Taylor, Melissa Dakers, Watersheds Canada, Canadian Wildlife Federation*

The WLPP in partnership with Watersheds Canada and the Canadian Wildlife Federation (CWF) ran a 2-day BioBlitz on May 27th-28th, 2016 on the North shore of White Lake. A BioBlitz is an intense period of biological surveying in an attempt to record all living species within a designated area. Scientists, naturalists and volunteers conducted the study continuously for 24 hours during which 518 different species and over 723 observations were logged into the CWF's iNaturalist website.

The public was invited to join walking tours of the site with experts who provided information on the species inhabiting the surroundings. A special program was provided for children. Species at risk (SARs) observed during the BioBlitz included snapping turtle, Eastern whip-poor-will, and Eastern wood-pewee. These sightings were reported to the Ministry of Natural Resources and Forestry.


Invasive species in White Lake - Eurasian Watermilfoil

2017: Invasive Species Presentation: *Doug Smith, Brook Schryer*

At the invitation of the WLPP the Ontario Federation of Anglers and Hunters (OFAH) made a sobering presentation with examples and photographs describing the invasive species currently in, and with potential to arrive in, White Lake and surrounding lakes and wetlands. Turnout for this presentation was excellent and a good indication of how important this topic is to lake residents.

2018: Create a Native Species Lakefront Garden *Doug Smith, and Watersheds Canada*

A pilot program was offered to a limited number of people to try out a new app being developed by Watersheds Canada. The app is being designed to assist waterfront property owners who plan a shoreline restoration on their own property using native plants best suited to the area. Native plants help attract native species of wildlife, provide food and shelter and also help prevent storm water run-off which can be very damaging to a lake. For more details on the app and release data, please contact Watersheds Canada.

September, 2019: Lake Protection Workshop *Doug Smith*

This workshop was organized by the WLPP to introduce the recently published Lake Protection Workbook. Invited speakers covered the following topics: 1) The myths and gritty realities of septic systems with Eric Kohlsmith; 2) Updates on the aquatic and terrestrial invasive species in White Lake and area with Dave Overholt and J.P. Thonney; 3) The importance of natural shorelines to species diversity with Leora Berman of The Land Between, who made a passionate presentation on the importance of biodiversity in preserving natural shorelines; and 4) Chloe Lajoie of the Natural Edge Program who provided pointers on how to restore affected areas.

The White Lake Preservation Project Volunteers

Dr. 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 Preservation Project 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.

Adam Pugh's family has owned and operated Cedar Cove Resort on White Lake for over 10 years. Adam has spent a good portion of his life on the lake, and has developed a passion for the conservation and biology of local fisheries and wildlife. He completed the advanced diploma program in Fish and Wildlife Technology and Sir Sandford Fleming College in Lindsay and now owns his own business providing guided fishing and hunting trips on White Lake and the surrounding area. Adam has been awarded the Youth Entrepreneur Award from the Township of Lanark Highlands as a result of the success he achieved with his ice hut rental business.

Shirley Roy-Schertzer is a property owner on White Lake with several years of marketing and communication experience. She connected with the White Lake Preservation Project to get a better understanding of how lake water quality may be changing, the science behind it and how she could do her part as a property owner to help preserve the lake.

Beate Schiffer-Graham has a Masters in Public Affairs, and a Masters in Political Science and has over 20 years experience in performance measurement, evaluation, review and consulting engagements with a focus on organizational improvement and learning, based on evidence. Beate enjoys the challenge that each new project brings and thrives on working in a multi-disciplinary team.

Dr. Doug Smith completed 4 years of basic science prior to his degree in Dentistry. He had an Ottawa based private practice for 38 years, after which he was invited to join the staff of the Civic Hospital where he treated medically compromised and "at risk" patients for a further 10 years. He brings to the team considerable experience on the functioning of local, provincial and national organizations. Having served on the board of a professional regulatory agency, Doug understands how Provincial policy is applied to lower tier organizations.

Janet Taylor has a BSc in microbiology and an MSc in biochemistry. She spent 30 years with the federal government in pesticide regulation, working in chemistry, toxicology and environmental sciences. She work-shared with scientists/regulators of the US Environmental Protection Agency, and with the United Nations Food and Agriculture Organization and the World Health Organization on international standards for pesticides, and in training pesticide regulators in developing countries.

Jean-Pierre (JP) Thonney earned an MSc in Fisheries Science and Aquaculture from the Institute of Aquaculture at the University of Stirling, Scotland. He holds a BSc Honours in Fisheries Ecology from Memorial University and a D.E.C. in Fish and Wildlife Management from Vanier College. His 30 years of international work experience includes environmental assessment and mitigation, fisheries management, aquaculture, and sustainable development. He is currently working at the Ecosystem and Biodiversity Science Division at Fisheries and Oceans Canada in Ottawa as a Science Advisor. JP has been involved with the WLPP providing diving and other field work regarding recent biodiversity assessments of the lake. He has also reported on the presence of microplastics in White Lake.

PART II
Water Quality Parameters

8.0 Algal Blooms – 2019

This year two algal blooms were recorded in White Lake. The first type of algal bloom which occurred was from filamentous green algae. This bloom lasted, as in previous years, from the end of June until mid-September. Large and small patches of this algae were observed in almost every part of the lake save Hayes Bay and the Village Basin. This is a nuisance bloom which occurs along shorelines and can cover very large areas.

The second type of bloom was from a blue-green alga which was concentrated in the lower half of Three Mile Bay. In September of 2018, there were two blue-green algal blooms which occurred in the same area, but were more extensive covering most of Three Mile Bay and parts of the greater lake. The first of these blooms was certified as toxin producing, the second was not tested, but presumed to likely also be toxic. 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"[13]

We 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. Currently only two volunteers are monitoring the 22 Km^2 of White Lake, which has a shoreline stretching nearly 100 km!

8.1 Green Algal Blooms

The first algal bloom of the year started in late June and continued until the end of September. This filamentous green algae (Sirogonium) grew in large patches along the shoreline. Nutrients, such as phosphorus, supporting this alga comes from both the sediments as well as dissolved in lake water.

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 falls to the bottom of the lake.

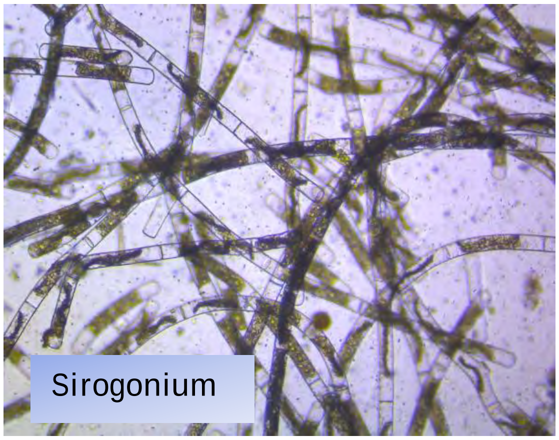
Blooms such as the ones pictured below were common in 2019, as in previous years, all along the western shore of White Lake and also in other areas and along island shorelines and Three Mile Bay. This bloom was essentially lake-wide and similar to blooms which occurred in 2017 and 2018 at the same location.

[13] 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.

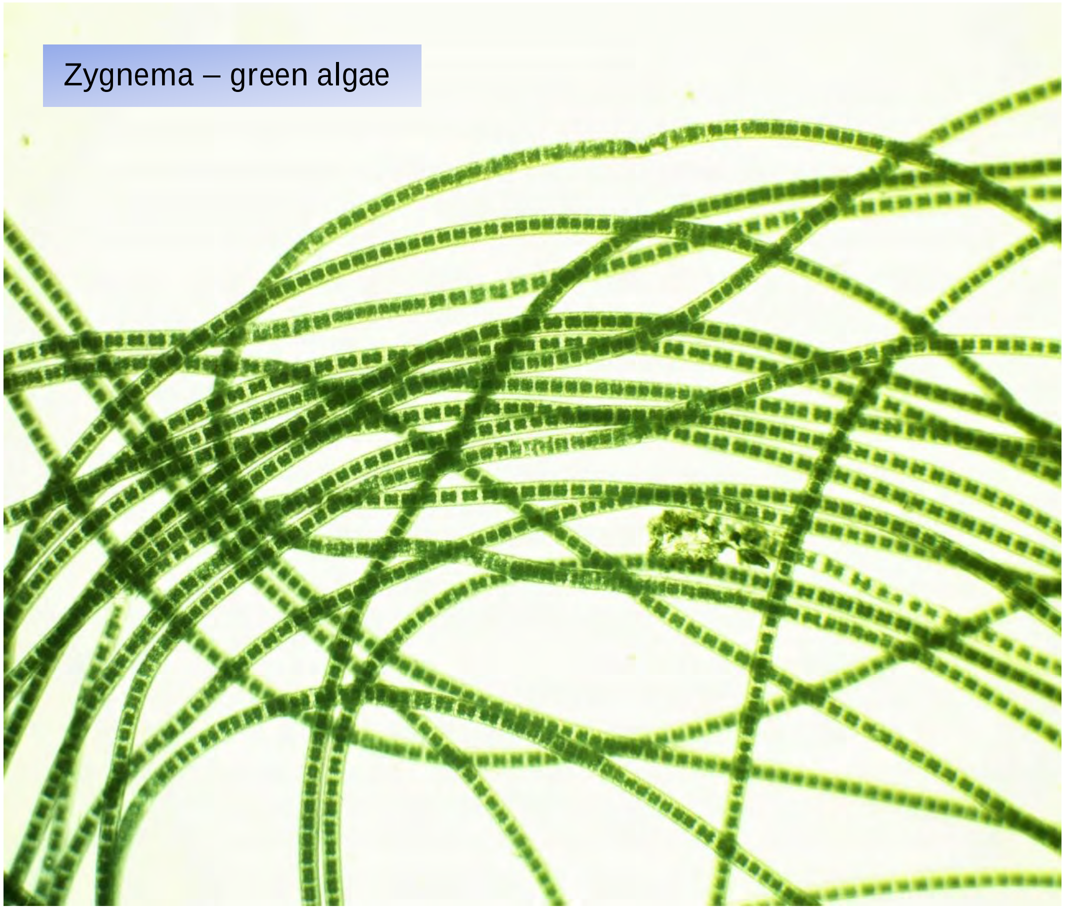

Three Mile Bay – July 1, 2019


Waba Island – August 17, 2019

The algae responsible for these blooms is Sirogonium, one of a large family of filamentous green algae found in White Lake. Blooms of filamentous green algae are stimulated by the presence of zebra mussels in White Lake. Zebra mussels concentrate nutrients from deeper parts of the lake and deposit them in shoreline areas where they thrive. Warmer daytime water temperatures, abundant light and nutrients, provide ideal conditions for the propagation of filamentous green algae along shorelines.



Even with the onset of cooler weather in late September and October, another filamentous green alga of the Zygnema genus thrives where Sirogonium was present earlier in the year. The algae resemble bright green garlands draped over aquatic plant and persists right up to ice formation on the surface of the lake.



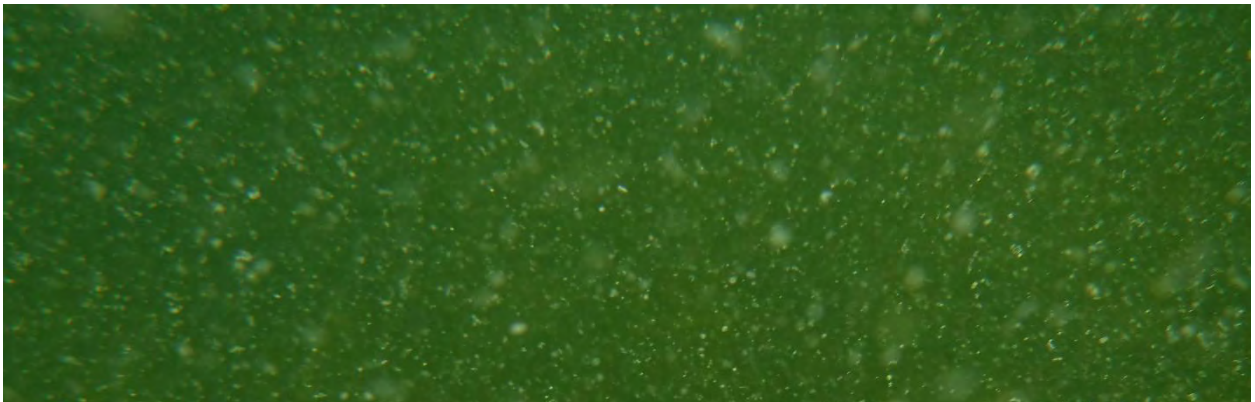
8.2 *Blue-G*reen Algal Blooms

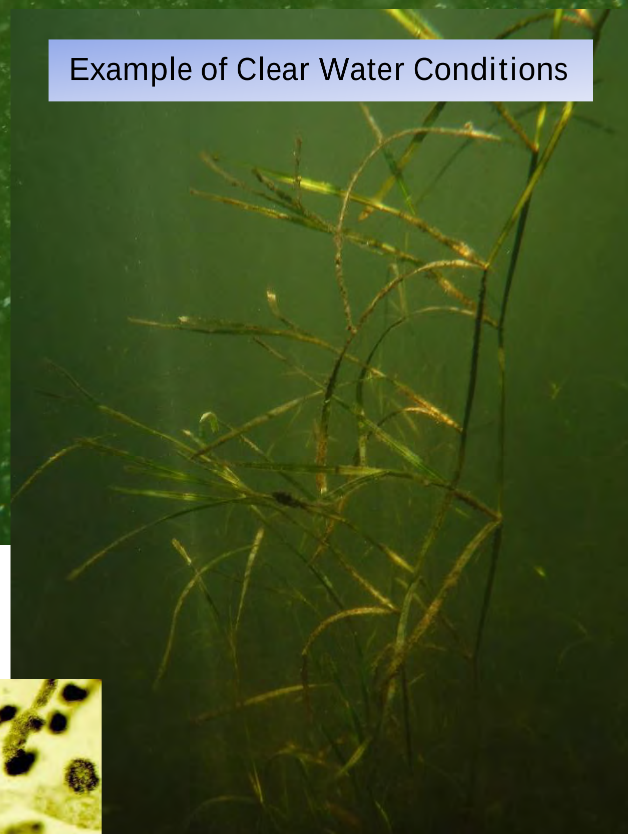
Blue-green algal blooms are not benign and so warrant special attention. When these blooms occur, they can create a public health hazard and anyone using the lake should be apprised of the seriousness of this issue.

This year, White Lake hosted one blue-green algal bloom. The bloom occurred in the Eastern half of Three Mile Bay and lasted for over a month starting in mid-September.

Although we had identified the blue-green algae as *microcystis*, we did not report it to the Ministry of the Environment or to our local Health Unit. This is because the bloom did not result in a surface scum which signals the large-scale death and decay of the algae. Microcystin toxins are usually released at this stage of the algal bloom.

Instead, the very intense algal bloom filled the water column in this part of the lake. The water was visibly opaque and full of clusters of blue-green algae. The photos below are underwater photos of the affected waters. A comparison photo showing how the water should look at this time of year is provided for comparison purposes. The identifying photomicrograph of the algae itself is also provided.





Example of Clear Water Conditions

Microcystis: Three Mile Bay 2019

It is possible that local conditions such as wind, temperature, etc. moderated this blue-green algal bloom preventing it from developing further before it has a chance to dissipate.

In 2018, there were two such blooms in Three Mile Bay, one of which was determined to be toxic and the other, although not tested, was potentially toxic as well. It may be no coincidence that these blooms took place on the most altered shoreline on White Lake.

Note that monitoring the extent and longevity of an algal bloom requires much time and effort. Although we try to provide current up to date information, we would need more volunteer help to provide a complete picture of any algal bloom. For blue-green blooms, the Leeds, Grenville and Lanark District Health Unit provides a useful guide for individuals to use in assessing when water becomes safe to use after a toxic bloom is identified.

We must keep in mind that the "Ministry of the Environment regards any cyanobacterial (blue-green algae) bloom as potentially toxic, whether or not toxins are detected in the water upon testing". See literature reference above.


Photo by Sue Munro

9.0 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 by 138%! At locations further away from shorelines, the Secchi depth (see box on right) has increased by about 109%. In the middle of the lake, the increase is about 95%.

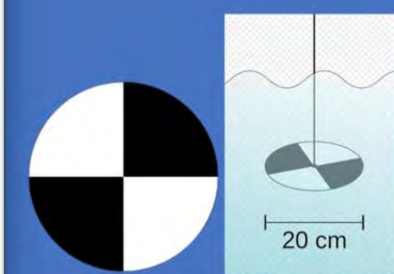
In July of 2015, the Secchi depth in Three Mile Bay was 2.1 metres and by July 2018, the Secchi depth had increased to 5.0 metres. We are now measuring Secchi depths of over 9 metres at some locations. So what?

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

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

WHAT IS SECCHI DEPTH AND HOW IS IT MEASURED?

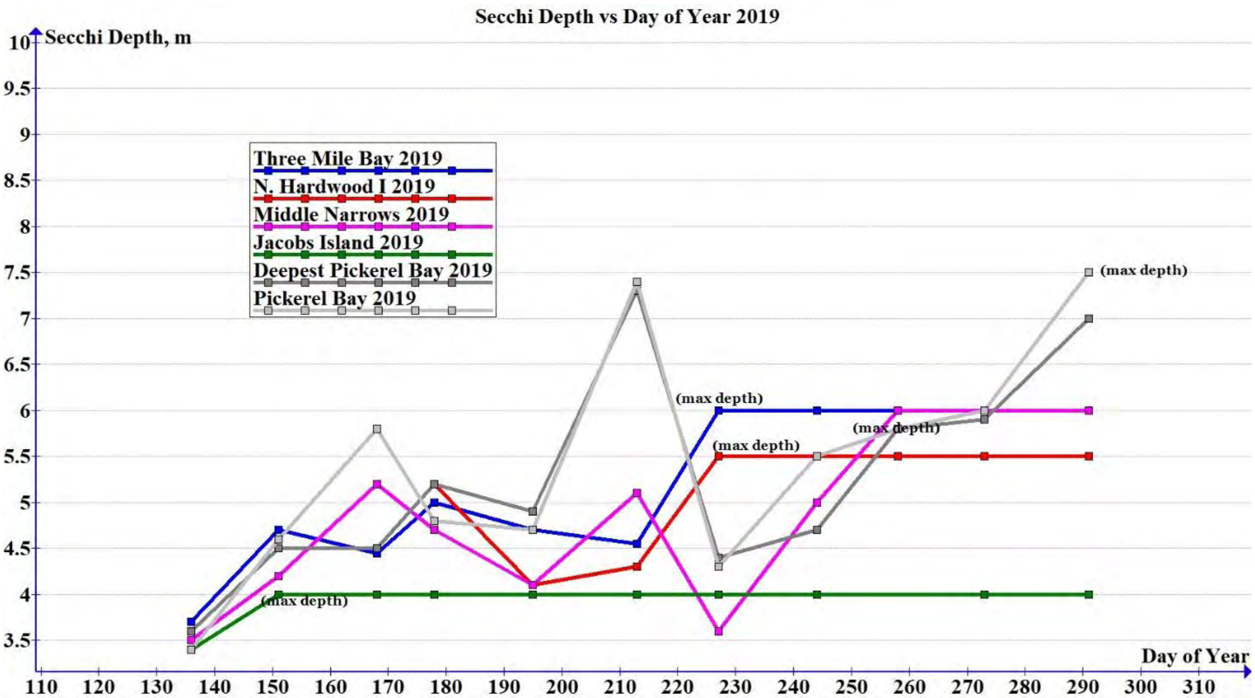
The Secchi depth is a measure of the clarity or transparency of the water. The Secchi disk, named after an Italian scientist, is used to make the measurement. The disk is segmented black and white and 20 cm in diameter:



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

9.1 Secchi Depth Data:

Below is a graph containing the Secchi depth readings for White Lake taken during the 2019 ice-free season.



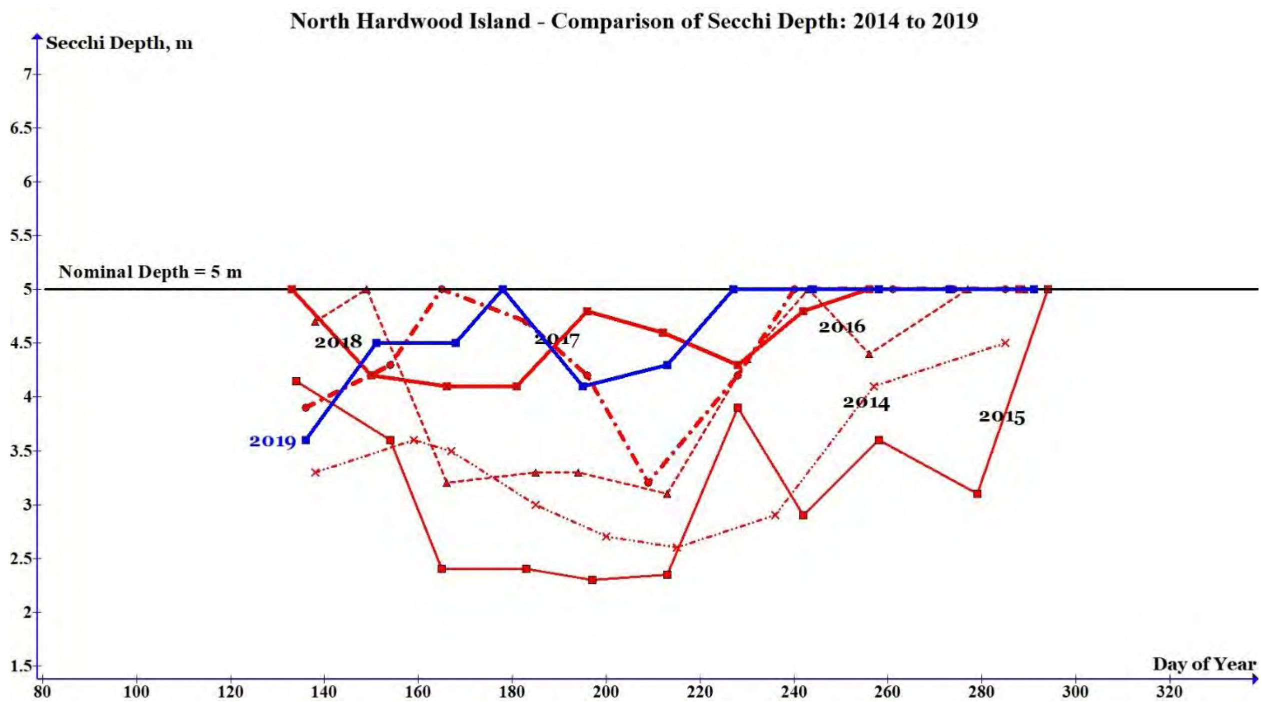
The pattern of Secchi depth readings is somewhat different this year from those observed during the past several years. Secchi depths increased as the lake water column became uniform in temperature and then decreased as the temperature of the lake increased. At higher temperatures there is more biological activity as well as supply of nutrients. Minimum Secchi depths of about 3.5 m (lowest water clarity) were recorded in mid-August with a maximum of 7.5 m recorded in mid-October.

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. What was different this year from precious years was the large changes occurring in secchi depths during the first half of the ice-free season. For the past several years the secchi depths remained at or below 5m and then reached their maximum values by mid-September. This year, there was more variation throughout the ice-free season with some sites increasing while others decreased in water clarity on the same sampling date.

It is difficult to explain why this pattern occurred. One can speculate that it may be related to the wet spring we experienced along with cooler temperatures. Alternatively, the presence of reduced numbers of zebra mussels may also have had an effect in decreasing water clarity. This year, the first generation of zebra mussels died and were replaced only later in the year with one or more newer generations. Please refer to section on zebra mussels for more information on this topic.

The figure below shows Secchi depth data for the North Hardwood Island site taken during six consecutive years from 2014 to 2019. The 2019 data line is highlighted in blue.

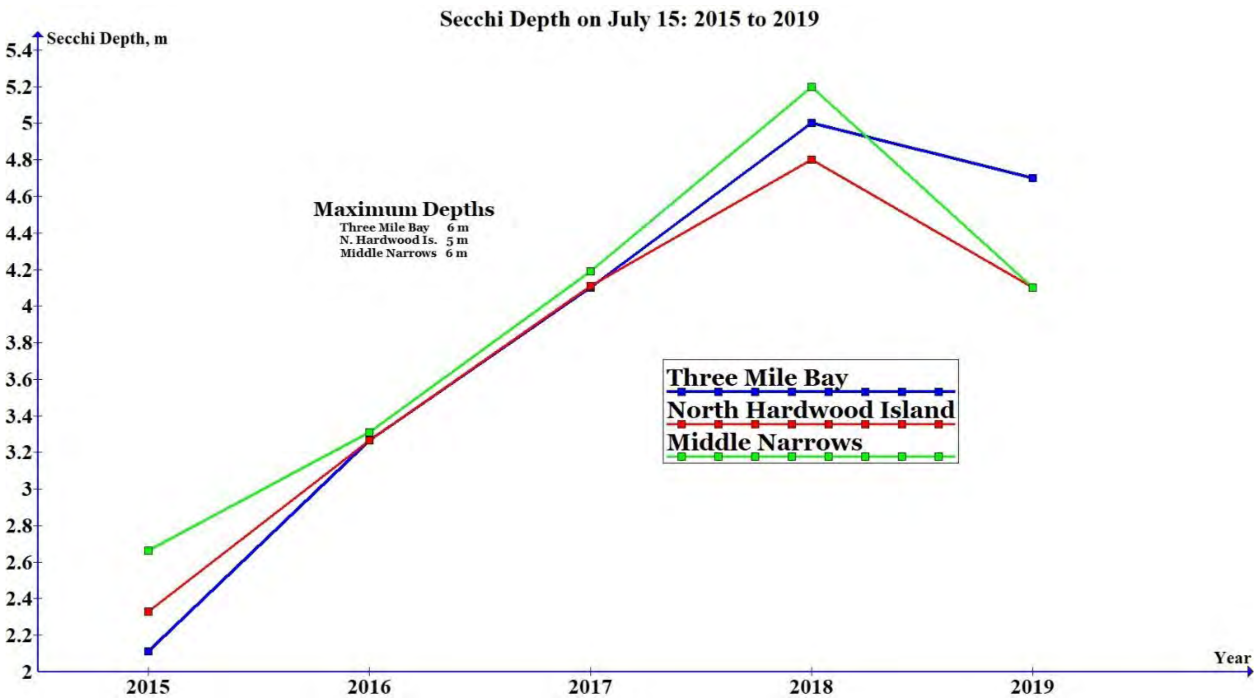
The data shows that from 2014 to 2019, the Secchi depth readings have been steadily increasing, especially since the introduction of zebra mussels in White Lake in 2016. Weather, including water and atmospheric temperatures, can influence plankton growth, and hence the Secchi depth, and so it may be difficult to quantitate the trends from one year to the next.



One way to look at this data is to plot the Secchi depth readings taken in mid-July for the years 2015 to 2019 for three sites located in Zone 1, the Main Water Body.

The graph below shows that the water clarity, expressed as secchi depth, increased significantly during the years 2016 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 2008. This may be linked to populations of zebra mussels reaching an equilibrium or a net decrease in zebra mussel numbers resulting from the death of the first large generation of zebra mussels present starting in 2016. More information will be derived from new data obtained in 2020 and future years.



9.2 <u>Frequency of Secchi Depth Readings Exceeding Sampling Site Depth</u>

Another way of showing how the clarity of White Lake has been increasing in recent years is to consider the number of times we were unable to obtain a Secchi depth (because the secchi depth was greater than the depth of the sampling site) at each of the five deep water sites we monitor on a regular basis.

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

*maximum number of measurements made per year

These data show that for any given sampling site, the number of times the Secchi depth could not be read because of water clarity increased with each year up until 2019. For example, for Jacobs I., in 2015, there were only two occasions out of a possible 11 that the

Secchi depth exceeded the water depth at the site. This increased to 8 times in 2016 and finally 11 in 2017 and 2018, and 10 in 2019. Looking at the total number of times Secchi depths could not be read for all sites combined, these increased from 4 in 2015, then to between 23 and 24 starting in 2017. These data along with the graphs above, indicate that water clarity may have stabilized. Future observations may reveal that these numbers track the health of the zebra mussel populations in White Lake.

Finally, we can consider the number and percent of Secchi depth readings exceeding sampling site depths and calculate the percentage of lake bottom which is now exposed to sunlight. For this calculation, the 'Deepest Pickerel Bay' sampling site was used because it has a depth of 9.1 m, the deepest in the lake.

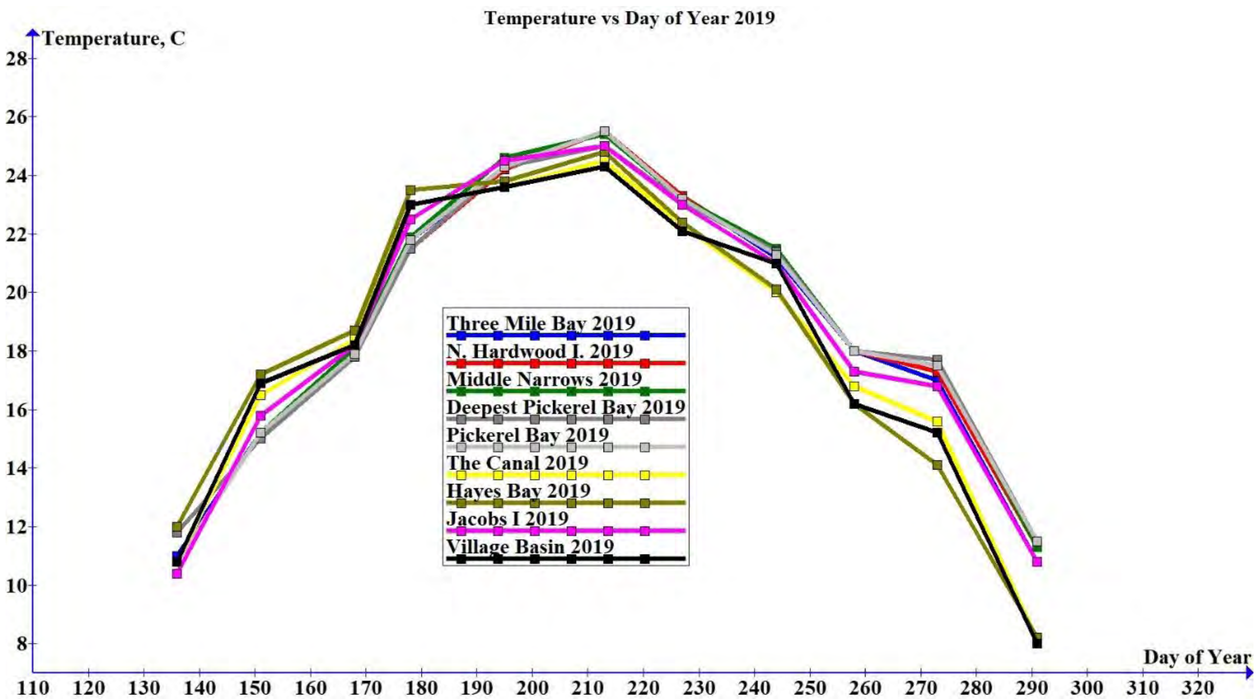
Deepest Pickerel Bay	2015	2016	2017	2018	2019
#/max #	3/11	7/11	10/11	9/11	9/11
Percent	27.3%	63.6%	91.0%	81.8%	81.8%

One must also consider that the Secchi depth reading, in metres, represents only half of the distance through which light will travel in the lake. So, if there is a Secchi depth reading of 4 m, this means that sunlight will travel 8 m towards the bottom of the lake. Of course, the intensity of sunlight diminishes as it penetrates or travels through the water column, but only 1% of sunlight reaching the bottom of the lake can be enough to promote plant and algal growth as well as change the temperature of lake sediments, which may result in increased quantities of phosphorus entering the lake from these sediments (internal loading).

The results contained in the above table indicates that in 2019, the percentage of time during daylight hours that sunlight could penetrate to the bottom of the deepest part of the lake was 81.8%. Since less than 10% of the lake has a depth of 9 m, this means that only about 1.8% of the surface of the lake floor was 'dark' during the summer months. Put another way, more than 98% of the lake bottom now receives sunlight and is subject to increased plant and phytoplankton growth as well as increased release of phosphorus from now warmer sediments.

10.0 Water Temperature

Temperature is one of the most important water quality parameters to study. 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 (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 2019 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 (see below). 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 and surface runoff. Not evident in the figure above, are differences in temperatures at 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 our 2016 Water Quality Monitoring Program Report available on our website www.WLPP.ca.

The table below gives the Zone location for both the low and high lake temperatures recorded for each lake sampling date. Data highlighted in yellow are for shallow sites.

Date	Low Temp.	Zone		High Temp.	Zone	Difference, ◦C
May 16	10.4	1		12.0	2	1.6
May 31	15.0	1		18.7	2	3.7
June 17	17.8	1		18.7	2	0.9
June 27	21.5	1		23.5	2	2.0
July 14	23.6	1		24.8	2	1.2
Aug. 1	24.3	4		25.5	1	1.2
Aug. 15	22.1	1		23.2	1	1.1
Sept. 1	16.2	4		21.5	1	5.3
Sept. 15	16.2	2		18.0	1	1.8
Sept 30	14.1	2		17.7	1	3.6
Oct. 8	8.0	4		11.5	1	3.5

Zone 1 = Main Water Body; Zone 2 = Hayes and Bane Bays; Zone 4 = Village Basin

This data shows that the largest differences in temperature occur at the beginning and again at the end of the ice-free season with a maximum difference of 5.3 ◦C.

Starting in June and until September, the temperature range between low and high temperatures in White Lake is close to 1◦C.

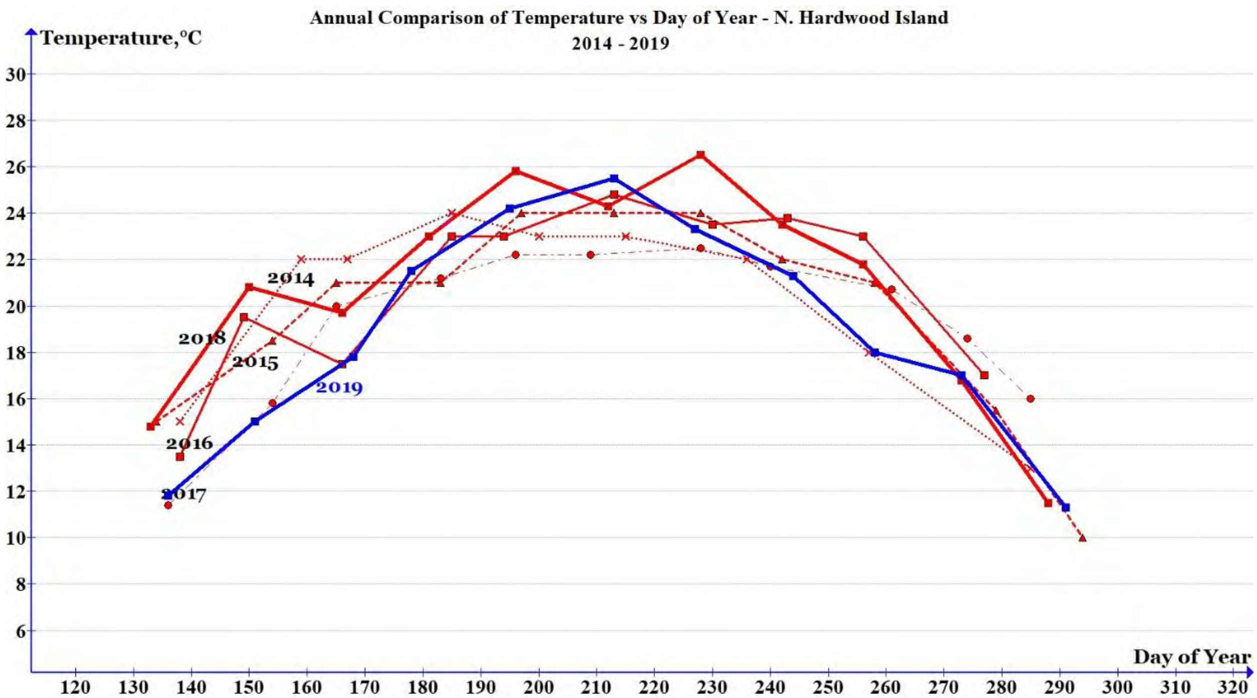
It is not surprising that, depending on the date, the high and low water temperatures are either found in Zone 1 or Zones 2 and 4 of White Lake. Zone 1 comprises the deepest parts of the lake which would both heat up and cool down more slowly than shallower parts of the lake. Zones 2 and 4 comprises the shallowest parts of the lake with an average depth of approximately 1.5 m. At this depth, waters in Hayes Bay and the Village Basin would both cool and heat up more quickly than in Zone 1 or any deeper location on White Lake.

10.1 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 at www.WLPP.ca). 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 six consecutive years of water temperature measurements for the deeper sites (Zone 1: Main Water Body) on White Lake. The figure below gives temperature measurements obtained at the North Hardwood Island site for the years 2014 to 2019.



Clearly, the 2019 data (blue line) shows that temperatures were generally lower by several degrees than in most previous years.

The table below gives maximum temperatures recorded for White Lake during the past six years. 2018 has the highest temperature which was 2.2 ◦C higher than previous years.

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

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

11.0 Dissolved Oxygen

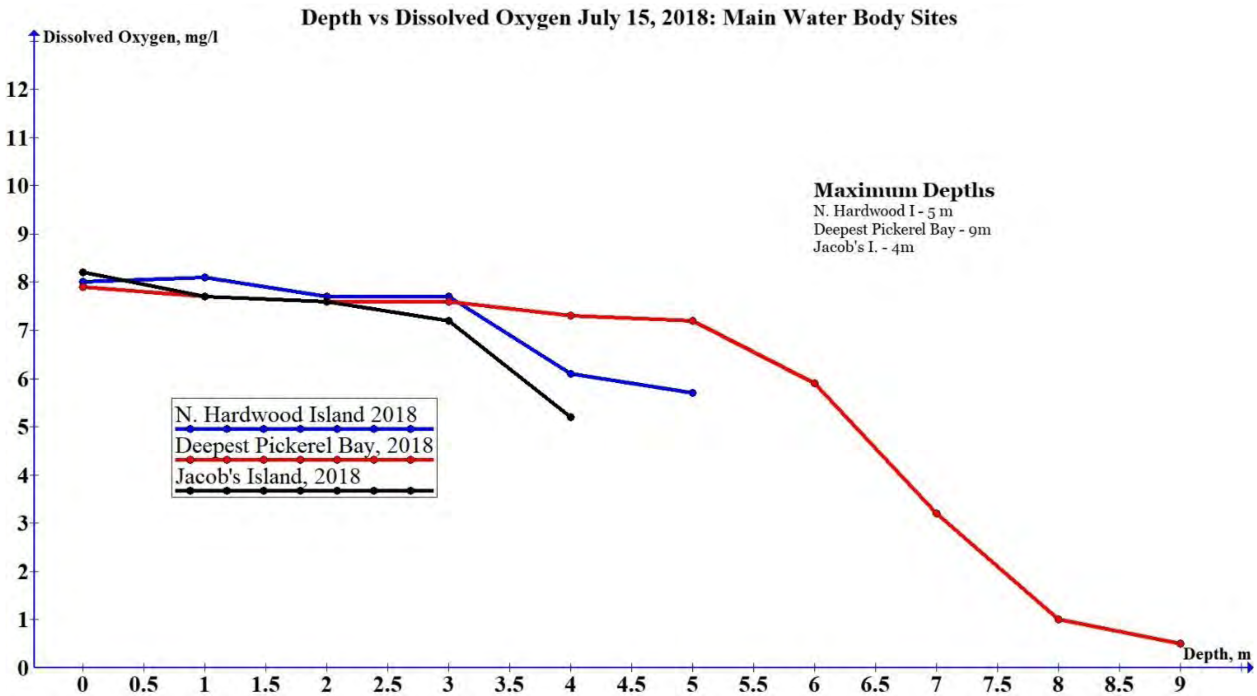
Oxygen is an essential element in any aquatic system. Oxygen is needed by all organisms to sustain life. The amount of oxygen dissolved in lake water varies from day to day and even between night and daytime. Most of the dissolved oxygen in lake water comes from the atmosphere and becomes dissolved into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

Because of the dependence of oxygen levels on many environmental factors, it is easy to see that the concentration of oxygen in lake water can vary greatly during the ice-free months and can certainly vary from year to year.

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

Oxic conditions are said to exist when there is dissolved oxygen in the water. When there is no oxygen present, anoxic conditions are said to exist. Clearly, where oxygen levels are too low, fish populations can be threatened. Another important consequence of anoxic conditions, especially at the water-sediment interface, is the chemical release of phosphorus back into the water column. Sediments contain phosphorus concentrations hundreds of thousands of times greater than phosphorus concentrations in the water just above it. Phosphorus released from the sediment back into the water column (see 'Phosphorus' section of this report) can promote the occurrence of algal blooms. This effect is called phosphorus back-loading and the lake is described as having an internal load.

Oxygen concentrations levels as a function of depth have been measured in White Lake for three consecutive years starting in 2015. The results obtained for these three years can be found in WLPP Water Quality Monitoring reports listed on our website. Measurements were made with a YSI multi-parameter probe.



These results shown in the graph above was collected on July 15, 2018. Three sites of up to 9 m in depth in Zone 1 of White Lake were studied. Dissolved oxygen concentrations were virtually constant from the surface of the lake to a depth of about 3 metres. At greater depths, oxygen concentrations decreased slowly up to a depth of about 5.5 m and then decreased rapidly. For the 'Deepest Pickerel Bay' site, which is the deepest in the lake, oxygen concentrations reached dangerous levels (for fish) at depths exceeding about 6 metres. At the lake floor, virtually anoxic conditions prevailed with concentrations of 0.5 mg/L. At a temperature of 20.6 ^{0}C at the bottom of the lake, this represents a saturation level of only 5% compared to 96% saturation levels at the surface of the lake.

Under these conditions, it is clear that part of the lake becomes a 'death zone' for fish during the summer months. Also, prevailing anoxic conditions would favor the release of phosphorus from sediments (internal loading). It is well known that off-shield lakes like White Lake, which are alkaline and high in calcium, are also low in iron. Iron binds strongly with phosphorus and can essentially prevent it from being re-dissolved into the water column, even when oxygen is very low. For White Lake, phosphorus is likely only weakly bound in sediments and making its release under milder conditions possible. Very low iron concentrations of 0.05 ppm were reported for White Lake by MOE scientists (Ferris, 1985)

Below is a table listing the data obtained for the shallow sites on White Lake. These sites are no more that 2 m in depth. We expect that the water column at these sites would be homogeneous because of the action of wind and waves resulting in effective mixing of the water column.

Depth Profiling Data for White Lake – Shallow Sites July 15, 2018

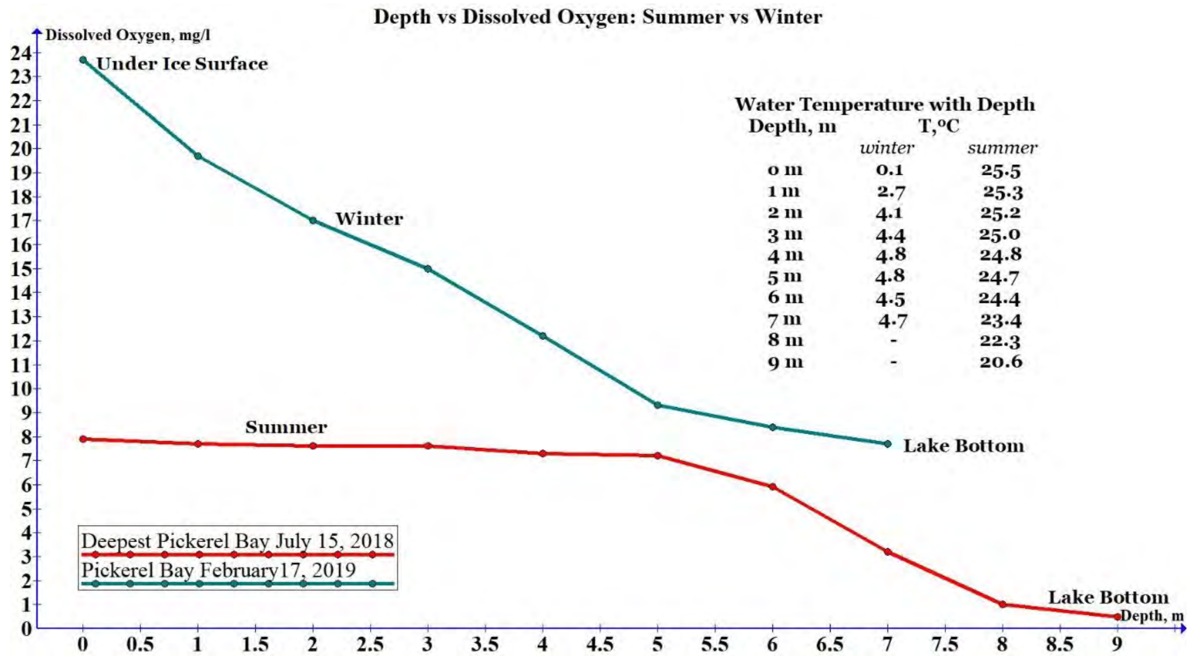
Sampling Site	Depth, m	Temperature, ^{0}C	% Oxygen Saturation	Dissolved Oxygen, mg/L
The Canal	0	26.1	92	7.5
	1	26.1	92	7.4
	2	26.1	93	7.6
Hayes Bay	0	26.7	99	7.9
	1	26.4	100	8.3
Village Basin	0	26.6	99	8.0
	1	26.4	100	8.1

As expected, all of the shallow sites have very high oxygen saturation and concentrations and virtually uniform water temperatures.

11.1 Depth Profiling: Comparison of Summer and Winter Data

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

The density of water is at its maximum at +4^{0}C. Water expands when heated above this temperature and when water is cooled below this temperature. This partially explains why we hear the ice 'crack' loudly during the winter, why we see pressure ridges breaking out from the ice surface from time to time and why we see the familiar berm surrounding the



lake along undeveloped shorelines. This effect also explains why the lake does not freeze solid from top to bottom, especially for shallow lakes like White Lake.

Water just under the ice is cooled while water at the bottom of the lake is warmed by the sediment. The temperature difference, and resulting density difference, between the top and bottom waters results in a diffusion current where warmer water is constantly rising from the bottom of the lake and cooler water descending.

The table contained in the above graph shows that in winter, the water temperature is close to a constant 5 degrees from a depth of 2 metres and below. In summer, the temperature differential from 2 metres to 9 metres varies by about 5 degrees Celsius.

The graph above shows the difference in oxygen concentrations and temperatures with depth during the summer and winter periods. Although the data was collected in different years and locations, previous depth studies at both sites in 2017 showed very similar results to those obtained above. These two sites are about 1 km part in the deepest part of the lake.

What is clear from the figure above is that the concentration of oxygen dissolved in lake water is far less in summer than during the winter. A combination of factors is responsible for this observation: First, oxygen is less soluble in warm water than in cold water; Second, there is less bacterial action in sediments and less oxygen demand from living things in cold water than in warmer waters; Third, the lake is constantly mixing in winter because of thermal diffusion.

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

In addition to illustrating well known lake science, the important point which this section makes is that during the summer, the deeper parts of White Lake become severely oxygen

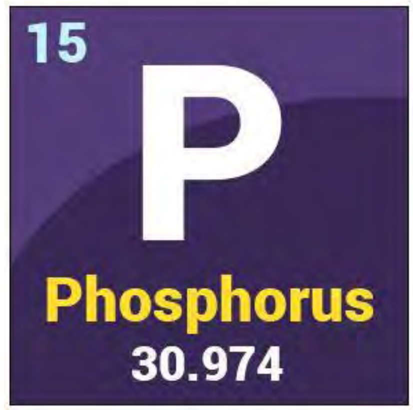
Michael Murphy, Carleton U. graduate student, prepares to sample White Lake in Winter

depleted which both threatens fish and other life and also accelerates the release of phosphorus from sediments.

12.0 Phosphorus

What is Total Phosphorus?

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



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

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

But where does it come from? Phosphorus occurs in nature mostly as the mineral apatite which is also called calcium phosphate $Ca_5(PO_4)^+$. It can enter lake water by a number of ways including: rain which contains atmospheric dust; pollen which is high in proteins; fertilizers, detergents, septic systems, etc.; surface soil runoff, and ground water containing dissolved phosphorus compounds. It has been estimated 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 (see Ferris in Bibliography).

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. Everything else including phytoplankton, small zooplankton, particles containing phosphorus, dissolved inorganic and organic phosphorus compounds pass through the filter and are measured together as total phosphorus. These are true total phosphorus 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). For this reason, these larger organisms must be filtered out prior to analysis. Note that the operational definition of total phosphorus and the use of filtration are a standard practice adopted by most of the scientific community. In this way, scientists are able to compare their results with those of others and is useful over time to study long-term trends in total phosphorus levels in water bodies including lakes like White Lake.

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.

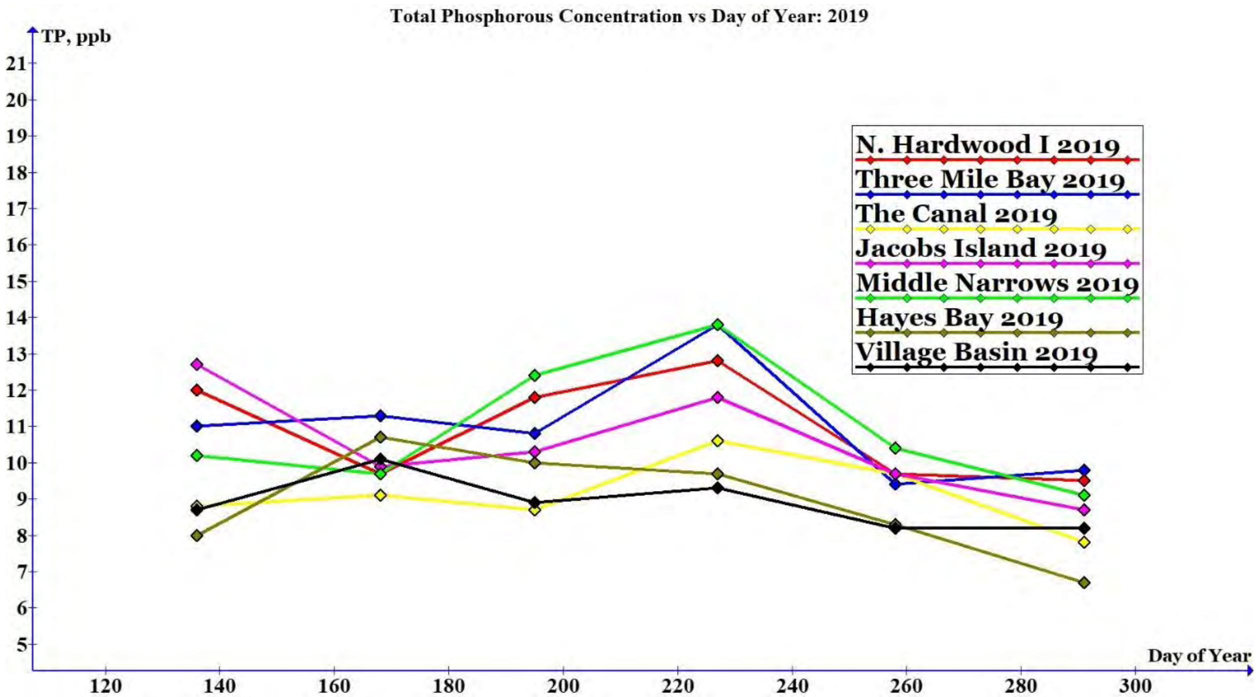
Since zebra mussels have established themselves in White Lake, the total phosphorus concentrations measured in the lake have decreased by about 50%. This is because zebra mussels are filter feeders and they very efficiently remove all particulate material (down to 1 micron) containing phosphorus. The phosphorus which remains in solution is not filtered out by mussels, but remains available for algal growth. In effect, even though overall total phosphorus concentrations have diminished, the amount of available 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 change in phosphorus inputs by nature or humans, nor does it reduce the 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 2019.

The graph below shows the change in total phosphorus concentrations during the 2019 ice-free season.

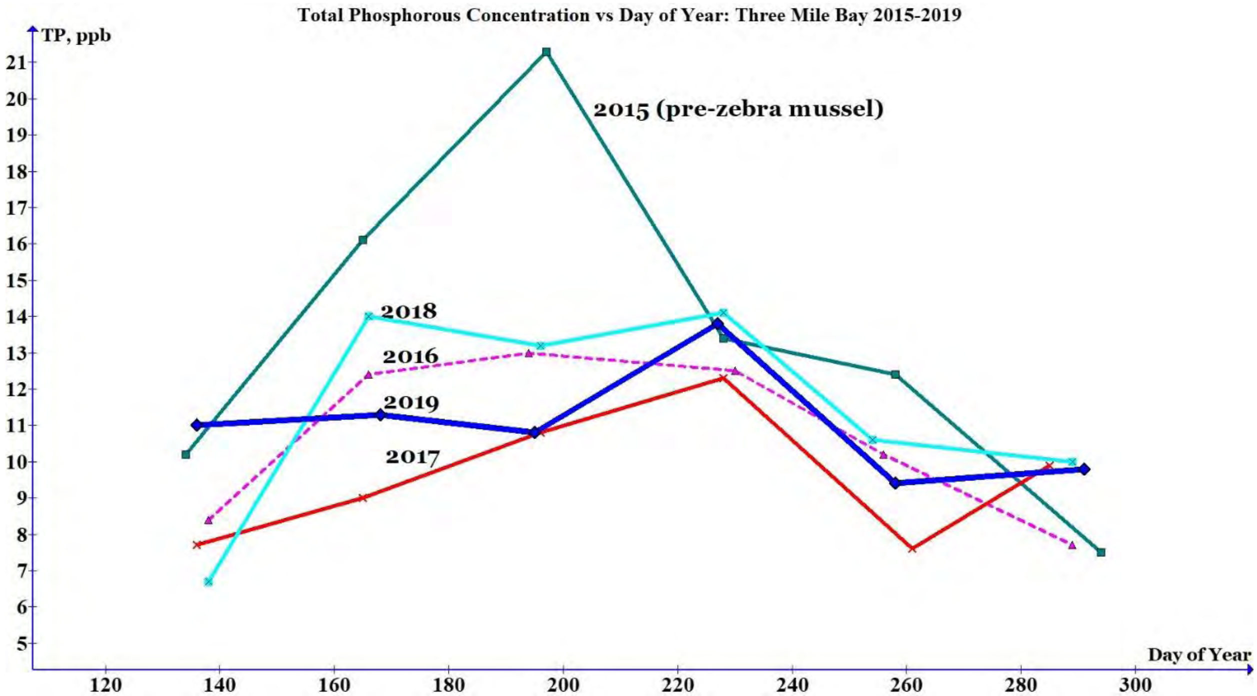


The data for 2019 (above) show an increase in the total phosphorus concentration over the summer months reaching a peak or highest value in mid-August. This is about one month later than observed for previous years starting in 2015. After this date, the total phosphorus concentration decreases into the fall. These data also show that the highest total phosphorus values were obtained at the southern part of the lake nearest Three Mile Bay. These results and trends are in agreement with measurements recorded during the last ten years by government agencies and volunteers.

The results for Three Mile Bay spans five years starting in 2015. The results shown for 2015 exceed a maximum total phosphorus concentration 21 ppb. Note that 2015 is the year prior to the invasion of White Lake by zebra mussels. The graph below shows the trend in total phosphorus concentrations over the five-year period.

Total phosphorus concentrations declined significantly from those in 2015 starting in 2016 and again in 2017, likely because of the zebra mussel infestation which went into high-gear in 2016 and continued in 2017. Phosphorus concentrations declined in 2017 by 60% when compared to 2014 and 2015 levels and by 15% when compared to 2016 levels.

In 2018, the trend reversed with higher concentrations for total phosphorus at the beginning of the summer when compared to the two previous years. Concentrations however, are still much lower than for 2015. We believe that the 2018 data was influenced by two separate phenomena: 1) 2018 was an especially hot year with water temperatures about 2 degrees higher than any of the four previous years; 2) for some unknown reason, zebra mussels did not produce a new generation in early summer as was the case for the previous two years. Higher water and hence sediment temperatures could have increased the amount of phosphorus released to the water column (internal loading) from sediments, while at the same time less phosphorus was removed by zebra mussels. These are only speculations, however.



The 2019 data is intermediate between the 2017 and 2016 and 2018 data which again may reflect different conditions in White Lake. For example, spring and early summer air and water temperatures (see temperature section) were lower than in previous years and increased significantly for the remainder of the year. In any case, total phosphorus concentrations remained relatively low as compared to pre-zebra mussel years indicating the zebra mussels are still having a significant effect on lake chemistry and the cycling of phosphorus as discussed in earlier sections of this report.

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-July (currently), 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 this date, 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. As discussed below, the balance of total phosphorus inputs and sinks (losses) is now complicated by the presence and activity of zebra mussels.

Since the explosion of zebra mussel populations in White Lake, one might be tempted to explain the sudden decrease in total phosphorus levels to lower levels (compared to previous years) of phosphorus input into the lake. Unfortunately, there is no evidence to support this assertion. More likely there is a new pathway by which phosphorus is removed from the water column and it is this phenomenon which results in lower overall total phosphorus measurements.

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 phytoplankton 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) and algae alike. The phosphorus transferred to near-shore sediments by zebra mussels eventually becomes available for algae growth and has resulted in an increase in both green and blue-green algal blooms in White Lake. We have already observed blooms of filamentous green algae in most parts of the lake for several years as well as toxic blue-green algal blooms.

The shape of the phosphorus vs day of year curves shown in the graph above can be explained by the effect of sediment or back loading of phosphorus formerly bound in sediments which are released back into the water column.

Although the concentration of phosphorus in lake water is measured in the low tens of parts per billion (ppb), the concentration of phosphorus in the sediments occurs in the parts per million (ppm) range. This means that the concentration of phosphorus in the sediments is literally hundreds of thousands of times greater than that found in the waters above them. White Lake has a low turnover or renewal rate, estimated to less than 0.9 times per year. Thus, phosphorus entering the lake by whatever means is efficiently sequestered by living organisms which in the past died and settle to the bottom of the lake. Lake sediments become the phosphorus reservoir for White Lake, with those sediments holding the accumulation of most of the phosphorus entering the lake over many centuries, or even thousands of years.

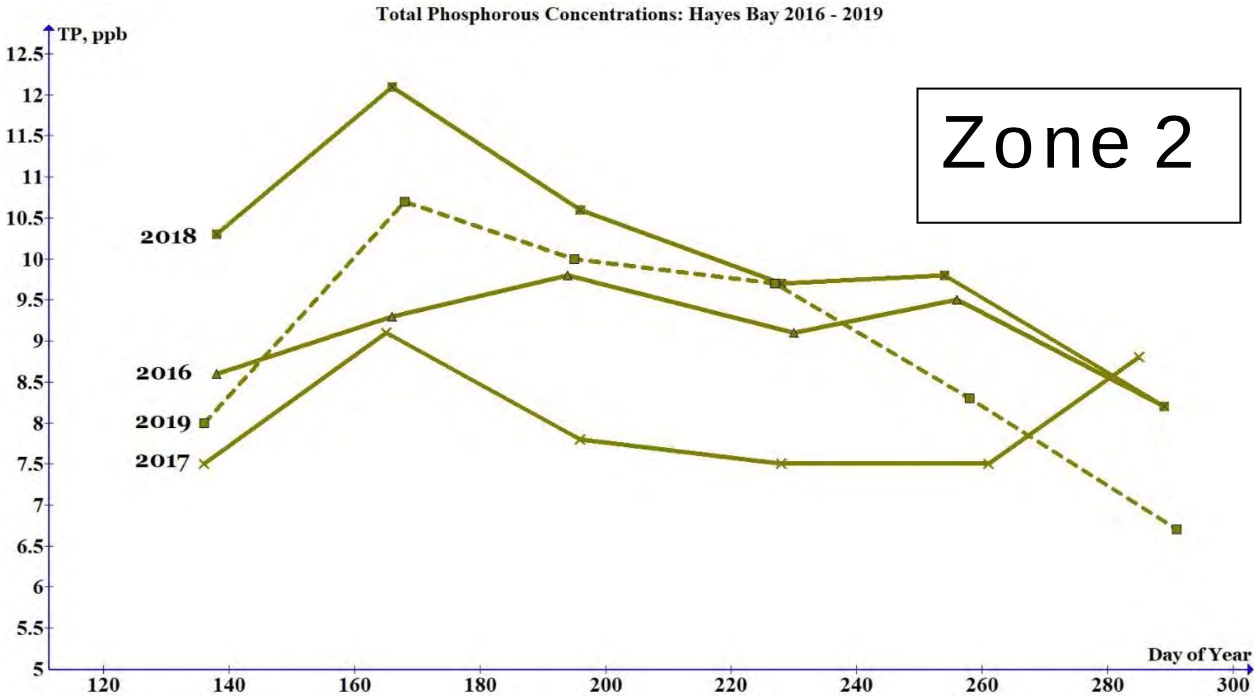
Oxygen levels in water and sediment contribute greatly to the availability of phosphorus for phytoplankton and algal growth. Phosphorus bound in sediments, organic sediment particles or chemically bonded to inorganic species such as iron oxide only remain chemically bound if there is sufficient dissolved oxygen present. When oxygen becomes depleted due to consumption by rotting vegetation, for example, a change in redox (reduction/oxidation) potential in the sediment takes place which creates chemical conditions favouring the release of phosphorus (chemically reducing conditions) back into the lake water above. When this happens, however, not all of the phosphorus is available for mixing with the water column above. Some of the phosphorus is tightly bound and remains that way. However, a small portion of the phosphorus can become mobile. For White Lake, sediments will hold their phosphorus unless there is a mechanism in place by which it can be released. The scientific literature suggests that phosphorus in about the first 18 to 20 centimetres of sediment is available for reintroduction into the water column under the right conditions.

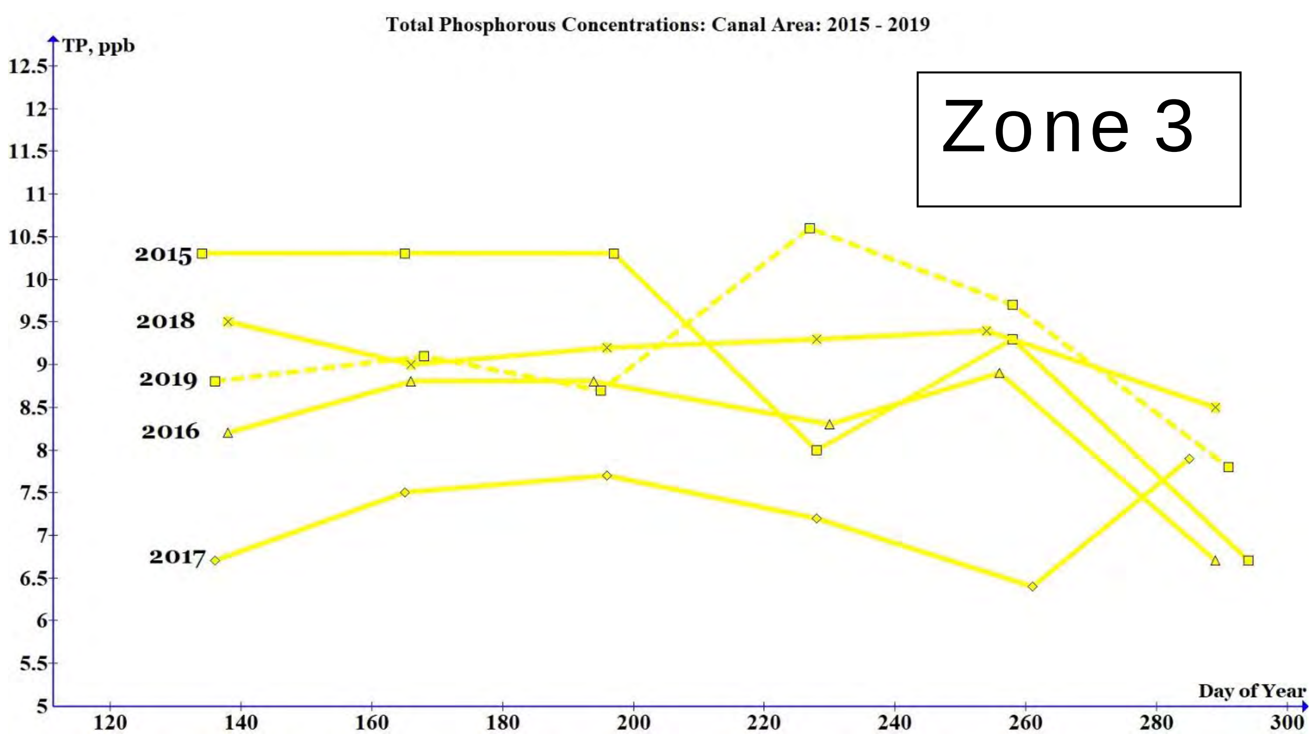
The interface between the bottom water of White Lake and the sediment is not as distinct or as sharp as one would imagine for a sandy-bottomed lake. White Lake has a muddy bottom. Organic matter settling out of the water column is generally in a very fine particulate form. When these particulates reach the bottom of the lake, they form an unconsolidated layer of what could be described as dense 'smoke' increasing in density as further down in the sediment column. Over time, and with the arrival of more material settling out of the water column, these sediments become more compacted and increase in density.

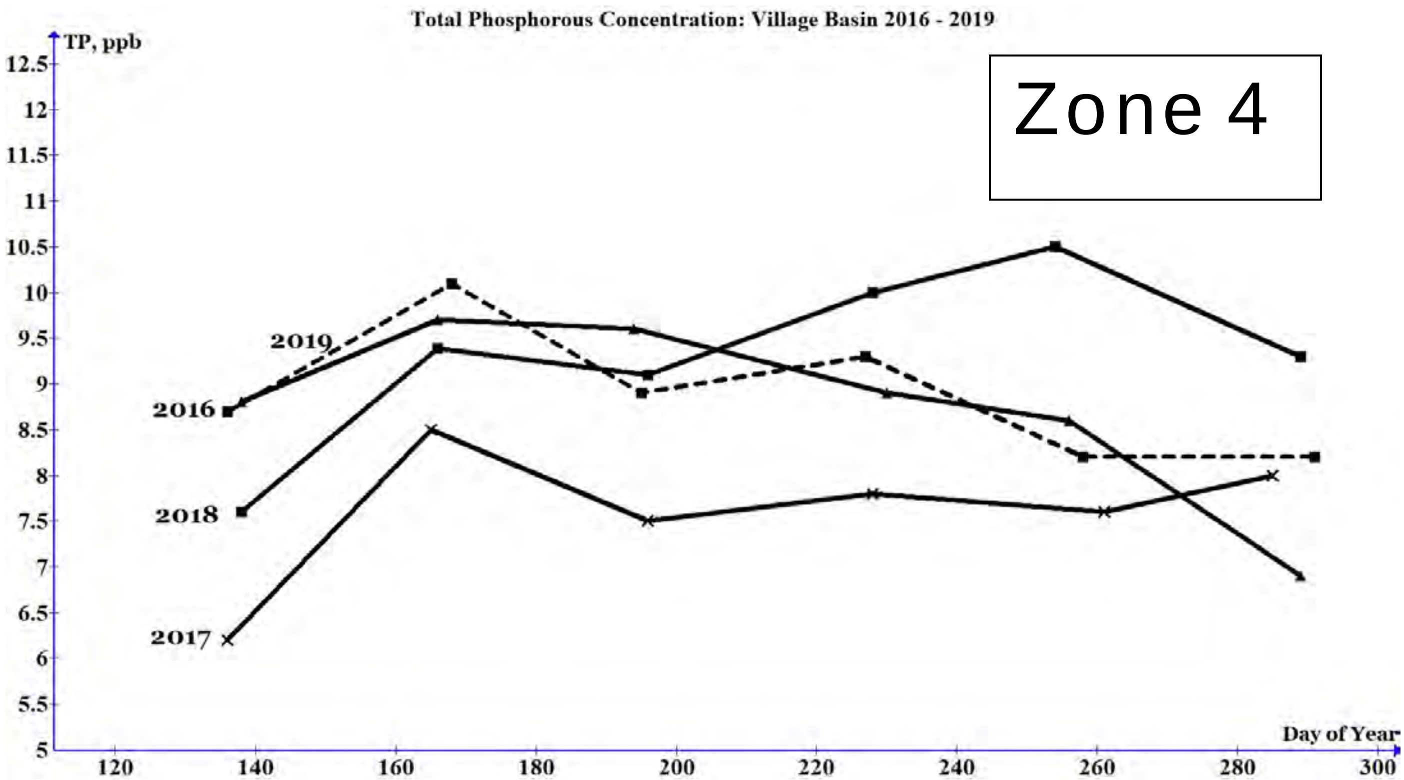
Anoxic (no dissolved oxygen) conditions were detected at several locations in White Lake waters during measurements taken during the ice-free months of 2017. However, during these measurements, if the oxygen measuring probe was lowered into the initial layers of sediment, the oxygen content did drop considerably, especially in Three Mile Bay. This observation may mean that in the unconsolidated layer of sediments, phosphorus could exist in a weakly bound or even free state. Movement of any free phosphorus out of this layer and into the water column could occur by such processes as diffusion within the sediment layers. Displacement of this phosphorus into the water column could also occur as a result of wind and waves and the disturbance of bottom water/sediment by the underwater wake created by boat motors especially in shallow areas. Another mechanism for back loading involves the role of micro-algae living in sediments creating anoxic conditions during the night resulting in the release of phosphorus into the water column.

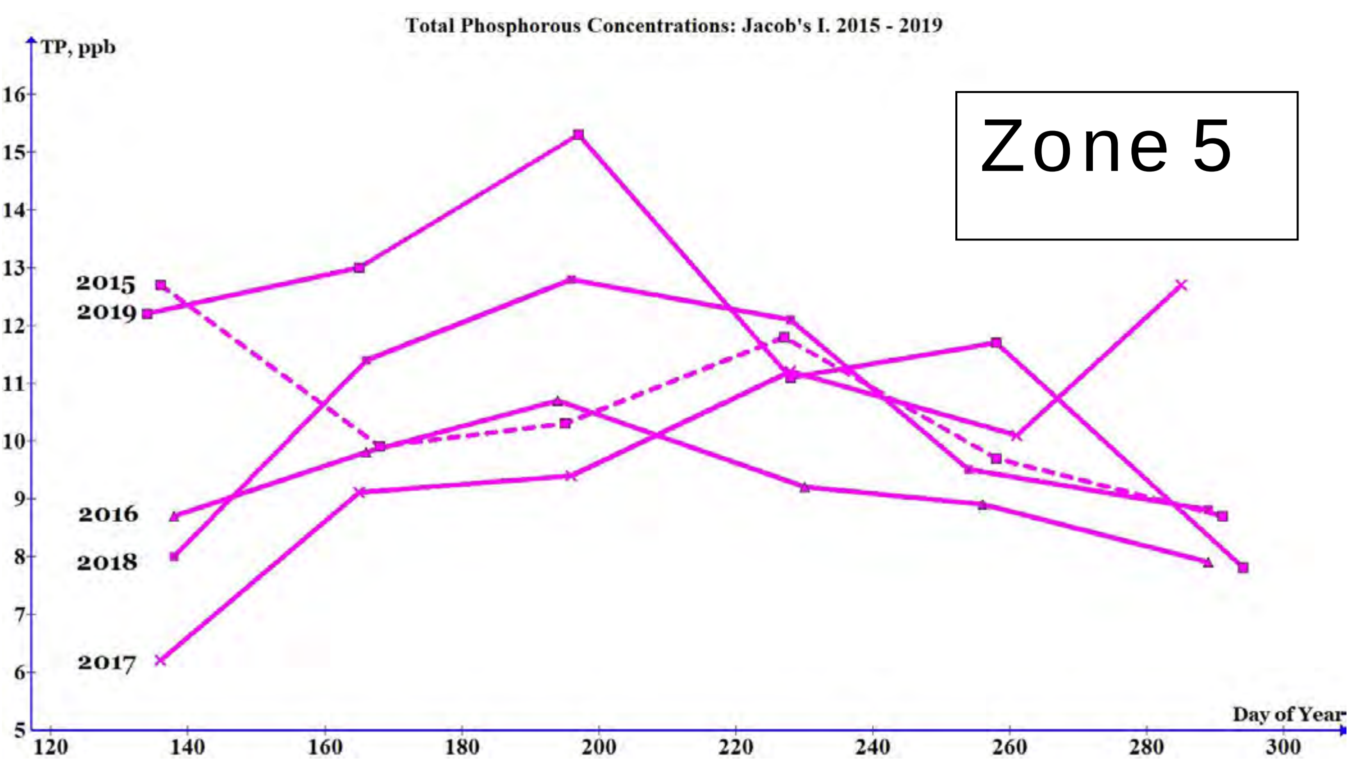
The release of phosphorus from sediments is also accelerated by an increase in water temperature over the summer season. During that time, bottom waters increase in temperature by about twenty degrees. The rate of chemical reactions (such as those releasing phosphorus from sediments) roughly doubles for each 10-degree rise in ambient temperature. So, we can expect that over the course of the summer, the rate of phosphorus released to the water column will also rise significantly further increasing the total amount of free phosphorus available to lake waters. The effects of diffusion, phytoplankton, and microbial action in sediments will increase accordingly with increases in temperature.

If we consider the graph above to illustrate trends in total phosphorus for Three Mile Bay as representative of all Zone 1 sites (and it is), it may be instructive at this point to consider trends in total phosphorus concentrations at other lake zones. Note that Zone 1 includes three sampling sites: Three Mile Bay, N. Hardwood I., and Middle Narrows.






Total Phosphorous Concentration: Village Basin 2016 - 2019
TP, ppb
Zone 4
2019
2016
2018
2017
Day of Year


Total Phosphorous Concentrations: Jacob's I. 2015 - 2019
TP, ppb
Zone 5
2015
2019
2016
2018
2017
Day of Year

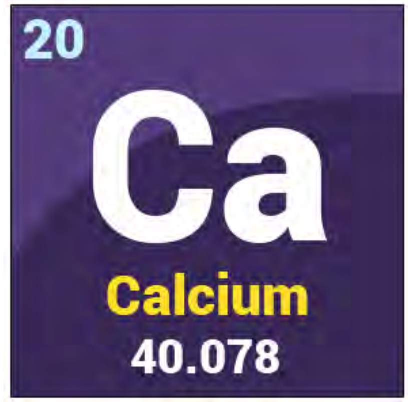
All five zone maps show the same trend with 2019 total phosphorus values intermediate between those obtained between 2015 and 2018. These data show that the influence of zebra mussels is continuing to effect total phosphorus concentrations in White Lake.

The data for The Canal sampling site (Zone 3) shows consistently lower total phosphorus values than for all other lake zones. This is due to the effect of marl in removing some phosphorus from waters entering this site via springs in the lake floor. This is a well-known and documented side-effect of active marl beds in lakes. Note that there are no 2015 total phosphorus data for zones 2 and 4 because these sites were added in 2016 (at our request by the Lake Partner Program) at a later date than the original five sites sampled starting in 2015.

A full discussion of long-term trends in total phosphorus concentrations is provided in other parts of this report.


A Storm is Brewing on White Lake

13.0 Calcium



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

The concentration of calcium varies 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.

The year over year concentration values appear to show a trend towards lower calcium concentrations with the passage of time.

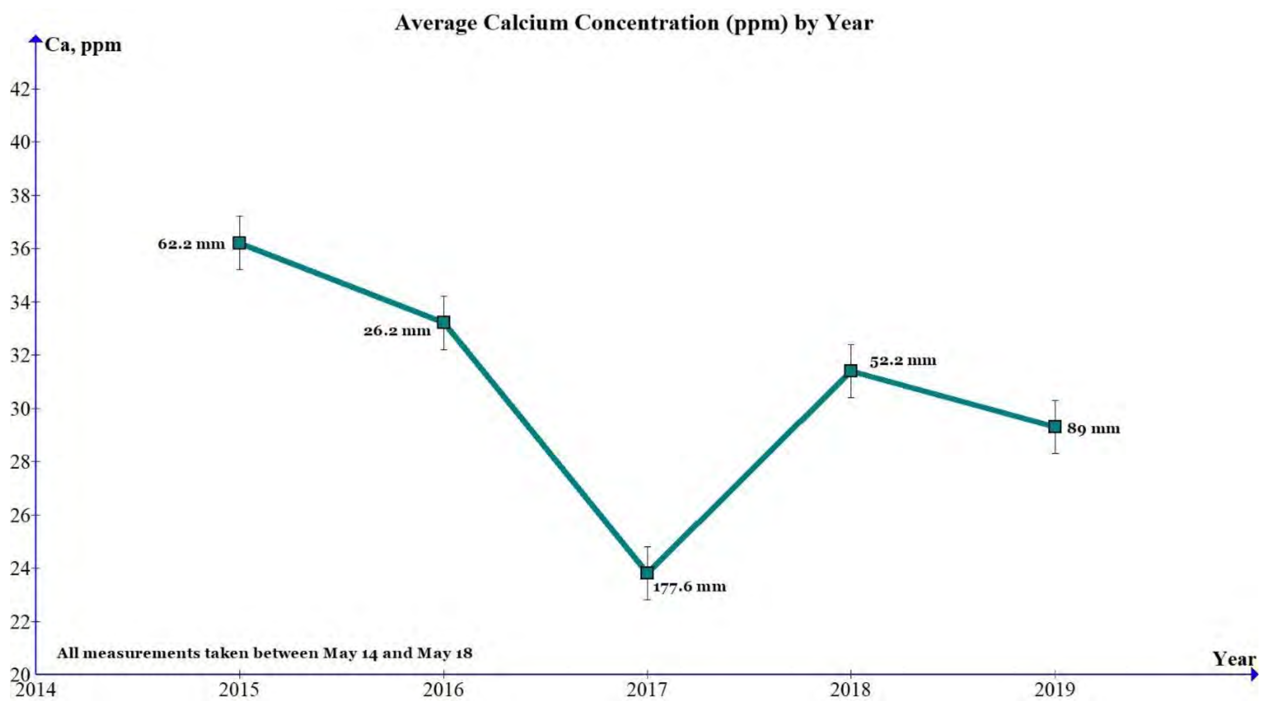
Calcium (ppm) – 2015 to 2019

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

Average Calcium Concentration (ppm) 2015 to 2019

Year	Average ± SD
2019	29.3 ± 1.0
2018	31.4 ± 1.0
2017	28.3 ± .74
2016	33.2 ± 2.5
2015	36.2 ± .7

The table above compiles the average value of calcium concentration in parts-per-million (ppm) for the month of May for years 2015 to 2019. The calculated standard of deviation is approximately 1 ppm for each of the annual average calcium concentration.



The above graph shows these values plotted. 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 with time 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, which contains 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, a correlation coefficient of 0.750 was obtained. The 'zero rainfall' intercept gave a calcium value of 36.4 ppm calcium. This value is (within error) identical to the value obtained in 2017.

These results support the conclusion (see 2017 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.

14.0 Chloride

The table below contains values for chloride concentrations measured in White Lake. All samples were collected between May 14 and May 18 of any given year. Analyses were performed at 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.

Chloride (ppm) – May, 2015 to 2019

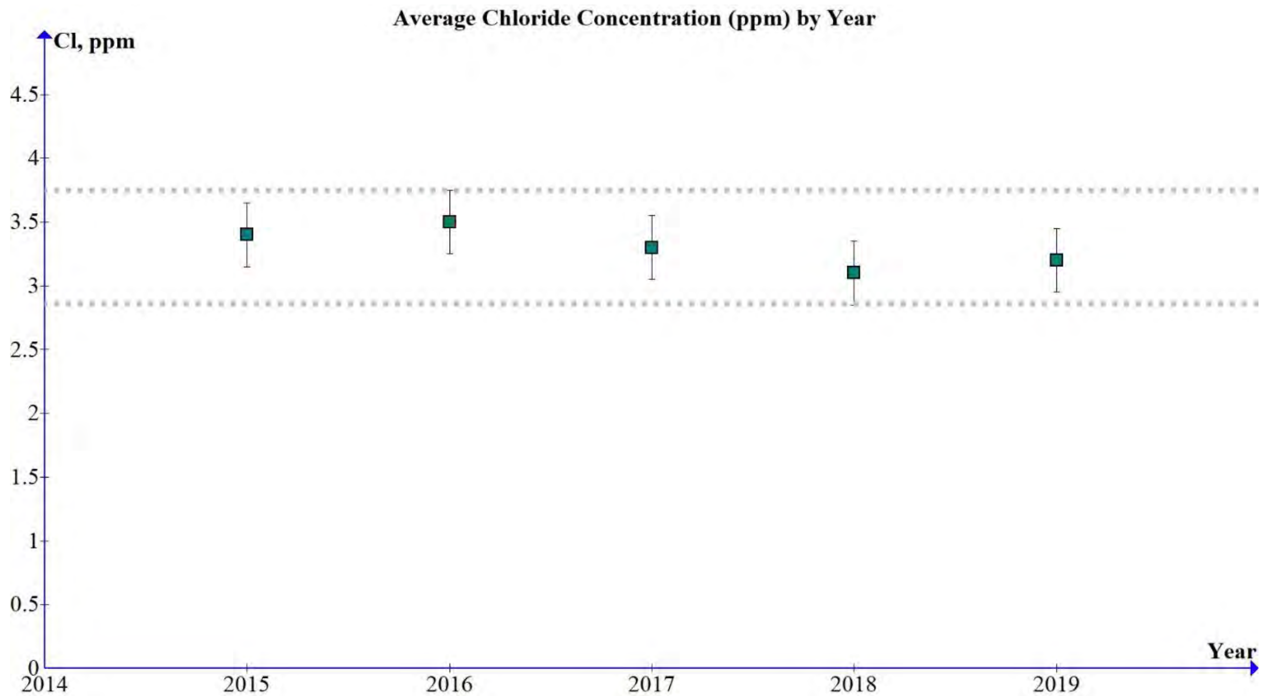
Sampling Site	2019	2018	2017	2016	2015
Three Mile Bay	2.8	2.9	2.8	3.4	3.5
N. Hardwood I.	2.8	2.9	3.1	3.4	3.3
Middle Narrows	3.2	3.5	3.3	3.5	3.5
Jacob's Island	3.6	3.2	3.7	3.7	3.45
The Canal	4.1	4.1	6.2	5.4	3.9
Hayes Bay	7.6	8.3	9.5	10.0	-
Village Basin	3.6	3.6	3.8	3.7	-

Average chloride data for 2015 to 2019 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 2019

Year	Average ± SD
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, it is clear from the error bars on each point that there was no significant change in chloride concentrations between 2015 and 2019.



In the *Conductivity* section of 0ur 2018 report, the Hayes Bay site gave anomalously high conductance values for all three sampling dates which spanned the summer months. This indicates that the high conductance value was due to the presence of higher concentrations of dissolved salts in this sampling site.

The source of the additional chloride is not likely to be from road salt since if this were the case, values for conductance would decline over the course of the summer months. Therefore, chloride is more likely to originate from subterranean brines reaching this part of the lake through the sediment layer. The elevated values for chloride found at The Canal are likely due to the mixing of waters from Hayes Bay with those of The Canal or its own weaker (Cl) source of subterranean brine. This is the only part of the lake where this phenomenon has been observed.

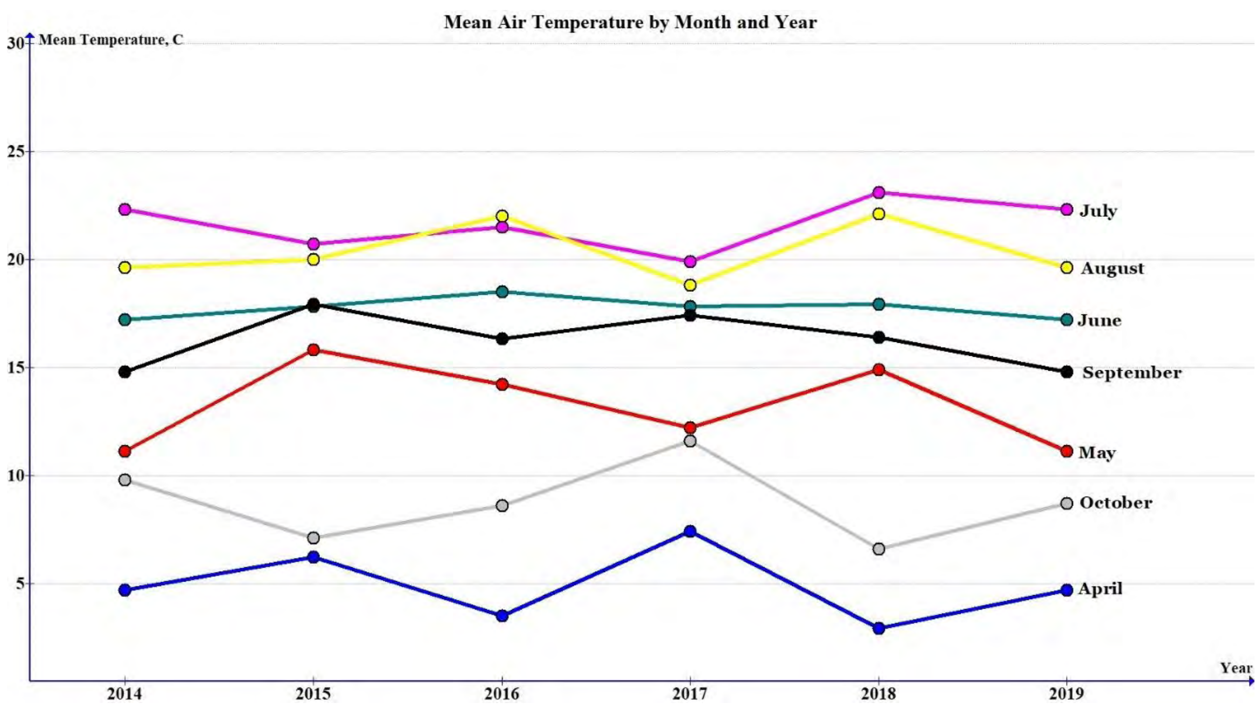
In order to completely account for the much higher conductance values obtained for Hayes and Bane Bays, it would be necessary to have a complete analysis of waters for all of the major cations and anions in solution.

In any case, concentrations for chloride are low, but worth monitoring for future changes which may indicate road salt entering the lake, especially near Hayes Bay.

15.0 Weather Conditions: 2014 – 2019

15.1 Mean Air Temperature by Month and Year: 2014 - 2019

Mean air temperatures for the six years are presented in the figure below. A cursory look at the data shows that for 2018, temperatures were generally lower from May to September then compared to the previous year. Also, temperatures were somewhat higher for April and October, 2019 when making the same comparison. This may affect somewhat lake water and sediment temperatures, which is discussed in the appropriate section of this report.



The table below gives the minimum, maximum and average air temperatures for April to October over the period spanning 2014 to 2019. Also provided are columns containing twice the calculated standard deviation and the percent standard deviation of this data. The data highlighted in yellow in the last column indicates that the months June to September show the smallest relative changes in temperatures (for a given month) year on year. For April, May, and October, there is a much greater deviation in average air temperatures from year to year indicating that the ‘weather’ during these periods was more subject to change from one year to the next. At this level of data precision, there is no observable trend in air temperatures for a given months from year to year. However, this data does show that April, May and October are subject to much greater variations from year to year.

Monthly Mean Air Temperature: 2014 - *2019*

Ottawa Intl. Airport	Minimum Temp., °C	Maximum Temp., °C	Average Temperature,°C	±2x Standard Deviation (95% confidence)	% 2x Std. Deviation
April	2.9	6.2	4.9	1.2	24.9
May	11.1	15.8	13.2	1.5	11.8
June	17.2	18.5	17.7	.34	2.01
July	19.9	23.1	21.6	.95	4.40
August	19.6	22.1	20.4	1.0	4.91
September	14.8	17.9	16.3	.94	5.78
October	6.6	11.6	8.7	1.3	15.24

*average value for Ottawa and Pembroke, ON

15.2 Monthly Meteorological Values: 2014 - 2019

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 2015 to 2019. 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.

A cursory examination of the tables below indicates that, with the exception of 2017, 2019 was an average year for precipitation when compared to values for other years starting in 2015. 2017 was an exceptionally wet year compared to other years. During the six-month period from April to October 2019, White Lake received 630.6 mm of rain and experienced 77 days with precipitation of 1mm or more of rain. During 2018, 552.7 mm of rain fell with 70 days experiencing greater than 1mm of rain. The year 2017 was wet with 990.4 mm of rain and 81 days receiving greater than a mm of rain.

Monthly Meteorological Values – Environment Canada: *2019*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	4.7	-7.8	19.8	126.6	12
May	11.1	1.0	23.9	89.0	14
June	17.2	2.1	30.1	114.4	15
July	22.3	9.2	33.9	52.1	5
August	19.6	9.4	30.4	52.7	8
September	14.8	3.2	28.1	64.4	14
October	8.7	-3.1	20.2	131.4	9
Total				630.6	77

*average value for Ottawa and Pembroke, ON

Monthly Meteorological Values – Environment Canada: *2018*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature.	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	2.9	-11.6	20.7	112.8	14
May	14.9	0.1	29.8	52.2	11
June	17.9	5.9	33.6	70.4	9
July	23.1	9.6	36.0	122.5*	9
August	22.1	13.0	32.8	79.6	7
September	16.4	3.4	32.0	58.8	10
October	6.6	-5.0	27.5	56.4	10
Total				552.7	70

*average value for Ottawa and Pembroke, ON

Monthly Meteorological Values – Environment Canada: *2017*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	7.4	-4.0	26.6	147.8	14
May	12.2	-1.8	30.9	177.6	14
June	17.8	4.8	32.7	130.0	15
July	19.9	9.5	29.5	249.8	13
August	18.8	5.3	30.4	75.6	8
September	17.4	2.2	33.0	50.8	6
October	11.6	-2.6	23.4	158.8	11
Total				990.4	81

Monthly Meteorological Values – Environment Canada: *2016*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	3.5	-11.1	23.1	43.8	5
May	14.2	-1.9	33.2	26.2	5
June	18.5	5.7	23.3	66.2	5
July	21.5	10.7	34.0	57.2	6
August	22.0	9.8	34.6	91.6	5
September	16.3	2.6	29.8	38.8	7
October	8.6	-4.2	24.5	107	11
Total				430.8	44

Monthly Meteorological Values – Environment Canada: *2015*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	6.2	-7.4	23.7	64.2	10
May	15.8	-2.8	30.7	62.2	9
June	17.8	3.5	27.8	108.0	12
July	20.9	8.4	34.3	40.8	5
August	20.0	8.9	31.5	100.0	10
September	17.9	3.3	32.1	69.4	6
October	7.1	-8.0	23.4	73.6	9
Total				518.2	61

Monthly Meteorological Values – Environment Canada: *2014*

Ottawa International Airport	Mean Temperature, °C	Lowest Monthly Minimum Temperature	Highest Monthly Maximum Temperature	Total Precipitation, mm	Number of Days with Precipitation of 1mm or More
April	4.7	-7.8	19.8	126.6	12
May	11.1	1.0	23.0	89.0	14
June	17.2	2.1	30.1	111.4	15
July	22.3	9.2	33.9	52.1	4
August	19.6	9.4	30.4	52.7	8
September	14.8	3.2	28.1	64.4	14
October	9.8	-2.5	26.0	65.0	14
Total				561.2	81

The actual weather on and just before lake water sampling dates are 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. 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.

15.3 Sampling Dates: Weather Conditions 2019

Date	Day of Year	Weather Conditions
May 16	136	Light rain on precious three days. High water levels on lake. Partly cloudy, but fairly bright. Air temperature: 10C.
May 31	151	Minor quantity of rain during past week; none over three days previous to sampling. Water levels remain high. Moderate pollen storm; no wind, sunny day with no clouds. Air temperature 12 to 15C.
June 17	168	No rain 24 hours previous to sampling; 26 mm of rain fell on four days previous to that; of that 15 mm two days previous to sampling. Clear and sunny with no wind. Air temperature: 20C.
June 27	178	High winds (40 km/hr. day before sampling, no rain during previous four days. Full sun day with no wind. Full sun day with no wind. Air temperature ranged from 15 to 20C.
July 14	195	Over cast skies; Air temperature 19 to 22C; Very windy previous day; 18 mm rain evening before sampling and 11 mm two days prior to that. Wind from 0 to 5 km/hr.
August 1	213	Air temperature from 20-24C; Full sun, no wind; 23 mm rain 2 days prior to sampling, otherwise, ten days of hot (>30C) dry weather.
August 15	227	Air temperature: 21-23C; Full sun day with no wind. No rain for previous 5 days. From Aug 5 to 9, 5.6 cm of rain fell.
September 1	244	Mostly clear day with some clouds. Air temperature 13C. 11 mm of rain fell three days prior to sampling. Wind less than 5 km/hr. Copious quantities of weeds observed along shorelines.
September 15	258	Air temperature 14C, Sunny day with winds less than 5 km/hr. Higher winds previous three days ~15 km/hr.
September 30	273	Air temperature 10C, Sunny day with winds ranging from 5 to 10 km/hr. No rain 4 days prior to sampling. 14 mm rain on September 26.
October 18	291	Air temperature 7-8C., 32 mm rain 2 days prior to sampling. Somewhat overcast, but bright enough to get good secchi depths.

16.0 Water Levels – White Lake Dam

Water Flow During Spring Freshet - April 24, 2019

White Lake Dam is managed by the Ministry of Natural Resources and Forestry, Kemtpville 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.

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

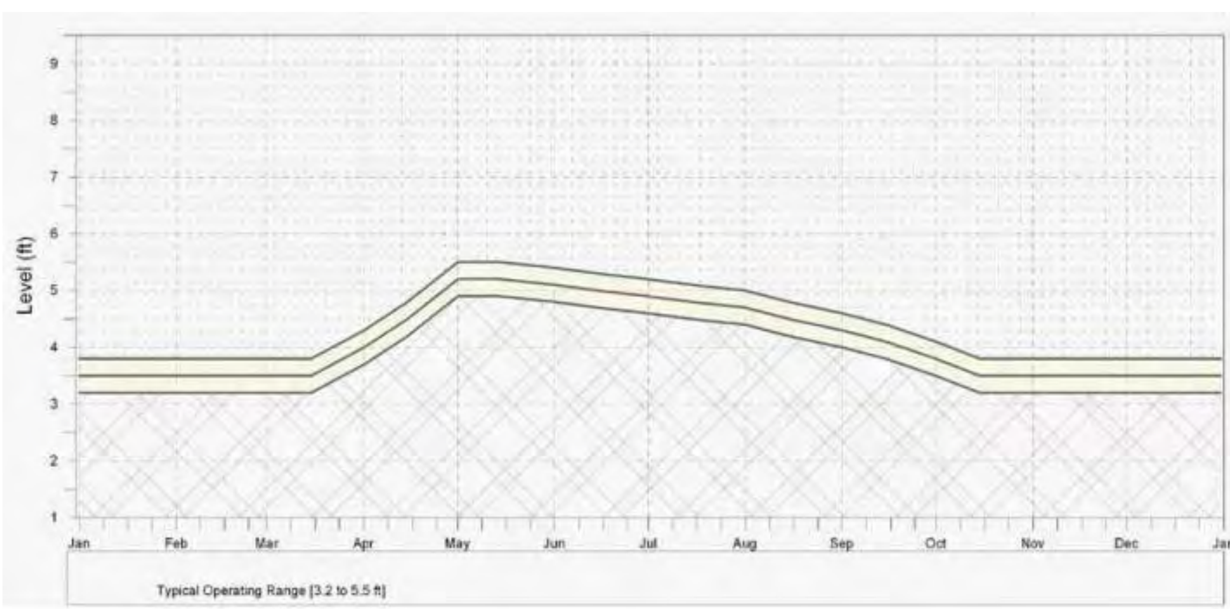
The annual variation of the operating band is given below. Water levels will decrease gradually from the spring flood peak in April to a constant level through the first half of May. In the middle of May, the summer drawdown will commence, which will bring the lake down to the winter holding level.

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

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

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

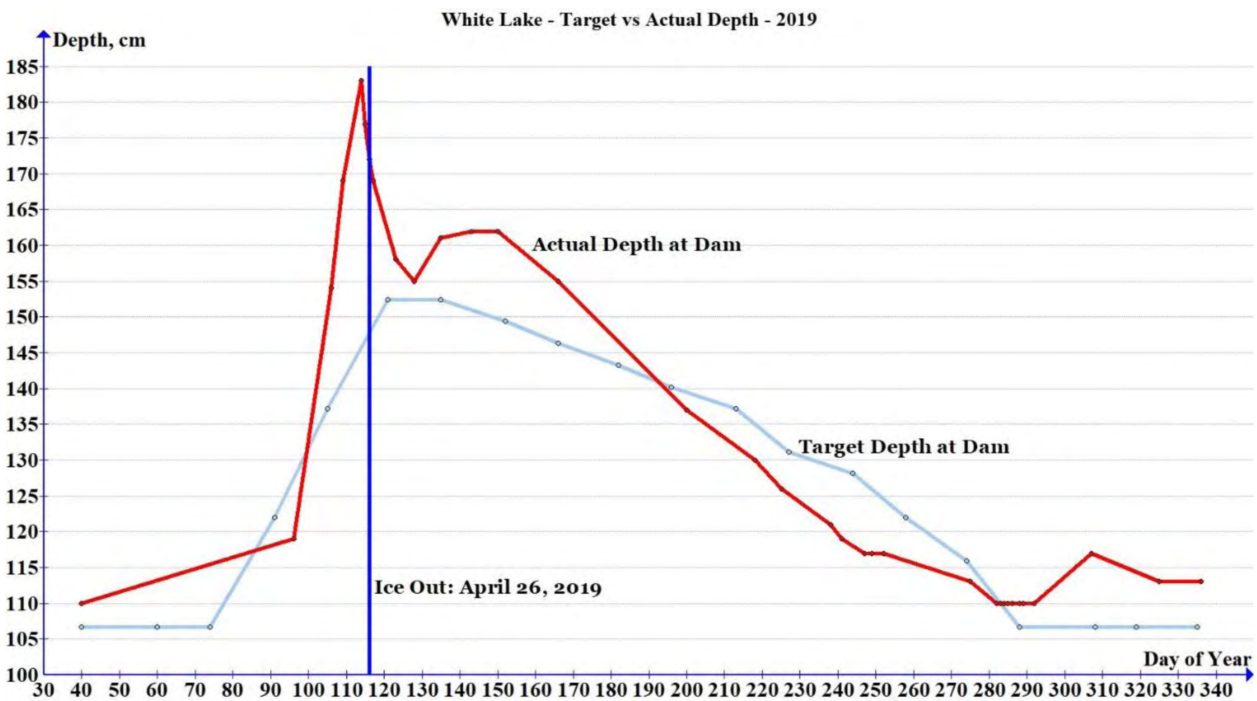
Fall & Winter: The fall/winter holding level is 3.5 feet which should be reached by October 15. If this level is not achieved by November 1, then that recorded level on this date will be considered the fall/winter holding level. Levels throughout the Fall and Winter should be maintained within ± 0.3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



During dry years, such as 2016, the challenge is to balance 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 we 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 calculated (red line) plotted with the target water levels for the same time scale (light blue line). The vertical dark blue line indicates the ice-out date for White Lake as published by the White Lake Property Owners association on their website.



When comparing the line showing actual depth readings with that for target levels, it is evident that lake levels were high during the spring and early summer months and only returned to normalcy by mid-July. Beyond this point, water levels were somewhat lower than target values and remained as such until mid-October. At its highest level, the lake was briefly 38 cm deeper than its target depth. This maximum value is clearly associated with the ice out date during which time water was entering the lake from all sources including melting ice, streams, surface runoff, and underground sources including springs. The greatest difference in actual vs planned water depth during the ice-free season was 14 cm.

This year (2019), we experienced heavy rains in July which accounts for the 'bulge' in water depth centered around Day 160 in the graph above. Changes made to water flows at the White Lake dam is counterbalanced by rainfall events and explains any differences we see in the graph above.

PART III

Research Activities

17.0 Zebra Mussel Observations - 2019

David Overholt

The first generation of zebra mussels representing the initial successful invaders of White Lake have reached the end of their life cycle. The shell size of the survivors of this initial population should approach the maximum size for zebra mussels. This is estimated to be shell lengths approaching 40mm. The shoals of Hardwood Island have some of the largest examples in this age-size class seen to date with shell lengths that exceed 37mm. (Fig. 1)

Figure 1. First generation zebra mussels - Hardwood Island shoals

17.1 Zebra mussel abundance - 2019

Figure 2. Ladder step #4 before zebra mussel recovery

This is the fourth consecutive season for sampling zebra mussels from the surface of a wooden boarding ladder. The ladder is attached to a floating wharf that is permanently anchored at the same fixed location throughout the summer season. The steps are located at the same depths below the surface of the lake. Sampling occurs at the end of each season when the ladder is removed from the water. This has provided a four-year data record for the number and size frequency of annual zebra mussel settlement. This allows us to look for multi-year trends in the zebra mussel population.

Samples were measured with a digital caliper or by optical measurement when shells fell below 5mm in length. Figure 3 shows one of the 10 specimen sets prepared and used to measure ladder step #4 sample. These shells were measured at 7x magnification using an optical measurement tool package from a digital software package.

Figure 3. plate set up for measuring small juveniles

The frequency distribution in Figure 4 shows that zebra mussel shell lengths in 2019 (yellow) were similar to the size range for all size classes in 2018 (blue). However, the frequency of occurrence for each size range was markedly reduced when compared to samples from 2018. This represents a shift to smaller size classes that continues a trend observed from 2016 to 2019 (Figure 5). This size dissimilarity from 2016 to 2019 must reflect changing conditions which are influencing the zebra mussel life cycle, such as the timing and occurrence of oogenesis (egg formation).

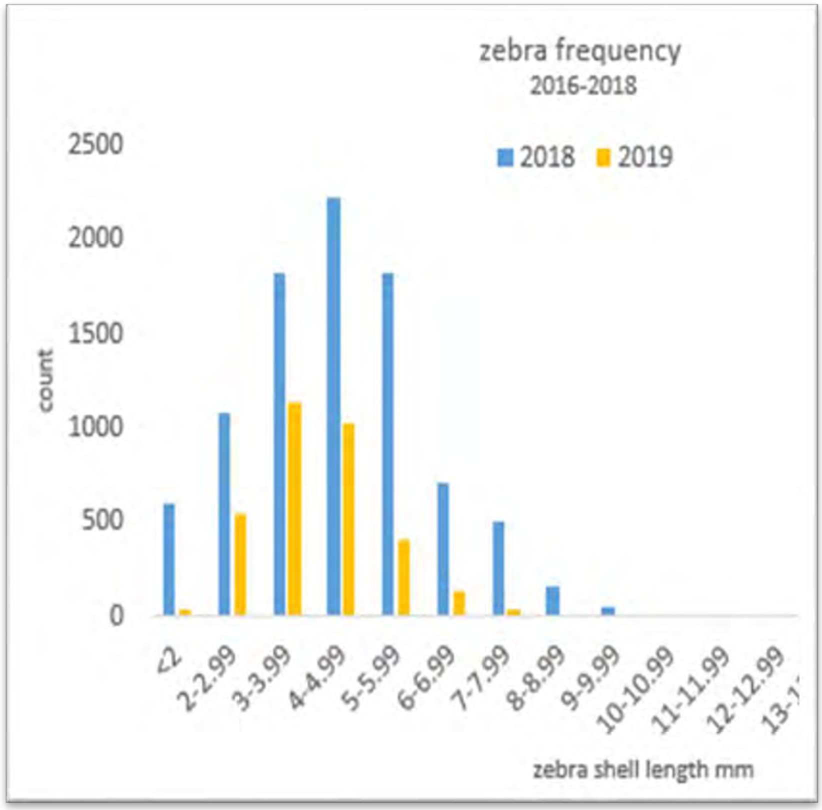


Figure 4. Size frequency comparison - 2019 to 2018

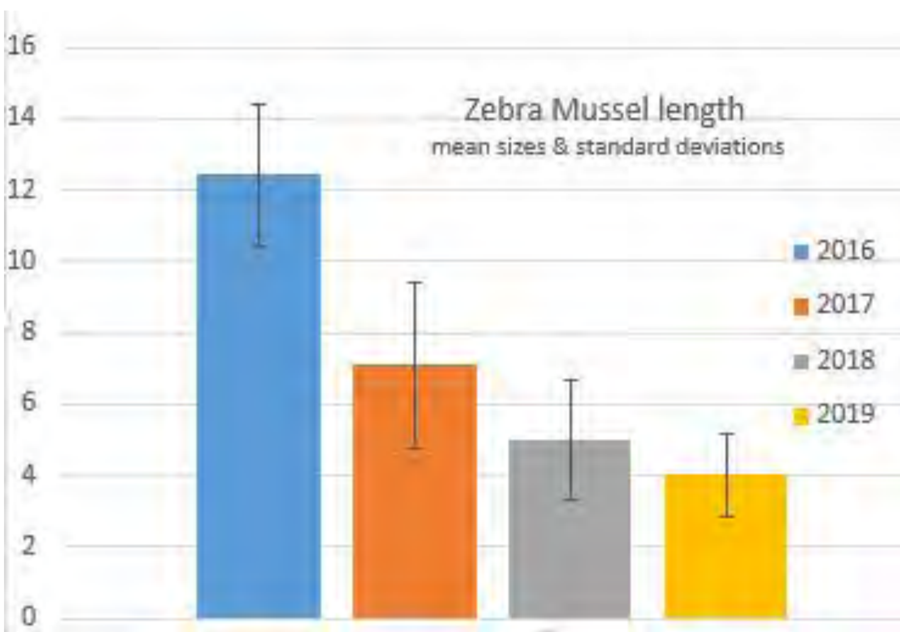


Figure 5. Mean and standard deviation of size classes

Many factors can affect zebra mussel demographics. The sheer abundance of zebra mussels itself will place inevitable limits on numbers and growth. However, there are other factors as well. Zebra mussels produce dense mats over hard substrates. This provides new habitat for benthic organisms. Mats of periphyton form a community of benthic algae composed of filamentous blue-green and green algae as well as diatoms. Such mats thrive on the hard structure and organic wastes produced by zebra mussels. This must restrict to some degree the capability of zebra mussels to disperse their progeny.

Figure 6

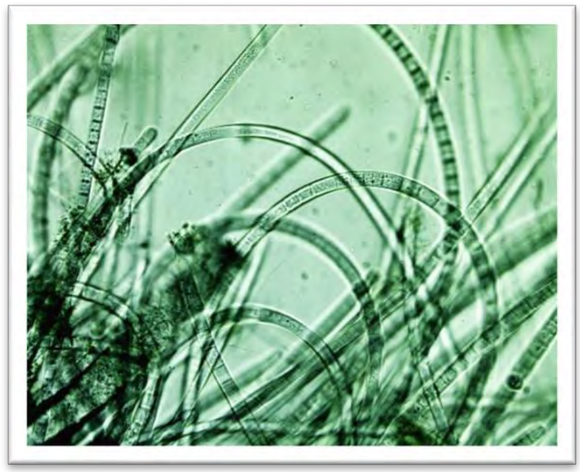


Figure 7

Figure 6. Upper left: periphyton mats covering zebra mussel beds. Hardwood Island 2019

Figure 7. Upper right: periphyton green and blue green algae, 400x

Figure 8. Lower left: egg masses on top of periphyton mats that cap the zebra mussel beds. White Lake 2019

Figure 8

17.2 Impact on Native Unionids (lake clams)

It is reported in the literature that zebra mussels cause great stress on the survivability of our native clams (unionids). A unique reproductive strategy used by virtually all North American unionids is to produce larvae (glochidia) that are dependent upon a host for their effective dispersal. Glochididae attach to the gills of fish which venture near enough that a unionid is able to expel its larvae into the gill chamber. These larvae live parasitically on the blood supply of the host fish during their short time of development. This strategy enables unionids to have a wide dispersal range with relatively few young. This evolved strategy reduces demands on their reproductive resources.

All unionids become easy targets for settlement by zebra mussels. Figures 9 &10 show a large unionid (86.9 grams) that is covered by an equivalent weight in zebra mussels (81.7 grams). Such colonies (druse) restrict the clam's ability to feed and to move. it must also interfere with its ability to reproduce.

Figure 9

Figure 10

17.3 Impacts on Insects

This year it was noticed that the larval stages (instars) of the dragonfly could also be affected by zebra mussel attachment. Several exoskeletons (exuviae) collected from this year's dragonfly emergence had zebra mussels attached to them. Dragonfly live as larvae for several years in the lake. They must molt many times in the course of their development. It is possible that numbers of zebra mussels settling on their exoskeletons could impede a successful emergence.

Fig. 11: exuvia with zebra mussel attached

17.4 Reproduction

Adult zebra mussels become reproductive in their second year following their settlement. Zebra mussels depend on synchronous events for successful reproduction. Egg (oocyst) and sperm development proceed throughout the winter months. Egg development is arrested at a late development stage enabling the majority of oocytes to attain the same stage. By early spring the zebra female gonad is filled with a dominant cohort of eggs at the same arrested development. This arrested stage may last as long as a month. A triggering event causes the release of this first large batch of unfertilized oocytes into the water column. It is thought that the neurochemical serotonin plays a role in triggering this phenomenon. Serotonin stimulates similar responses from nearby zebra mussels resulting in a cascading event. Such an event was photographed by chance at the shoals of Curly's Island on August 5th 2019 (Figure 12). Equal numbers of nearby male and female zebra mussel increases the chance that egg fertilization will occur before dilution effects take place.

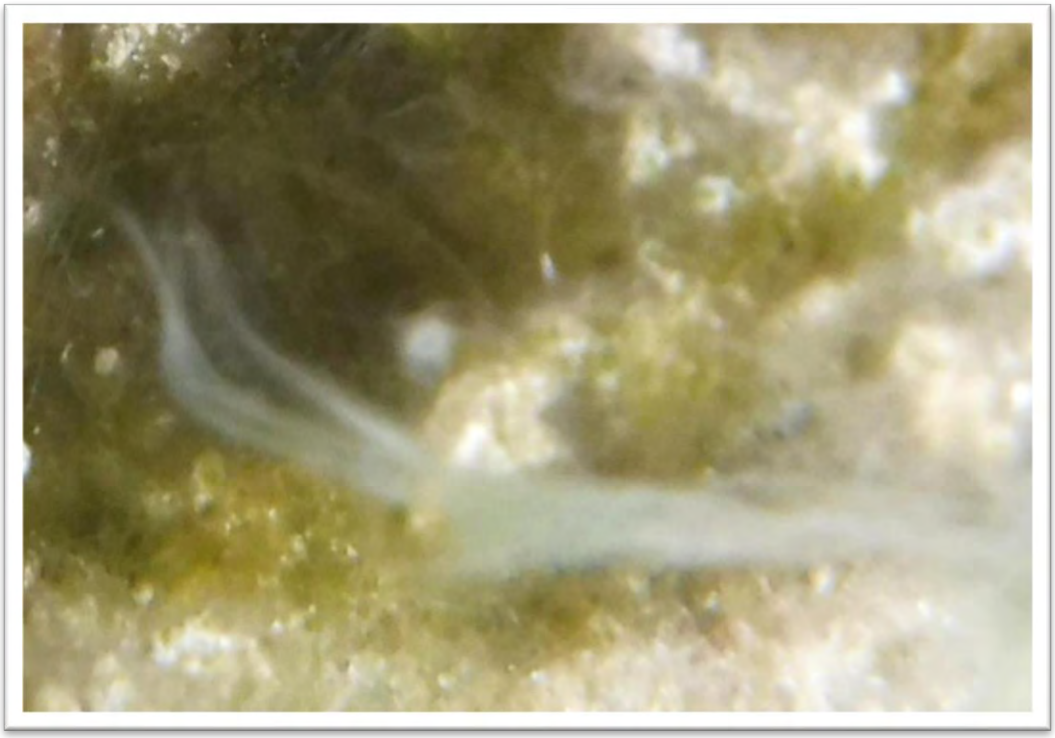


Figure 12. Spawning of the zebra mussel

17.5 Veliger occurrence in White Lake

Free swimming larval zebra mussels (veligers) form a large but time limited component of the pelagic plankton community in White Lake. Free swimming veligers will last from days to weeks within the water column.

A survey was conducted during the summer of 2019 to study the presence of zebra mussel veligers in White Lake. A total of 52 plankton net samples were taken on 24 separate occasions between June 8 and October 19. These dates span the same time period during which the wharf step latter was immersed in the lake, as discussed above. Each net sample represented plankton swept up by a vertical trawl of the water column. The volume swept varied by depth to avoid sediment contamination. An estimate of veligers present in the swept volume at each location was calculated and the results expressed as veligers/litre. Table 1 shows the occurrence of veligers over the course of these 130 days. These data show that the highest counts of veligers occurred from mid-June to mid-July (days 168 to 195). It is most likely that veliger production was well advanced by the start of the sampling schedule. Subsequent counts dropped off to zero by August 1st (day 213). This was followed by a second smaller occurrence of veligers around mid-August (day 227). Apart for one sample taken at Hardwood Island, veligers were not detected in White Lake waters after August 15. This pattern is not unique to White Lake. Lakes in northern temperate regions have cooler waters. Unlike examples from Europe, Russia or the American Mid-West, the beginnings of settlement start later in the Great Lakes region and thus the opportunity for growth is limited to fewer number of days. Both Mackie[14] and Martel[15] have observed zebra mussel maturation for shell lengths approaching 7mm. This suggests that maturation has not occurred in our 2019 step samples.

Table 1. Estimated veligers/litre for 6 sites on White Lake

DATE mm-dd	DAY	Three MB #1553	Three MB SITE 1	North Hrdwd Is.	Deepest Pickerel	Middle Narrows	Stanley Island
06-17	168	0	32	66	25	0	32
06-27	178	6	0	10	20	81	13
07-14	195	6	20	15	20	87	19
07-27	207	2	0	0	11	-	-
08-01	213	0	0	0	0	-	-
08-15	227	0	6	6	18	0	-
09-01	244	0	0	6	0	0	-
09-15	258	0	0	0	0	-	-
09-30	273	0	0	0	0	-	-
10-12	285	0	0	0	0	-	-

Table 1 suggests that the 2019 step samples are likely composed of two cohorts that settled during separate episodes of veliger production during the year. We can speculate on the growth rate of zebra mussels in their juvenile stage.

The mean size for the 2019 sample (4mm) suggests growth rates could range from .03 to .06 mm/day depending on which cohort the 4mm size class represents. The maximum size in the 2019 sample (8.9mm) suggests a daily average growth rates of .067 to 1.41 mm/day. Both sets of figures are lower than the daily growth ranges reported in a study of the zebra populations in the Rideau River (Martel 1995). It is likely the Rideau system is nutrient rich and has a constant current that promotes a more rapid growth when compared to the conditions found in White Lake.

17.6 Survivorship of Zebra Mussels in Weed Beds

Hard substrates are the primary locations accommodating zebra mussel beds, but it must be understood that large areas of White Lake are comprised of soft sediment covered with

[14] Renata Claudi, Gerald L Mackie 1993: Practical Manual for Zebra Mussel Monitoring and Control Lewis Publishers

[15] Andre Martel 1995: Demography and growth of the exotic Zebra Mussel (Dreissena polymorpha) in the Rideau River (Ontario) Can. J. Zool. 73:2244-2250 (1995)

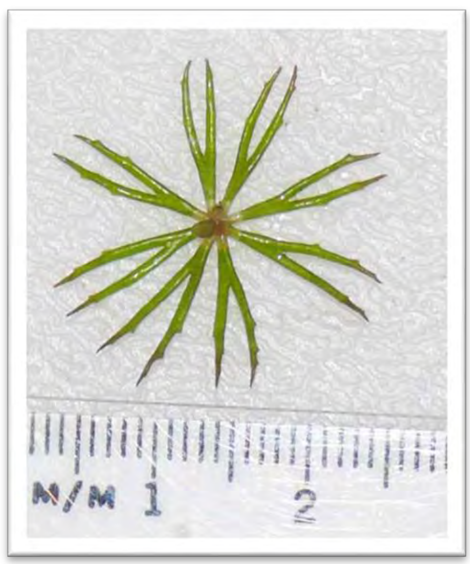
aquatic weed. Weeds provide important surfaces for veligers to settle upon. Weed density, plant size and duration of plant growth offer opportunities for settlement in areas that are otherwise denied to veligers.

Weed samples were taken from a transect in Three Mile Bay from depths exceeding five meters (no weeds present) to depths of less than two meters. Weeds were sampled by selecting individual whole plants from each recovered weed mass. Any roots present were removed and all zebra mussels were harvested from each intact plant until the weight of weed was obtained. The weed and zebra samples were weighed on a gram scale (accuracy to 0.1 g). In order to capture the complete growing period, these transect samples were collected late in the growing season, on October 5th and on October 29th. During this period water temperatures decreased from 14◦C to 10◦C.

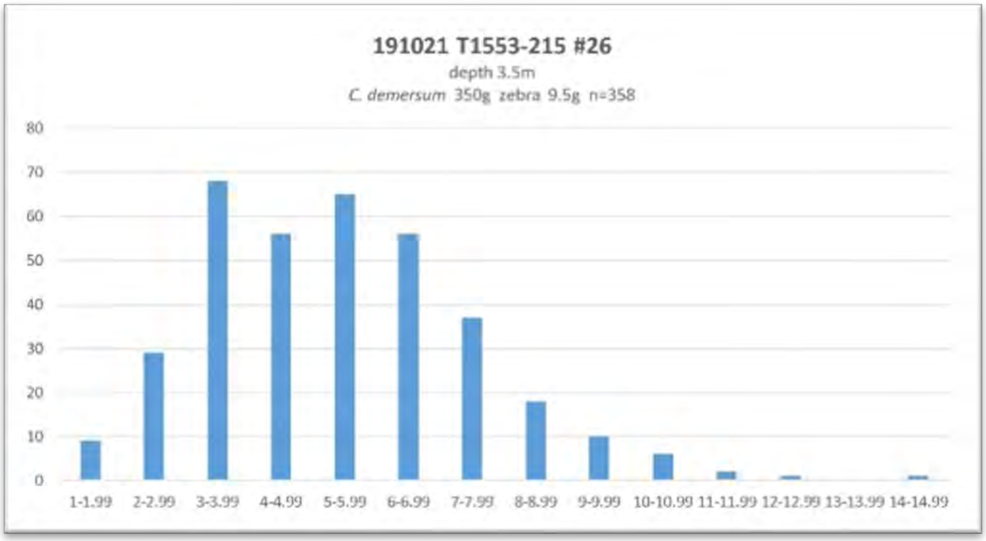
Three weed types were recovered at the transect. Each of these offered an opportunity for zebra mussel survivorship. Survivorship was considered to be the percentage of multi-year adults that occur within a sample. Maturation was considered to be shell lengths greater than 6.99 mm. Mussels with shell lengths of 9mm or greater were considered to be mature multiyear survivors.

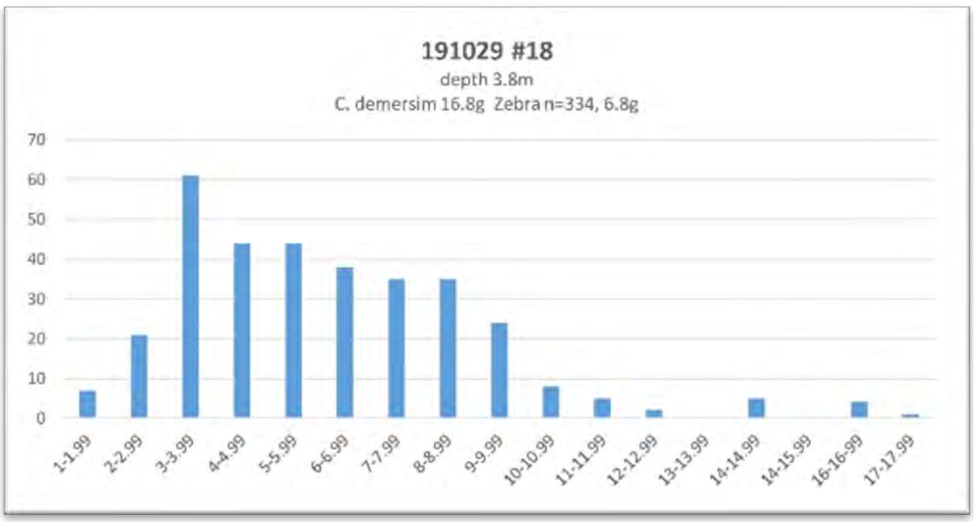
The three weed types recovered were *Ceratophyllum demersum* (coontail), *Najas flexilis* (slender Water Nymph), and *Potomogeton richardsonii* (Richardson's Pond weed).

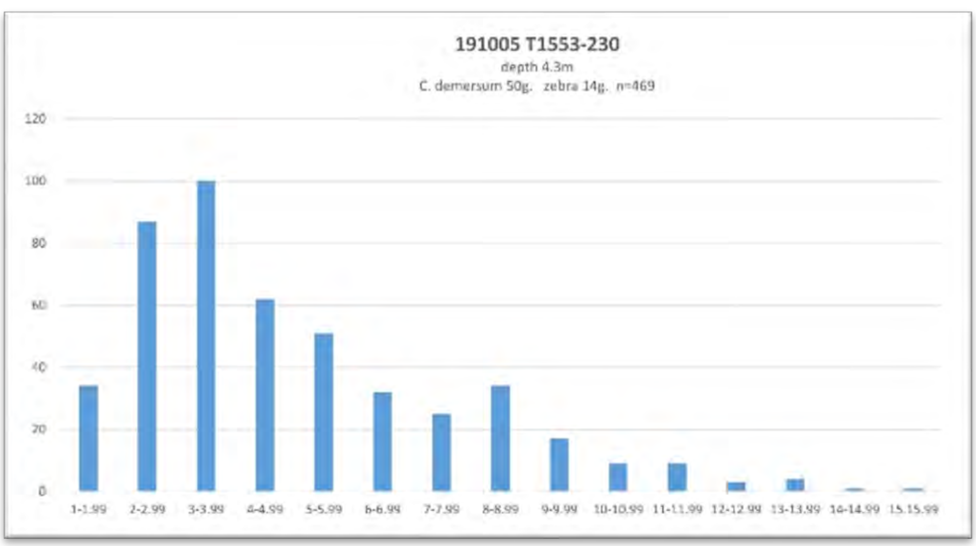
1. Ceratophyllum demersum: Three Mile Bay, October 5 and 21



Note that for all of the bar graphs below, the x-axis represents shell lengths in mm and the y-axis represents shell counts


191021 T1553-215 #26
depth 3.5m
C. demersum 350g zebra 9.5g n=358
80
70
60
50
40
30
20
10
0
1-1.99
2-2.99
3-3.99
4-4.99
5-5.99
6-6.99
7-7.99
8-8.99
9-9.99
10-10.99
11-11.99
12-12.99
13-13.99
14-14.99


191029 #18
depth 3.8m
C. demersim 16.8g Zebra n=334, 6.8g
70
60
50
40
30
20
10
0
1-1.99
2-2.99
3-3.99
4-4.99
5-5.99
6-6.99
7-7.99
8-8.99
9-9.99
10-10.99
11-11.99
12-12.99
13-13.99
14-14.99
14-15.99
16-16.99
17-17.99


191005 T1553-230
depth 4.3m
C. demersum 50g. zebra 14g. n=469
120
100
80
60
40
20
0
1-1.99
2-2.99
3-3.99
4-4.99
5-5.99
6-6.99
7-7.99
8-8.99
9-9.99
10-10.99
11-11.99
12-12.99
13-13.99
14-14.99
15.15.99

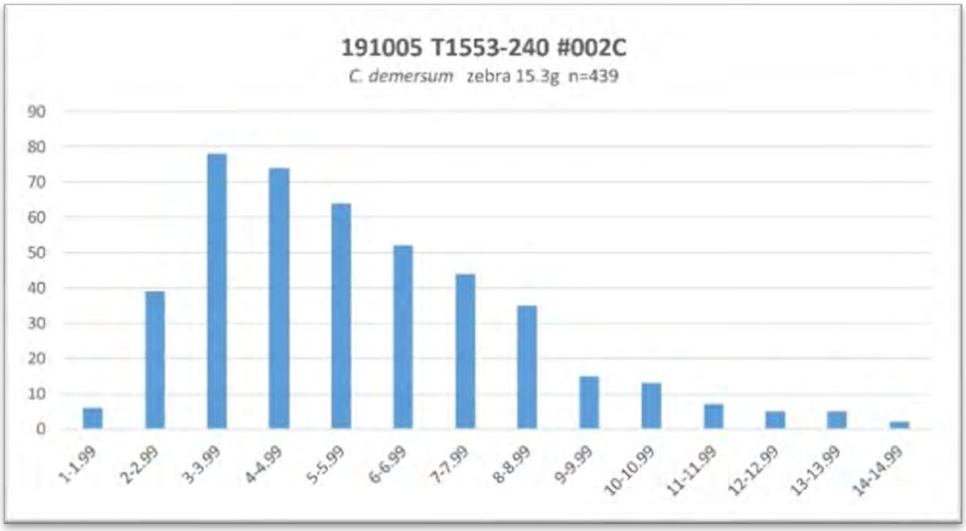


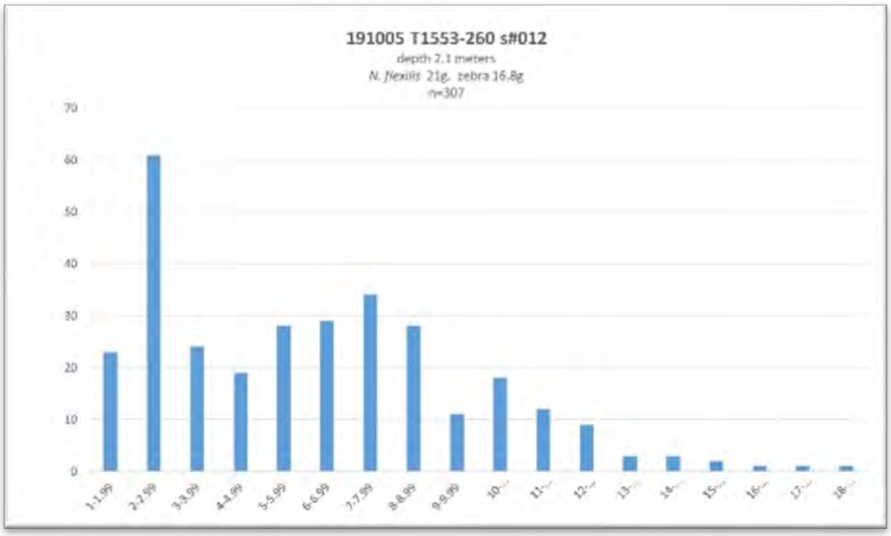
Table 2. Estimated Percentage of Multi- Year Survivorship in *C. demersum*

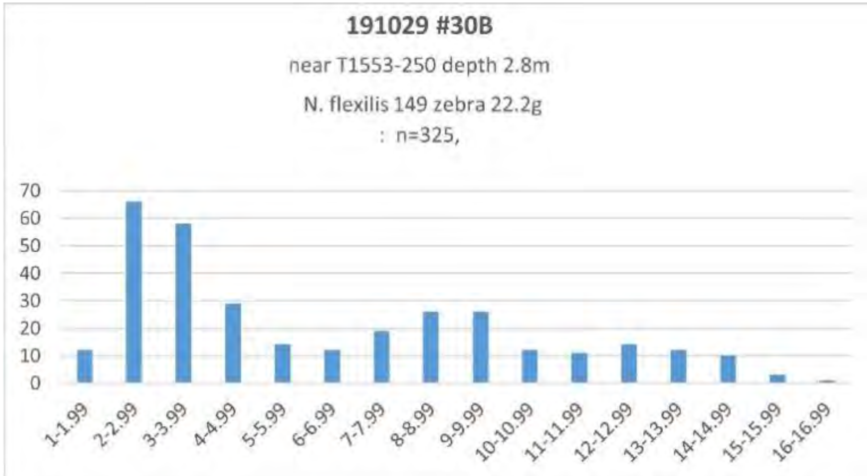
Sample	Depth	Weed wt, g	Zebra wt, g	Zebra n	>6.99 mm	>8.99mm	% Survivorship
-026	3.5	350	9.5	358	76	20	6%
-006	4.3	50	14	469	103	45	10%
-002c	3.9	-	15.3	439	126	48	11%
-018	3.8	511	16.8	344	120	49	14%

2. *Najas flexilis*: Transect of Three Mile Bay. October 5 and 21

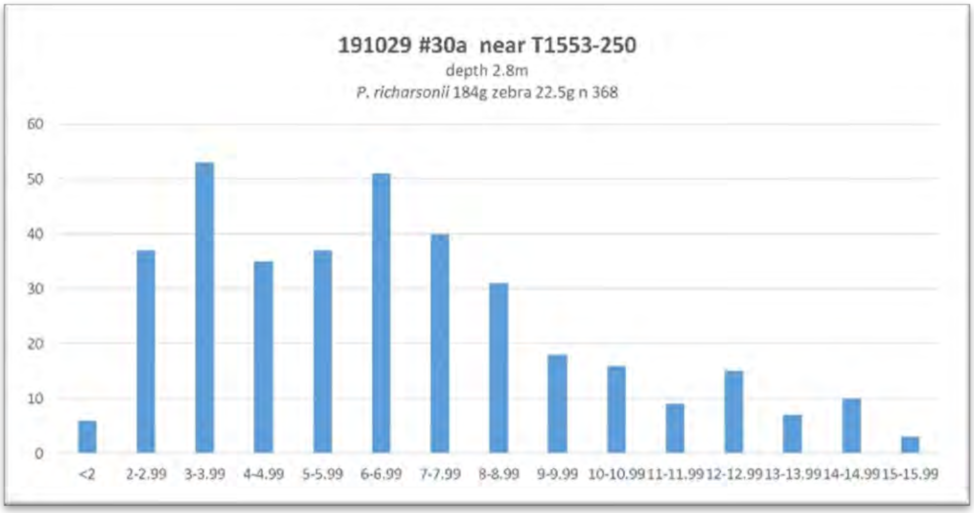
Table 3. Estimated Percentage of Multi Year survivorship on *Najas flexilis*

Sample	Depth	Weed wt grams	Zebra M grams	Zebra n	>6.99mm	>8.99mm	% survival
-030b	2.8	149	22.2	325	134	89	27.3%
-027	1.6	151	21.6	255	115	82	32.2%
-012	2.1	21	16.8	307	123	61	20%





3. *Potomogeton richardsonii*, Three Mile Bay October 5 and 21



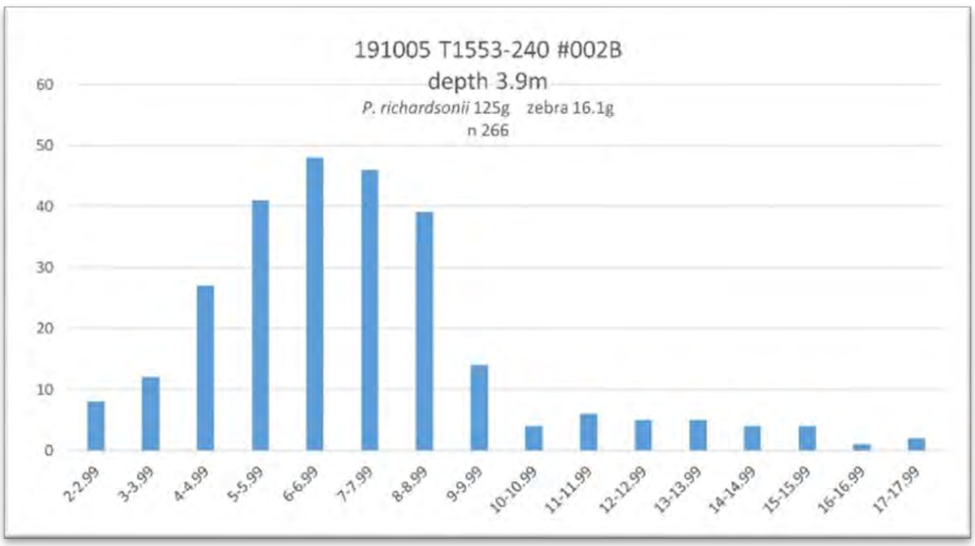


Table 4. Estimated Percentage of Multi Year Survivorship on *Potomogeton. richardsonii*

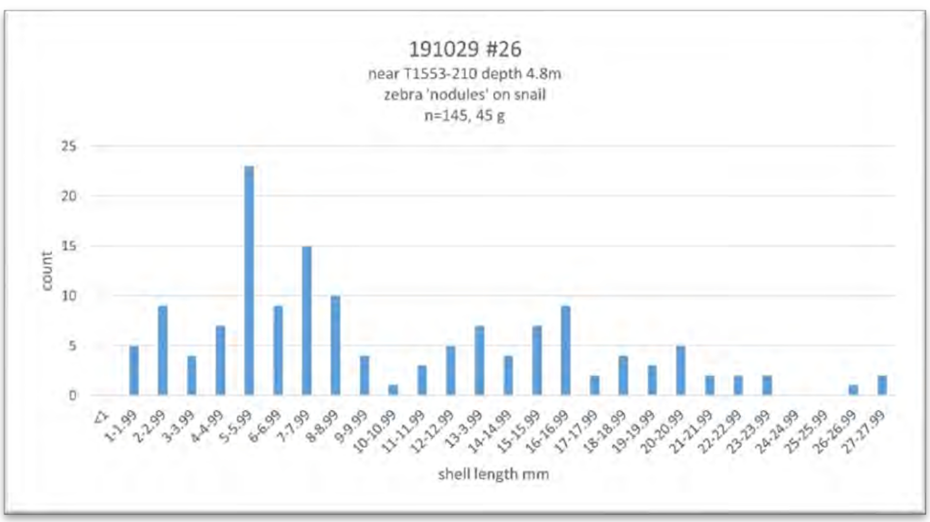
Sample	Depth meters	Weed wt grams	Zebra M grams	Zebra M, n	>6.99mm	>8.99mm	% survival
-30a	3.8	184	22.5	368	149	78	22%
-002b	3.9	125	7.3	260	130	45	17.3%

17.7 Examples of Zebra Mussel Nodules (Druse) formed on Mystery Snail, October Three Mile Bay October 5 and 21

A fourth unanticipated sample was composed only of nodules formed by zebra mussel druze that had settled on Banded Mystery Snail *Viviparus georgianus.* This attractive snail ubiquitous to White Lake is itself an introduced species from Europe (Clarke 1981)[16].

Nodules of zebra mussel formed on 1 snail

Mystery Snail grazing on soft sediment



[16] Clarke, Arthur H. 1981 THE FRESHWATER MOLLUSCS OF CANADA National Museum of Natural Sciences, Ottawa Canada

Unlike zebra mussels it is adapted to grazing alga from the surface of a soft substrate like the fine silt that is found in Three Mile Bay. Significantly, these nodules formed at depths beyond the current range for aquatic plants in Three Mile Bay (4.9 meters) [17]. This suggests the Mystery Snail will offer an opportunity for the zebra mussel to spread its range in White Lake.

The distinct multi- modal size frequency distribution for zebra mussels taken from the nodules formed on Mystery Snail shows the distinct multiyear growth and survivorship of zebra mussels lodged onto a snail.

Table 5. Estimated survivorship of zebra mussels in colonies on Mystery Snail

Sample	Depth	Snail count	Zebra M grams	Zebra M count	>6.9mm	>8.99mm	% survival
-026	4.9m	4	45	145	88	63	43%

The above 4 examples suggest that *Najas flexilis* supports a greater survivorship of zebra mussel than the other plant species most likely because of its sheer abundance and dense cover of Three Mile Bay. It is a ready recipient of veligers. *C. demersim* offers the lowest survivorship in the samples taken while *P. richardsonii* is in the middle. The nodule samples suggest that small numbers of multi-year zebras can survive in conditions that are not normally available to them.

17.8 Summary

Our ongoing observations of the influence of zebra mussels in White Lake were anticipated by some of the changes witnessed in other Ontario lakes. It is unfortunate that White Lake is afflicted by zebra mussels but they provide us with a wonderful example of the rapid and influential change that an aggressive introduced species can bring to an ecosystem.

Vanderploeg et.al[18]. summarized the impacts to a Great Lakes system by invading zebra mussels as follows:

" [the zebra mussel]....*continue to colonize hard and soft substrates of the Great Lakes and are changing ecosystem function through mechanisms of ecosystem engineering*

17 Note: All depths are standardized to the Fall drawdown at WLPP Three Mile Bay Site 1 = 5.5 m

18 Henry A. Vanderploeg, Thomas F. Nalepa, David J. Jude, Edward L. Mills, Kristen T. Holeck, James R. Lieberg, Igor A. Grigorovich, Henn Ojaveer: 2002 Dispersal and Emerging Ecological Impacts of Ponto-Caspian Species in the Laurentian Great Lakes
Canadian Journal of fisheries & Aquatic Science 59: 1209-1228

(increased water clarity and reef building), biofouling native mussels, high particle filtration rate with selective rejection of colonial cyanobacteria in pseudofeces, alteration of nutrient ratios, and facilitation of the rapid spread of their Ponto-Caspian associates, the benthic amphipod E. ischmus and the round goby, N. melanostromas, which feeds on zebra mussels....impacts of these benthic invaders vary with site: in some shallow areas habitat changes and the Dreissena→ round goby→ piscavore food chain have improved conditions for certain game fishes and waterfowl; in offshore waters, Dresseina is competing for settling algae with the native amphipod Diporeia spp, which are disappearing to the detriment of the native deep-water fish community. The predatory cladoceran C. pengoi may compete with small fishes for zooplankton and increase food-chain length".

Many of the factors listed by Vandergloeg are now present in our own lake. To what extent an organism or a system benefits and to what extent an organism or system fails to benefit from the presence of zebra mussels is a question that continues to be asked by those with a vested interest in White Lake.

Photo by Sue Munro

18.0 Microcystis Concentrations in Three Mile Bay

David Overholt

Microcystis is a blue-green alga that is often responsible for algal blooms on White Lake. The algae can be visible in the water column which may result in a surface scum. Microcystis responds to conditions of low available nitrogen and phosphorus. When the ratio of N:P is low, microcystis develops increased buoyancy by altering its internal structure. Conditions supporting blooms commonly appear in the fall of the year. Blue-green algae also secrete a compound which binds with iron in lake water making it very difficult for other algae to prosper.

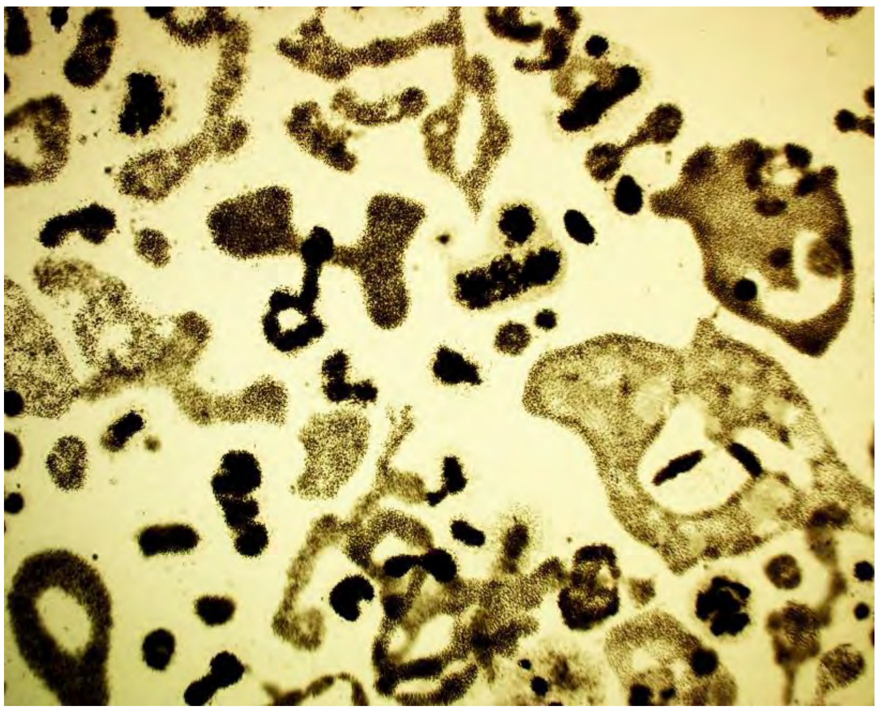


Figure 1. Microcystis from a flotation sample: magnification 100x

During September of 2019, an algal watch was maintained in anticipation of conditions which might be similar to those seen in 2018. Microcystis blooms occurred at least twice in 2018 in Three Mile Bay. These blooms appeared during periods of calm weather that followed high wind events. Both of these blooms were characterised as having a surface scum as well as a high algal density throughout the water column. Such conditions appeared to be developing again in 2019.

On the 18th, 24th & 30th of September 2019, microcystis colonies were very visible within the water column at Three Mile Bay. Accumulations did not form on the surface. Although the conditions to form a surface scum (such as a major wind event) were not present at this time the sampling of microcystis in the water column showed that buoyant colonies of microcystis were present.

Materials and Methods

To better assess the quantity of microcystis accumulating in the water column, a new semi-quantitative method was developed and is described below. Several 12 litre plankton net samples were collected on three separate days at a distance of approximately 100 meters off the north shore of Three Mile Bay. The most westerly sample site, at the entrance to Three Mile Bay, was used as a common GPS reference coordinate for all the samples. Distance from the reference site was calculated using EarthView (Google Earth). Distance was measured in kms as the radius of a circle beginning at the co-ordinate of a particular sample site and extending it to where its radius crossed the common reference coordinate at the mouth of Three Mile Bay.

Samples were obtained using an 80 micron plankton net. The plankton net was deployed at a depth of .1 to .2 meters below the surface. The horizontal tow length was double the length of the boat cockpit (2 meters). The total distance swept (4 metres) x volume swept/meter (3 litres) gave consistent volumes for comparison for each sampling day. The content from each net sample so obtained was washed into an 80ml volume sample bottle for transportation and storage. The sample was later placed in an inverted 80ml glass test tube and secured to a levelled base. The tube was sealed with a cork in a manner that allowed air to be displaced by the liquid in the sample. It was necessary to wet the cork to overcome surface tension which would otherwise entrap air in the tube. Tubes were left inverted and undisturbed for a period of time (see below) to allow microcystis to concentrate at the upper end.

Flotation was considered complete when clear water was left within the tube below the mass of floating algae. This required a minimum of two hours and varied with the amount of microcystis that was present in the sample. Once water clarification was achieved in all tubes, the flotation volume would remain stable for several hours. Eventually the products of respiration would generate gas bubbles and these would distort the sample volume if it was left for too long a time.

The volume of the floating algal mass was marked on the inverted test tube with adhesive labels and the sample returned to its storage container. The volume representing the concentration was replaced with tap water. This was then transferred to a graduated cylinder (10 ml with 0.2ml graduations) to determine its volume. Accurate sample volumes were obtained by filling and transferring the liquid using a long pipette for subsequent measurement using the graduated cylinder. Each sample was examined under a microscope to verify that the flotation products were indeed microcystis.

Results

The results from three sampling sessions show a progressive increase in algal concentration extending eastwards from the mouth of Three Mile Bay. The results are presented here as a concentration unit expressed as ml of algae per 12 litre sample. Individual sample concentrations were measured as the volume (ml) of floating alga which formed following a given settlement time. The photo below shows examples of microcystis masses that formed from such 12 litre plankton net samples. These were part of a series spanning a distance of 4.6 km.

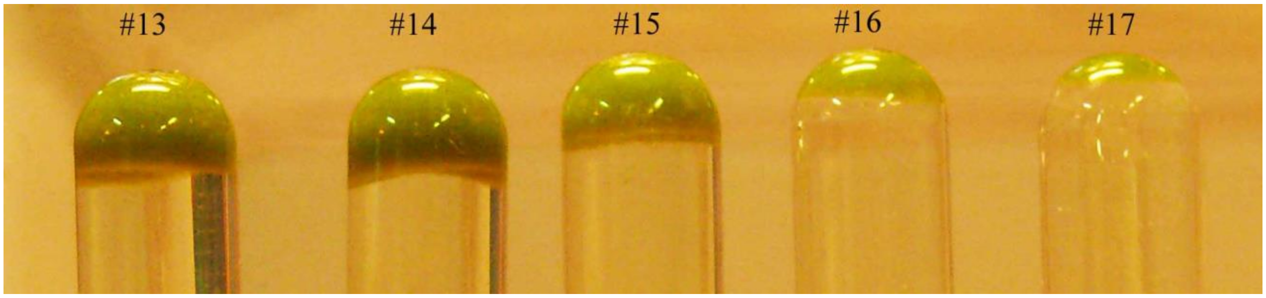
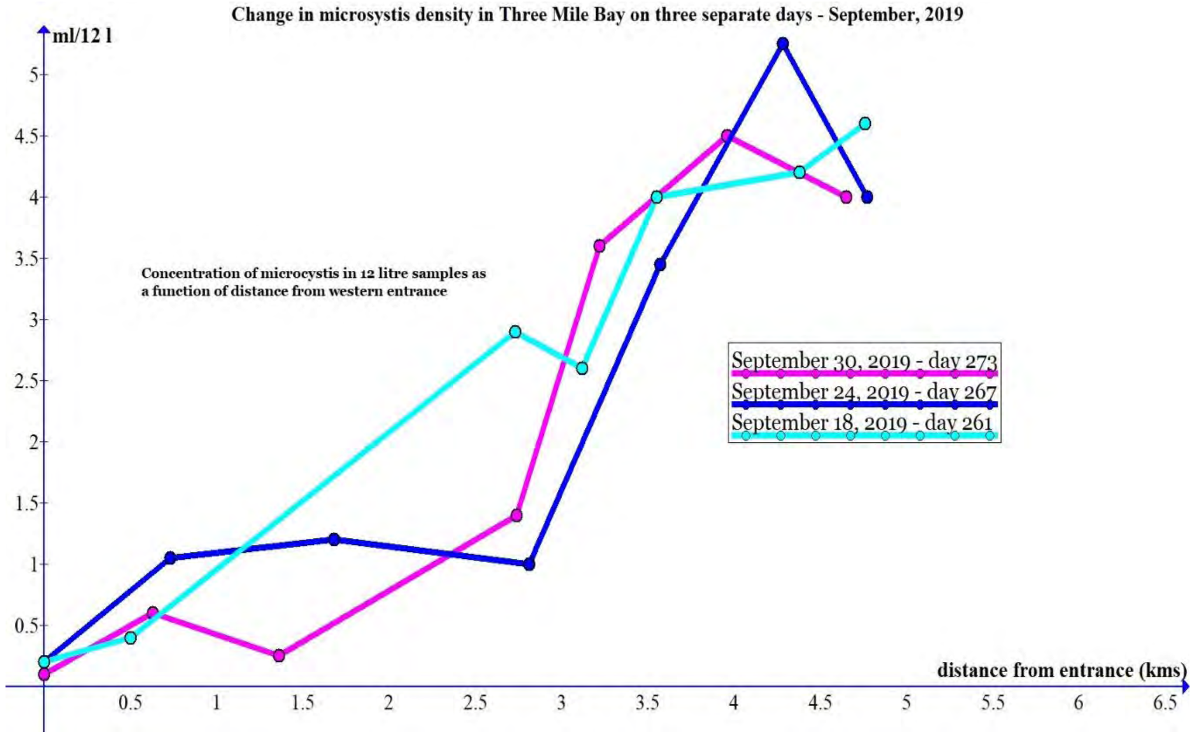


Figure 2. September 30, (day 273): Sample 13 is from the easterly end of Three Mile Bay and sample 17 is from the mouth of Three Mile Bay.



The graph above shows concentrations of microcystis (ml/12l) plotted against distance (km) extending from the mouth of Three Mile Bay (0 km) to the most easterly end of Three Mile Bay (4.6km). Concentrations of microcystis show an 18-fold increase over this distance on three separate sampling days in September.

Discussion

The dimensions of Three Mile Bay and its orientation to the prevailing winds are two factors responsible for the appearance of a surface scum resulting from an algal bloom. The formation of a surface scum forms when favourable wind conditions occur in conjunction with late season microcystis concentrations in the water column.

An interesting paper by Rusak et.al. (2018)[19] found a common global parameter associated with plankton blooms for all temperate lakes; wind speed and wind duration:

"Lower wind speed overall could reduce longer-term (monthly) variability of both wind and phytoplankton, but more frequent storms may increase the short term (hourly and daily) variability of wind speed and promote the development of algal blooms... Cyanobacterial blooms, in particular, may be triggered during calm periods following extreme weather events which can increase nutrient availability through water column mixing, external loading, and resuspension of sediments...."

Such wind events did arise on White Lake in 2018 as did late fall plankton blooms. Moreover the 2018 blooms, observed and reported for White Lake, closely matched similar events reported elsewhere. For several years the Mississippi Valley Conservation Authority has been participating in developing a model with Queens University (the Lake Nutrient and Algae Modelling Project) to predict conditions amenable to algal bloom formation. This model, developed by Dr. Nader Nakhael then at Queens University, was run for the first time in 2018. The preliminary results for 2018 were presented to the Lake Network Group on April 5, 2019. The model anticipated the periods of occurrence for two separate blooms on Mississippi Lake[20].

The following table shows the close correspondence in dates of actual algal blooms with dates predicted by the model. White Lake bloom events that were observed and reported parallel the observations on Mississippi Lake. The model includes regional parameters, which are independent of watersheds, such as data from Environment Canada. This result

[19] *J.A.Rusak et.al., Wind and Trophic Status Explain Within and Among-Lake Variability of Algal Biomass,* Limnology & Oceanography Letters 3, 2018 409-418, 2018.
[20] *Mississippi Lake Study: April 2019: Preliminary Results*
https://taywatershed.ca/documents/LNGdocs/9April04-MississippiLk-study-handout.pdf

demonstrates the regional predictive ability of the model. Prediction using this Model may prove useful in anticipating algal bloom in White Lake.

Comparison of modelled algal bloom prediction to 2018 Health Unit (HU) reports

Waterbody	HU report dates	Model prediction[21]	HU report dates	Model prediction
Mississippi Lake	Day 256 (Sept 13)	Day 250-260	Day 276 (Oct 3)	Day 275-285
White Lake	Day 257 (Sept 14)		Day 285 (Oct 12)	

Conclusions

Tracking the occurrence of microcystis colonies in advance of a bloom formation is possible using the proposed flotation method. This method can be used to follow microcystis colony formation even when such colonies are not readily apparent to the eye. An organized collection regime of such samples could be designed for use by White Lake citizen scientists. The data produced would lend itself to mapping patterns of concentration of microcystis that are present at a given time. The data collected for each algal bloom would also provide a semi-quantitative method for comparing the intensity of each algal bloom as they occur.

Tracking the buildup of microcystis within the water column and noting the frequency and occurrence of wind events and the local temperature regime during the late summer and fall will allow the anticipation of surface bloom formations.

It would also be of value in the future to track the correspondence between the Mississippi Lake study predictions and events occurring on White Lake.

[21] *Dr Nader Nakhaei, Dr Leon Boegman, Dr Geoffrey Hall*
Mississippi Lake Hydrodynamic & Biogeochemical Modelling
https://mississippilakeassociation.org>Vegetation>20181007-BGA-Recap.pdf

19.0 Microcystis Under the Microscope – (*Microcystis aeuruginosa*)

David Overholt

Microcystis has drawn the attention of biologists and water managers because of the potential it holds for serious water quality issues from surface algal blooms to health threatening neuro-toxicity. We should become familiar with this genus of blue green algae. Of the four types of microcystis described in identification keys, *M. aeuruginosa* receives much attention from limnologists.

Under the microscope *M aeuruginosa* exhibits clusters of dark dense cells that take on various shapes from spherical clusters of younger colonies to net-like structures of aging ones. Not always visible is a clear mucilage envelope encasing the entire colony. This envelop often has within epiphytic algae and bacteria. Inside this mucilage the small individual cells (2µm) of the colony appear granulated. This appearance is caused by gas vesicles forming inside each cell. Vesicles are incredibly small cylinders around 100nm (nanometers) in diameter. Under an electron microscope a microcystis cell is packed with these vesicles forming a honeycomb of minute hexagonal chambers. This trait is unique to the prokaryotes to which all forms of blue-green algae are a part[22].

Buoyancy & vesicle formation

Vesicles influence the buoyancy of the cell and the colony. The way and the reason why blue-green algae form these buoyancy structures is an area of active research. Some ideas on this suggest it is an adaptive strategy whereby blue-greens control the intensity of solar radiation that is needed for photosynthesis, access available nutrients and/or access atmospheric nitrogen. Various blue-greens by the configuration of the size and strength of their vesicles optimize for different strategies in differing conditions. Regardless of these differences, their vesicle walls are constructed from the same types of protein. The molecules that make up the outer wall are formed from a hydrophilic (water attracting) protein and an inner wall from a hydrophobic (water repelling) protein. The wall that is formed is a hydrogen bonded double layer that is cross- latticed and rib strengthened into a cylindrical shape with domed ends and essentially acts as a pressure vessel[23].

Proteins used in vesicle construction are formed from carbohydrates which are manufactured by photosynthesis. Carbohydrate molecules are heavy and enough of them can sink algal cells to deeper and more light-restricted waters. Under conditions of light restriction, carbohydrates continue to process protein molecules[24]. These molecules are lighter than the carbohydrate molecule. The result is a capacity for vertical diurnal movement of blue-green algae colonies through the water column. This ability confers an

[22] A.E. Walsby and P.K. Hayes, *Gas Vescicle Proteins*. Biochem. J., V. 264, pp 313-322, 1989.

[23] C. S. Reynolds, R. L. Oliver and A. E. Walsby, *Cyanobacterial Dominance: the role of buoyancy regulation in dynamic lake environments*, New Zealand Journal of Marine and Freshwater Research, Vol.21: 379-390, 1987.

[24] B. R. H. Thomas and A. E. Walsby, *Buoyancy Regulation in a Strain of Mcrocystis*, Journal of General Microbiology, 131, 799-809, 1985.

advantage to blue-greens allowing them to exploit resources, and outcompete other types of algae.
A variety of blue-greens create buoyancy vesicles but they will vary in the strength of their cell walls. For microcystis, the small size and restricted volumes of their vesicles are considered less efficient by volume when compared to other species but they are more resilient as they offer greater resistance to hydrodynamic pressure and internal cellular osmotic pressure (turgor) than their counterparts. It is possible there is reduction in buoyancy by ruptured vesicles when exposure to strong solar radiation which increases photosynthesis rates that in turn increase the osmotic pressure thus overcoming the strength of the vesicle wall.

Similarly, the increase in molecular weight of photosynthetic carbohydrates would also reduce buoyancy. Vesicles do not 'inflate' but by varying their numbers and their constructed size they determine cell buoyancy (Thomas and Walsby, 1985).

The difference in vesicle strength between species is thought to be a mechanism that reduces competition among blue-greens as it selects for different optimal conditions for different cyanobacterial species within the same water column. As a microcystis colony grows in size, vesicle production must keep pace to maintain an equilibrium in the water column. An interesting observation from laboratory research on microcystis is that turgor pressure and carbohydrate synthesis depend on the carbon that is available from CO_2 derived from the photosynthetic process. When this source of carbon is made limiting to algae, any blooms that have formed become unable to lose their buoyancy[25].

Buoyancy and the mucilaginous matrix

The clear structure that embeds microcystis colonies has also been considered a contributor to buoyancy regulation in microcystis[26]. It is described as a phycosphere, a microscopic habitat that supports a population of bacterial types which have adapted to its internal conditions. It is composed of extra-cellular polysaccharides (EPS). Such a matrix allows multiple colonies of microcystis to aggregate thereby increasing their buoyancy velocities. Polysaccharides adhere to cells to keep them clustered. As a gel polysaccharides gives microcystis colonies their shape. This shape will vary through the seasons by the degree of gelling.

Rates of buoyancy regulation vary amongst blue-greens. It is thought that fluctuating conditions of vertical mixing favour cyanobacteria like microcystis with its faster buoyancy response time. Buoyancy reversal in microcystis has been observed to happen within 4 to 12 hours. Compared to other blue greens which would take days, microcystis under ideal conditions, can clear a 15 metre column of water (by sinking or floating) in less than 2 hours (Kromamp and Mur, 1984).

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[25] B. R. H. Thomas and A. E. Walsby, *Buoyancy Regulation in a Strain of Mcrocystis,* Journal of General Microbiology, 131, 799-809, 1985.

[26] J. C. Kromkamp and L. R. Mur, *Buoyant density changes in the cyanobacterium Microcystis aeruginosa due to changes in the cellular carbohydrate content FEMS,* Microbiology Letters 25 (1984) 105-109, 1984.

Microcystis and nutrient limitations

Important to limnology is the concept of a limiting resource for organisms living in a lake environment that is in a state of flux. The progression of the growing season brings on many limitations in temperature, chemistry and solar radiation as well as other factors. But any particular limitation and its associated values are not uniform for all species. Any particular factor becomes limiting when it is scarce in the environment or is otherwise unavailable to a particular species. Phytoplankton succession from one species dominating the water column to another as a progression through the seasons is a consequence of just such limits.

Nutrient limits of phosphorus (P) has drawn the attention of limnologists as this element is complicit in algal bloom formation. Historic studies in Ontario's Experimental Lakes Program demonstrated the response of various blue green algae to limited and non-limited concentrations of phosphorus. When limits were reached, the continued growth of an organism became constrained even though other nutrients were in good supply. This limiting value will vary amongst different algal species. Phosphorus is regarded as the chief limiting nutrient as it is only available in very small amounts and for only short periods of time during the year. The non-availability of this macro-nutrient is often the first to be encountered by phytoplankton.

Cyanobacteria can be divided into two groups: those which can directly access atmospheric nitrogen (the diazotrophs) and those that depend on exoginous water soluble sources (the non-diazotrophs). Microcystis is a non-diazotroph. This means that microcystis bloom formations are not directly associated with exploiting atmospheric nitrogen. Rather the behaviour of microcystis seems to be optimized for late season conditions when both phosphorus and nitrogen concentrations are low.

Limnologists study the ratios of nutrients and by experiment can often determine at what ratios certain nutrients are limiting. In general, the ratio of nitrogen to phosphorus is regarded as high when the N:P ratio is 15:1 or greater (by weight). The value of N:P changes through the seasons. In late summer, microcystis reaches a limiting value as the ratio of N:P drops to 4:1. Such a ratio is at the lower end of the range found amongst algal species. This must imply that microcystis has resilience to seasonal declines in the nitrogen concentration of lakes.

Microcystis and Blooms

The notion that P concentrations alone affect plankton blooms is seriously tested by the current example of microcystis blooms in Lake Erie. A study by Gobler et al[27] found a relationship between Lake Erie microcystis blooms and nitrogen. The Lake Erie study examined a dilution gradient associated with the discharge from a small river into Lake

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[27] C. J. Gobler, JoAnn Burkholder, T. Davis, M. Harke, T. Johengen, C. Stow and D. Van de Waal, *The Dual Role of Nitrogen Suply in Controlling the Growth and Toxicity of Cyanobacterial Blooms*, Harmful Algae 54, 87-97, 2016.

Erie. Values of N and P were traced from the discharge source into the lake proper. The discharge source of the gradient had the highest values of both nitrogen and phosphorus. It was dominated by a diazotropic community of cyanobacteria. As this gradient dilution fell to low values, the cyanobacteria community switched to non-diazotrophs amongst which microcystis dominated. In spite of low P values and lower N values, the low N:P ratio still supported microcystis blooms. Studies performed under controlled conditions have demonstrated that microcystis cell growth can continue for days and even weeks with nitrogen values at near undetectable levels.

Microcystis and Nitrogen availability

There are several sources of nitrogen which are available to microcystis (Gobler et al, 2016). These include:

-Nitrogen from diazotrophs by way of scavenging amino acids and ammonia leaked into the waters.

-Nitrogen from sediment decomposition by bacterial action on organic matter creating anoxic conditions that in turn release the nitrogen bonded to iron molecules.

-Nitrogen from invertebrates like zebra mussels that release ionized ammonia to the water column.

To this list another potential contributing source for both nitrogen and phosphorus is directly introduced by plant matter at time of senescence. Microcystis has an affinity for ammonium (NH_4) over other forms of nitrogen so it responds more quickly to higher ratios of NH_4^+:NO_n^- than do other algae with which it must compete. Studies of aquatic macrophytes (water weeds) show the effects of senescence on local water chemistry. Enclosure studies in open water stands of invasive *Myriophyllum spicatum* have shown that periodic pulses of both phosphorus in the form of SRP (soluble reactive phosphorus) and nitrogen in the form of ammonium (NH_4^+) ion enter the water column and are associated with periodic dieback of the plants. They are also associated with spikes in chlorophyll-a, indicative of a rapid algal response[28].

Microcystis and bacterial interaction

Bacteria that colonize microcystis mucilage may have symbiotic relationships with their host. Comparisons of strains of the same bacterial type show that mucilage-associated bacteria grow slower and are larger than their pelagic counterparts. This suggests that microcystis-associated bacteria are protected from the predations of zooplankton and are living at near the carrying capacity of the mucilage they inhabit. A study comparing the density of bacteria found in mucilage with the density of bacteria in the external water column determined that a large percentage of the late summer bacterial biomass (40%) was represented by bacteria associated with microcystis.

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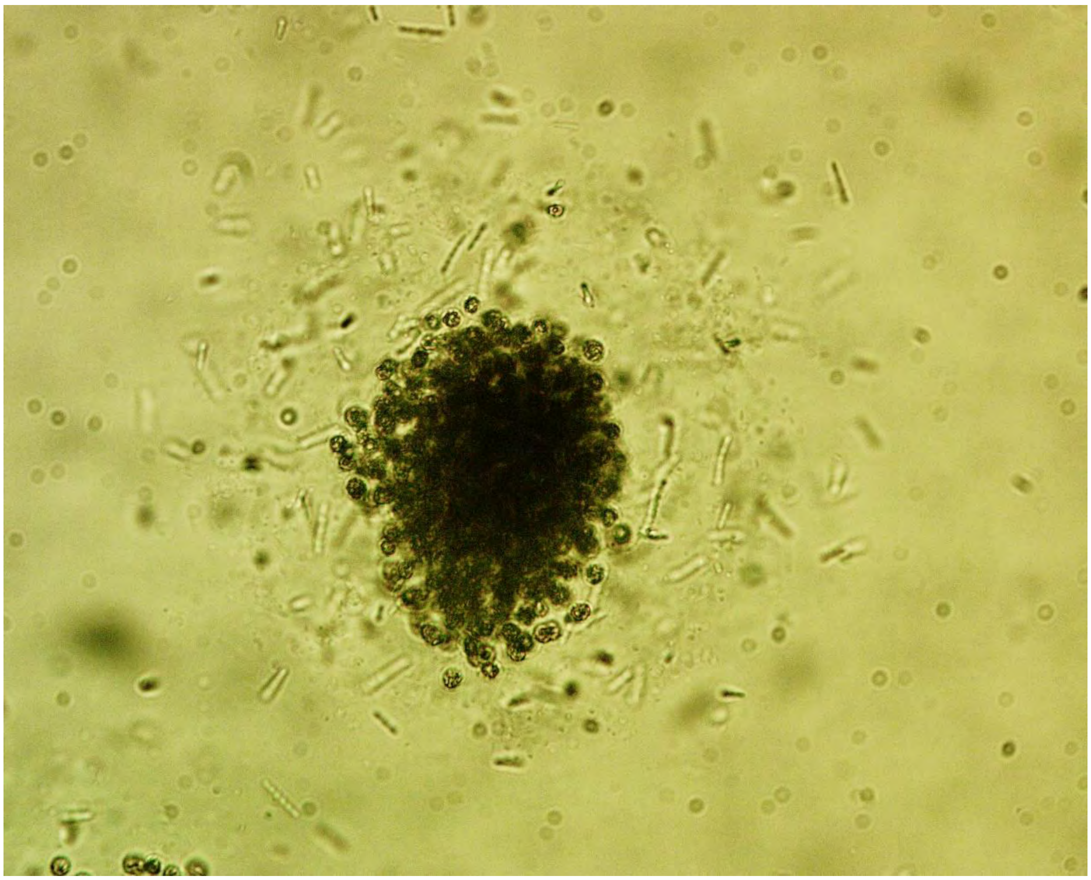
[28]Dixon H Landers, *Effects of naturally senescing aquatic macrophytes on nutrient chemistry and chlorophyll a of surrounding waters*, Limnol. Oceanogr. 27(3), 1982, 428-439, 1982.

During cold winter months, microcystis colonies sink to the sediment with their bacterial load. In this state they contribute a major component of the benthic bacteria found in sediment. Microcystis colonies can survive for years within sediments[29].

We can follow-up on the ongoing research on lake dynamics, and this will contribute to our understanding of the processes affecting our own White Lake.



Microcystis aeuruginosa: A 'young' colony embedded in mucilage which is supporting an epiphytic species. Three Mile Bay, White Lake Sept. 8 2019; 400x

[29] Anna-Kristina Brunberg, *Contributions of bacteria in the mucilage of Mycrocystis spp. (Cyanobacteria) to benthic and pelagic bacterial production in a hypereutrophic lake FEMS*, Microbiology Ecology 29 (1999) 13-22, 1999.

20.0 Summary of Microplastics Found in White Lake

J.P. Thonney

Background

Microplastics are not a specific kind of plastic, but rather any type of plastic fragment that is less than 5 mm in length. They enter natural ecosystems including lakes from a variety of sources, including cosmetics, clothing, and industrial processes.

Two classifications of microplastics currently exist. Primary microplastics are any plastic fragments or particles that are already 5.0 mm in size or less before entering the environment. These include microfibres from clothing (Fig 1), microbeads and plastic pellets.

Secondary microplastics are microplastics that are created from the degradation of larger plastic products once they enter the environment through natural weathering processes. Such sources of secondary microplastics include water and soda bottles, fishing nets, and plastic bags breaking down to fragments and film (Fig 2). Both types are recognized to persist in the environment at high levels, particularly in aquatic ecosystems.

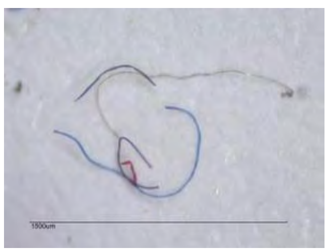


Fig 1- Example of microfibres

Fig 2- Example of fragments

Impacts of Microplastics on Environment and Health

Plastics degrade slowly, often over hundreds if not thousands of years. This increases the probability of microplastics being ingested and incorporated into, and accumulated in, the bodies and tissues of many organisms including humans.

There is concern that microplastics could harm human health as they move through the aquatic food web. Microplastics both absorb and give off chemicals and harmful pollutants. Plastic ingredients or toxic chemicals absorbed by plastics may build up over time and stay in the environment.

Additives added to plastics during manufacture may leach out upon ingestion, potentially causing serious harm to an organism. Endocrine disruption by plastic additives may affect the reproductive health of humans and wildlife alike. Plastics and polymers derived from mineral oils are virtually non-biodegradable.

White Lake Study Results

The tables contained in Appendix 3 show findings from shore-based and offshore water sampling conducted for 'microplastics' (plastics particles < 5mm) in June and July of 2019. Observations were based on a total of 63 samples collected at 22 sites on White Lake. Replicate samples were collected from 8 inshore locations on June 22nd and repeated on June 30th. Single samples were collected from 16 different offshore locations with sampling carried out by boat on July 13th and repeated on July 18th.

Sampling and analysis was carried out according to the Florida Microplastic Awareness Protocol. Using this protocol, particles were categorized into *Fibres* (artificial and natural strands), *Fragments* ('chunks' rather than strands), and *Film* (thin plastic bag like consistency).

Results given in Tables 1 and 2 (Appendix 3) from inshore water samples revealed the presence of artificial materials in 26 of 31 (84%) samples. The predominant material type observed were 'fibres' which were found in a range of lengths and colours. There was little difference in results for samples obtained on June 22 and June 30 where 13 of 15 samples and 13 of 16 samples, respectively, had some microplastics present. The average number of individual plastic particles observed per litre was similar for both days with an average of 2.1 on June 22nd and 2.3 per sample on June 30th. The number of particles per litre of water ranged from 0-7 with some fibre 'bundles' (fibres tangled together) also observed and recorded as one entity.

Tables 3 and 4 (Appendix 3) report findings from the 16 offshore sampling locations. The analysis revealed that 26 of 32 samples (81%) contained some artificial materials. There was little difference in the number of particles per sample, with an average of 1.9 particles per litre for samples collected on July 13 and July 18. The number of particles per sample ranged from 0-5 with some fibre 'bundles' found as was the case for inshore samples.

General Summary

This study is qualitative in nature so it is not possible to derive highly detailed findings. Taking this into account, we can say that the presence or absence of particles were detected in the same percentage of inshore and offshore samples. However, there were a relatively lower number of particles per sample for offshore when compared to inshore samples.

The main message to be taken from this study is that microplastics in a variety of forms are present throughout White Lake. The amount of microplastics in the lake can be reduced through lifestyle choices. Measures can include avoiding products with excess packaging, choosing glass or metal drink containers over plastic, avoiding disposable plastic bags by using reusable bags, and choosing garments made from natural rather than synthetic fibres.

21.0 Paleolimnology


Dr. Conrad Grégoire (left) and Prof. Jesse Vermaire

Paleolimnology is the study of sediments to track changes in lake conditions over time. The first study of White Lake was completed in collaboration with WLPP scientists in 2014 by Prof. Jesse Vermaire of Carleton University. The study found that nutrient levels in White Lake have been increasing in recent decades. The second collaborative study, completed in 2019, assessed water quality changes in White Lake over the past 130 years and documented the recent history of poor water quality due to water level changes, nutrient loading and invasive species.

A paper (co-authored by C. Grégoire with M. Murphy and J. Vermaire) entitled "Ecological response of a shallow mesotrophic lake to multiple environmental stressors: a paleolimnological assessment of White Lake Ontario" will be published in the *Journal of Lake and Reservoir Management*. The full paper will be available in the WLPP website.

Abstract

White Lake, located in Eastern Ontario, Canada is a large (surface area 56.08 km^2), shallow (mean depth = 3.1 m), recreational lake that has a recent history of poor water quality due to water level changes, nutrient loading and invasive species. The lake is currently mesotrophic (average annual maximum total phosphorous =13 µg/L) and is being actively colonized by zebra mussels (*Dreissena polymorpha*). With monitoring data only extending to 2014, lake managers lack the long-term data needed to make informed decisions regarding lake management strategies. A paleolimnological study was conducted to assess water quality change in White Lake over the last 130 years using diatoms as indicators of water quality. Damming of the lake in 1845 resulted in lake level increasing by approximately one meter and increased the relative proportion of littoral area in the lake. Productivity increased after this time and remained high throughout the core. The recent introduction of zebra mussels has lowered nutrient levels and greatly reduced turbidity with Secchi depth reading jumping from 1.8 m to 7.5 m depth. This recent increase in water clarity has opened much of the lake bottom to benthic production and is driving much of the recent ecological change in the lake. However, the largest single change in the diatom assemblage of White Lake likely relates to water level changes through the damming of the lake and subsequent changes to the water level management plan for the lake.

22.0 Creel Survey for White Lake – 2018

Adam Pugh, Adam's Outfitting, Cedar Cove Resort

Every year I keep detailed records of fish caught during the many guiding fishing trips I lead on White Lake. In this way, I am able to assess the health of our fisheries based on this creel survey. This year, data was recorded from May 15 to August 16, 2018. Unfortunately, my guiding season was shorted as a result of a personal injury.

In previous years fish scales were collected and other data useful in determining the age of fish caught. This was not done for the 2018 season. However, the lengths and catch numbers where recorded for six species with the main focus being on walleye. The 2019 the creel survey, not completed at this time, will focus primarily on the Smallmouth and Largemouth bass fishery and completing the aging (age dating) project for walleye in the 20 to 30-inch range. The largest walleye caught in 2018 was 26 inches in length. For both bass species, the size class and numbers are declining which is giving us cause for concern.

In 2018 there was one creel survey handed in from the public. The remainder of the creel surveys were filled out by Adam's Outfitting. Because the main focus was on walleye, the numbers generated for other species may not accurately reflect the health of these populations.

Below are some key findings from the 2018 fishing season based on 87 anglers sampled over the course of 119 angling hours over 28 trips.

1. Walleye: 195 caught. The smallest was 12" and largest was 26" in length.
2. Of the 195 walleye caught in 2018, the average size was 15.34" up from 15.15" in 2017 and down from 17.12" in 2016.

3. If one fished for 1 hour on White Lake you would expect to catch 1.63 walleye per hour.

Results for 2018 trend well with those of 2017 with the average walleye size protected by the slot limitation which will encourage a sustainable walleye fishery for another year. Although I would like to devote more effort in characterizing the bass population, this is not in line with my clients who generally want to concentrate on catching walleye. An anecdotal observation is that in years when more Smallmouth bass were caught as a by-catch, that pickerel catches were lower. We now observe higher pickerel catches and a lower bass catch.

Areas of Concern:

I am concerned for both the Largemouth and Smallmouth bass fishery. The numbers of Largemouth bass caught are relatively high, but the average size and grow rates seem to be low. I would like to complete an age study on our bass population in the near future. I feel we have a weak gene pool of Largemouth bass in the lake from years of over harvesting larger fish in the population. Although there are no real slot limits on bass in Ontario, perhaps there should be even though I know it would challenge the tournament fishing scene. However, I think we have to instill in the younger generation that the larger fish are not as desirable for table fare and the smaller fish should be kept for consumption. In other words, “breeders ain’t eaters”. There is now a stigma being created concerning this topic, which is good. I know that 10 years ago it was common to have a person walk to the fish cleaning station at our campground with a stringer of their 6 biggest bass to clean and people would stare in amazement. Now, many of our campers will look at this as unnecessary, unethical and show disgust at the practice. The Smallmouth bass fishery remains our largest area of concern.

We are hoping to get more information on the fishery as a result of a Broad-Scale fisheries survey to be completed in 2019 by the Ministry of Natural Resources,

Fish Species totals 2018:

Walleye: 195
Largemouth bass: 286
Smallmouth Bass: 36
Pike: 73
Sunfish: 47
Perch: 154
Brown Bullhead: 1
The largest Largemouth bass caught this season was 21” in length and weighed 5.7lbs. This is the largest ever caught in three years of creel surveys.

If you were to take a guided trip with my outfitting company you could expect on average to catch 6.65 fish per hour, up from 5.45 fish per hour in 2017. I feel that this is a very good result for a lake as small as White Lake with all the fishing pressure. A very healthy fishery over all.

23.0 Loon Survey and Wildlife Observations June 29 to July 6th, 2019

Joyce Benham and Bob Carrière

The weather: Our first venture on the lake, on July 29, was cut short by menacing black clouds moving into the area. We did manage a quick tour of the Broad Brook area and managed to beat the rain back to the cottage. The rest of our observation period was beautiful, with warm and usually calm conditions for all of our morning and evening outings.

General Observations:

- Water levels were higher than in 2018. Known (2018) nesting sites were flooded and not used in 2019.
- The loon population was strong in all the familiar areas. Most of the adults with chicks had twins with only a few exceptions having a single offspring.
- Interestingly, there appeared to be a greater variety in size/age of the chicks. Some were very small and recently hatched, while others were quite large, already diving on their own and no longer relying on their parents for rides.
- In some areas such as Broad Brook and Sunset Bays, lake water clarity continued to increase allowing us to see to greater depths.
- In certain areas such as Eggshape Bay and the far end of Three Mile Bay, shore waters appeared compromised, with a higher density of vegetation and clouds of algae present.
- We noticed a significant increase in vegetation (compared to 2018) starting from the shoreline of Broad Brook Bay to the far end of Sunset Bay. Some of the vegetation reached the surface of the water and was dense enough to fowl our motor propeller.
- As in previous years, adult loons gathered at nightfall in the channel stretching from the entrance to Sunset Bay northward between the western lakeshore and the length of Hardwood Island. These cooperative line-fishing gatherings, involving at times 6 to 8 loons, likely indicated that fishing was successful in this area.
- This year, we did not visit the far end of the lake near White Lake Village, not venturing past the opening to the Village Basin. We did confirm that the Osprey nest in the area, which had disappeared during the last few seasons, was never rebuilt. We also did not venture to the far East end of the lake (Hayes Bay) and went only as far as the White Lake marina. A lack of time and a distraction by a very colorful Chinese Dragon boat paddled by visiting seniors, prevented us from venturing farther. We did observe an osprey fishing in the large grassy bay just east of White Lake Marina.

Site specific observations:

1. As has been observed in previous years, Broad Brook Bay hosted two adult loons with two large chicks. The family was calm and tolerant of our presence. These loons were active feeders near the south end of Hardwood Island and appeared to be feeding in deeper water thus avoiding near-shore areas of dense aquatic plant growth.
2. Sunset Bay remains devoid of permanent loon residents. Starting at the southern end of the lake in Sunset Bay, aquatic plants are increasing in density and spreading further into the bay itself. At the mouth of Sunset bay, we observed an adult (Mallard?) ducks caring for three ducklings. Several adult loons were observed feeding in the bay but no chicks or pairing of adults was observed.
3. Near the mouth of Sunset Bay and on the western shore, we observed several Great Blue herons. These are very shy birds and must be approached with care if one is hoping to get within photographic range.
4. Just before the entrance to Three Mile Bay, on the eastern shore, we observed two adult loons with a single very small chick. The family was seen close to cottage docks when feeding.
5. The osprey nest on the east side Hardwood Island continues to be active. Only one chick was seen in the nest and although not yet flying, was noisily jumping up and down, anticipating its parent's return with food. On the eastern side of Harwood Island, we observed on several occasions, adult Bald Eagles either circling the area or perched on high tree tops in search of food. We did not discover the nesting site.
6. Within the deeper channel that separates the last small island at the southern end of Hardwood Island, two adult loons were observed but with no chicks.
7. The bay on the western side of the lake just south of McLaughlin's I., appears to be a favorite fishing spot for Blue Herons. We observed a large population of little minnows at that spot which explains the presence of the Herons.
8. Off the shore of Birch Island facing the opening to Three Mile Bay, were two adult loons with two medium-sized chicks in an area where food was readily available.
9. In those parts of the south side of Three Mile Bay where there are no cottages, we logged in three separate sightings of two adult loons with two medium-sized chicks.
10. Several adult loons were observed close to Cedar Cove, coping with passing boat traffic. When we were on the lake, most of the north shore of Three Mile Bay, which is heavily developed with cottages, was contaminated with some form of cloudy algae floating near the shore line. The bloom extended right up to the very mouth or entrance of the bay.
11. The eastern end of Three Mile Bay appeared stagnant. There is a very high density of aquatic plants present, and although a productive area for loons in past years, this area is now empty with the exception of small birds darting in

and out of the tall grass. However, at the small bay on the southern side where the water is deeper and darker, we observed a very active pair of loons with two medium-sized chicks.

12. On the south shore of Three Mile Bay opposite Cedar Cove, we recorded two adult loons with two small chicks. This family stayed very close to unpopulated wooden areas.
13. Just past the entrance on the south shore of Pickerel Bay, we observed two adult loons and two large chicks. The osprey nest on the highest dead tree on the center island was very active with two large chicks. Although not yet flying, they were very vocal and trying out their wings.
14. At the far end of the bay near Pickerel Bay Lodge and beyond, the water appears very slimy, stagnant and with lots of algae. No loons observed. This area was a productive location just a few years ago.
15. We observed no loons in Eggshape Bay, but did notice a marked increase in aquatic vegetation. No Herons were seen amongst the tall grass as in previous years.
16. Windy Point hosted the usual two adult loons and 2 medium-sized chicks. These loons were observed on the far side of the small islands adjacent to the point.
17. Amongst the smaller rocky outcrops on the northern end of Stanley Island, we observed two adult loons caring for 2 medium-sized chicks. This family was repeatedly observed in that immediate area and did not wander off. The Bald Eagles' nest located there still looks to be in good shape but no chicks were seen, possibly because they had fledged. Two adult eagles were seen, on separate occasions, flying above the channel between Stanley Island and the eastern shoreline. In this location, we observed several Great Blue Herons.
18. Just south of Dead Man's Island, on the eastern shore, the large bay located there hosted an osprey nest with two very vocal chicks. The open section of the bay held two adult loons with two very small chicks. Deeper in the bay, but not accessible to the pontoon boat we were using, were two additional adult loons. We could not, however, see any chicks although they could have been hidden in the grassy area.
19. In the area just opposite the White Lake Marina, we observed on several occasions, three of four adult loons feeding. Adult Mallard ducks were also observed as were several Great Blue Herons.
20. On the south side of The Canal near the White Lake Marina, we observed two adult loons and two large chicks actively feeding. Further to the east, there was a small rocky island with a tall dead tree. This unique perch was being used by an osprey to spot fish below. After spending several hours waiting, we were fortunate to witness a successful osprey catch. At one point, the osprey successfully caught a fish about 12 inches long and struggled to gain altitude after

the capture. We quickly followed the osprey to the south shore of the bay where it was perched on a dead tree while eating its catch with great gusto.

21. On the north side of the same area, and in the narrow channel between the mainland and Myrtle and Jacob's Islands, two adult loons and two small chicks were observed feeding. Continuing through the channel to where it opens up just before the White Lake Marina, we observed one adult loon and two small chicks. All were braving the boat traffic coming from the marina.
22. Birch Island continues to host a Bald Eagle nest. This year there were two adults and two chicks. The chicks had fledged by the time we saw them, but were staying in close proximity to the nest while being fed by their parents.

Summary of Loon observations:

Total number of adult loons:	38
Number of nesting pairs:	12
Total number of chicks:	23

Photo by Joyce Benham

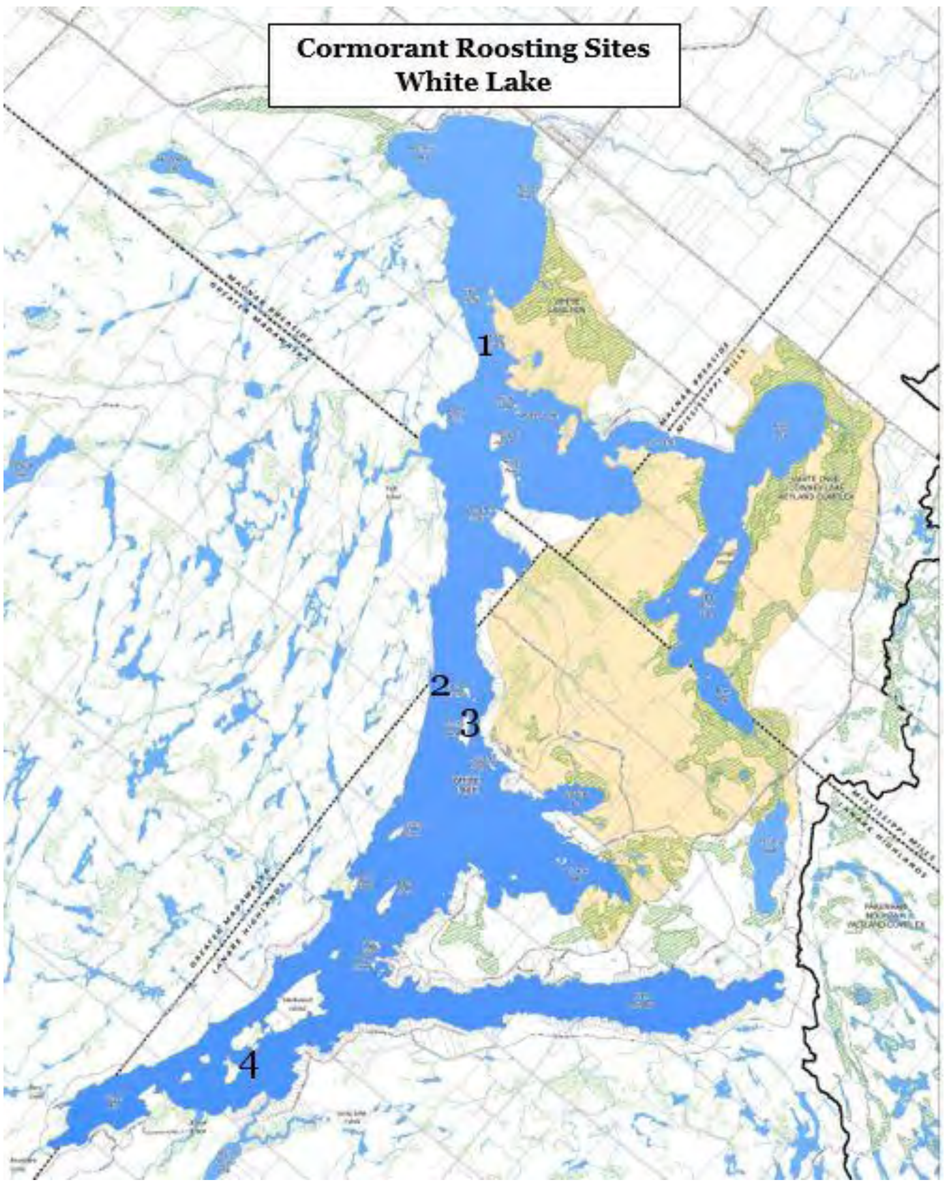
24.0 Double-Crested Cormorant Survey - 2019

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. 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 hunts by swimming and diving. Its feathers, like those of all cormorants, are not waterproof and it must spend time drying them out after spending time in the water. Once threatened by the use of DDT, the numbers of this bird have increased markedly in recent years (WikipediA).

When large numbers of cormorants congregate in a roosting or nesting area, their droppings can kill trees and other vegetation. They also compete with loons and other fish-feeding birds for food.

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 was increasing. As part of our water quality monitoring program, we decided to start monitoring cormorant numbers on White Lake. Every two weeks we patrol and sample 9 sites in all parts of the lake. Samples for total phosphorus are collected as are plankton samples, water temperature and secchi depth. During this two-hour period, we collect data on the location and numbers of cormorants at 4 specific sites, where they have been observed to roost. We do not know the location of the nesting sites at this time. Sites 1,2 and 4 (see map) are exposed rocks where local gulls also roost. Sites 2 and 4 are submerged until late summer whereas site 1 is available during the entire summer. Site 3 is a small islet on the north end of the Stanley Island group. Cormorants were observed there roosting in the tall pines as well as on the rocks along the shoreline.

The number of cormorants observed for each date in the table below can be taken as a minimum number of resident cormorants. From the table it is probable that there were two to three nesting pairs producing at least 5 surviving offspring. The much larger number of cormorants counted on September 15 likely included many birds in migration southward.



Cormorant Count on White Lake - 2019

Date	Map Location					Number		Total #
	1	2	3	4	other	Adult	Juvenile	
May 16	-*	-	-	-	4 in flight	4	-	4
May 31	-	-	-	-	-	-	-	-
June 17	-	-	-	-	-	-	-	-
June 27	3	-	-	-	-	3	-	3
July 14	3	-	-	-	1 Village Basin	4	-	4
August 1	-	-	3	-	-	-	3	3
August 15	6	-	1	-	1 in flight	5	3	8
September 1	4	-	3	-	1 in flight	5	3	8
September 15	10	5	1	3	2 in flight	15	6	21
September 30	3	-	-	-	1 in flight	4	-	4
October 18	-	-	-	-	-	-	-	-

*none observed

We will continue monitoring cormorant populations on White Lake and also ascertain the specific nesting site(s) if possible.

Hidden Bay, West White Lake

PART IV
Acknowledgements
and
Author Profiles

25.0 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 members of the Science Committee of the White Lake Preservation Project. The micro-plastics work was supported by the Gottlieb foundation.

26.0 Author Profiles

Conrad Grégoire is a retired Research Scientist in Inorganic Analytical Chemistry. He earned his Masters degree from the University of Manitoba and his Ph.D. from Carleton University. His professional career was spent at the Geological Survey of Canada where he was Head of the Analytical Chemistry Research Laboratories. For over 20 years, he was also an Adjunct Professor of Chemistry at Carleton University. Conrad is interested in studying the chemistry and biology of White Lake and to establish base line values for water quality parameters. He is also the Webmaster for the White Lake Preservation Project.

Dave Overholt worked in a small business in Toronto for over 30 years, and his wife Carol was a school teacher with the Toronto Board of Education. When they retired, they decided to move to Almonte to be closer to the family cottage. Dave has been spending summers on White Lake since he was 9 years old. (he is now 66). David's enthusiasm for things aquatic was stimulated by Rachel Carson's *The Sea Around Us*. When he gained access to a microscope, he discovered that many of the creatures she described in her book could be found in his own back yard. Although he does not have a science background, he would like to contribute in any way possible to the lake research conducted by the WLPP.

Adam Pugh's family has owned and operated Cedar Cove Resort on White Lake for the past 10 years. Adam feels privileged to have spent a good portion of his life on this beautiful lake. Growing up there led him to develop a passion for conservation and the biology of local fisheries and wildlife. Adam's passion took him to Sir Sandford Fleming College in Lindsay, Ontario where he completed the advanced diploma in Fish and Wildlife Technology. He now owns his own business providing guided fishing and hunting trips on White Lake and the surrounding area. Adam has been awarded the Youth Entrepreneur Award from the Township of Lanark Highlands as a result of the success he achieved with his ice hut rental business.

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 document 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.

Jean-Pierre Thonney earned an MSc in Fisheries Science and Aquaculture from the Institute of Aquaculture at the University of Stirling, Scotland. He holds a BSc Honours in Fisheries Ecology from Memorial University and a D.E.C. in Fish and Wildlife Management from Vanier College. His 30 years of international work experience includes environmental assessment and mitigation, fisheries management, aquaculture, and sustainable development.

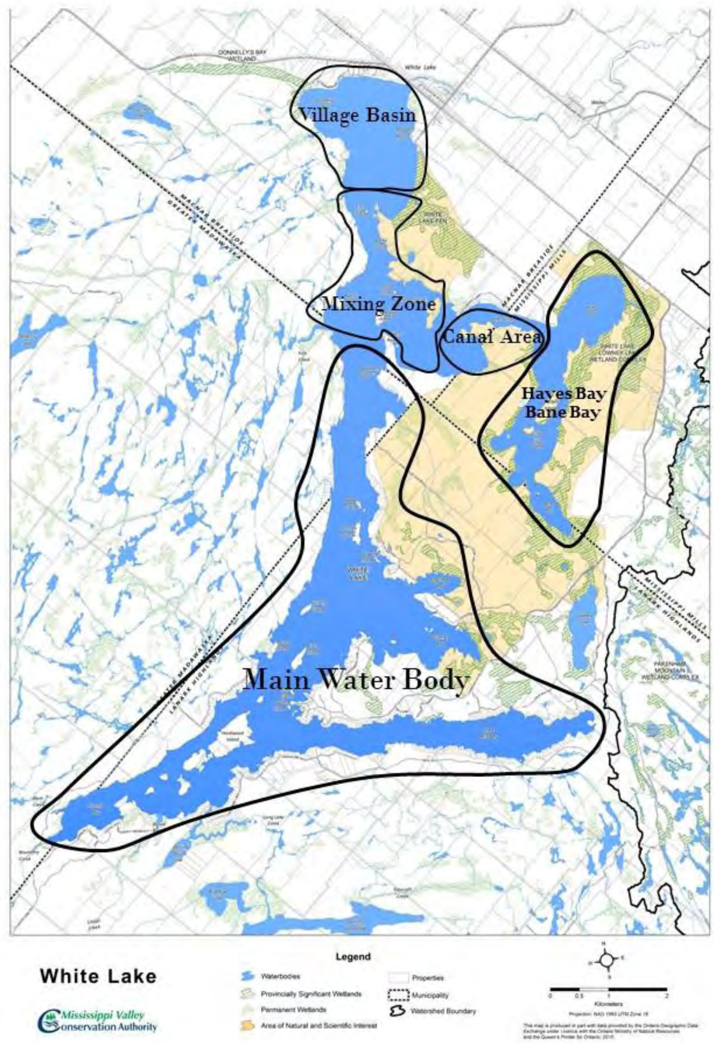
PART V
Appendices

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.

Photo by Donna Gaines

Appendix 2: Chemical and Physical Data - 2019

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

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Total P, ppb	Ca, ppm	Cl, ppm
May 16	10:15	136	3.7	11.0	12.6, 9.4 (12.0)	28.8	2.8
May 31	10:06	151	4.7	15.2	-	-	-
June 17	10:03	168	4.45	17.9	11.6, 11.0 (11.3)	29.7	3.4
June 27	9:59	178	5.0	21.8	-	-	-
July 14	9:57	195	4.7	24.2	10.8, 10.8 (10.8)		-
August 1	10:03	213	4.55	25.5	-	-	-
August 15	10:01	227	> depth	23.3	14.0, 13.6 (13.8)	-	-
September 1	10:00	244	> depth	21.2	-	-	-
September 15	9:58	258	> depth	18.0	9.0, 9.8 (9.4)	-	-
September 30	10:34	273	> depth	17.0	-	-	-
October 18	10:02	291	> depth	10.8	10.0, 9.6 (9.8)	-	-

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

Date	Time	Day of Year	Secchi Depth, M	Temp, °C	Total P, ppb	Ca, ppm	Cl, ppm
May 16	10:22	136	3.6	11.8	11.4, 12.6 (12.0)	28.6	2.8
May 31	10:13	151	4.5	15.0	-	-	-
June 17	10:15	168	4.5	17.8	9.4, 10.0 (9.7)	28.4	3.47
June 27	10:13	178	5.2	21.5	-	-	-
July 14	10:07	195	4.1	24.2	11.6, 12.0 (11.8)	31.4	3.31
August 1	10:09	213	4.3	25.5	-	-	-
August 15	10:19	227	5.5	23.3	13.0, 12.6 (12.8)	-	-
September 1	10:30	244	> depth	21.3	-	-	-
September 15	10:16	258	> depth	18.0	9.6, 9.8 (9.7)	-	-
September 30	10:44	273	> depth	17.3	-	-	-
October 18	10:11	291	> depth	11.3	9.4,9.6 (9.5)	-	-

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 16	10:22	136	3.6	11.8	-	-	-
May 31	10:13	151	4.5	15.0	-	-	-
June 17	10:15	168	4.5	17.8	-	-	-
June 27	10:13	178	5.2	21.5	-	-	-
July 14	10:22	195	4.9	24.3	-	-	-
August 1	10:34	213	7.3	25.0	-	-	-
August 15	10:40	227	4.4	23.1	-	-	-
September 1	10:34	244	4.7	21.4	-	-	-
September 15	10:29	258	5.8	18.0	-	-	-
September 30	10:58	273	5.9	17.7	-	-	-
October 18	10:23	291	7.0	11.5	-	-	-

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 16	10:45	136	3.4	10.8	-	-	-
May 31	10:41	151	4.6	15.2	-	-	-
June 17	10:38	168	5.8	17.9	-	-	-
June 27	10:39	178	4.8	21.8	-	-	-
July 14	10:26	195	4.7	24.3	-	-	-
August 1	10:48	213	7.4	25.5	-	-	-
August 15	11:01	227	4.3	23.2	-	-	-
September 1	11:04	244	5.5	21.3	-	-	-
September 15	10:43	258	5.8	18.0	-	-	-
September 30	11:17	273	6.0	17.5	-	-	-
October 18	10:28	291	> depth	11.5	-	-	-

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 16	10:59	136	3.5	10.8	10.8, 10.0 (10.4)	30.3	3.2
May 31	11:00	151	4.2	15.2	-	-	-
June 17	10:50	168	5.2	18.1	9.2, 10.4 (9.7)	29.2	3.5
June 27	10:51	178	4.7	21.9	-	-	-
July 14	10:36	195	4.1	24.6	12.4, 12.4 (12.4)	30.7	3.5
August 1	11:09	213	5.1	25.4	-	-	-
August 15	11:13	227	3.6	23.2	13.8, 13,8 (13,8)	-	-
September 1	11:25	244	5.0	21.5	-	-	-
September 15	10:58	258	> depth	18.0	10.4, 10.4 (10.4)	-	-
September 30	11:26	273	> depth	17.7	-	-	-
October 18	10:44	291	> depth	11.3	9.4, 8.8 (9.1)	-	-

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 16	11:13	136	>depth	10.8	8.6, 9.0 (8.8)	30.8	4.1
May 31	11:08	151	>depth	16.5	-	-	-
June 17	11:04	168	>depth	18.4	9.2, 9.0 (9.1)	30.1	5.0
June 27	11:04	178	>depth	23.0	-	-	-
July 14	10:48	195	>depth	23.6	8.6, 8.8 (8.7)	-	-
August 1	11:23	213	>depth	24.5	-	-	-
August 15	11:27	227	>depth	22.3	10.4, 10.8 (10.6)	-	-
September 1	11:40	244	>depth	20.0	-	-	-
September 15	11:11	258	>depth	16.8	9.4, 10.0 (9.7)	-	-
September 30	11:36	273	>depth	15.6	-	-	-
October 18	10:57	291	>depth	8.1	7.8, 7.8 (7.8)	-	-

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 16	11:28	136	>depth	12.0	8.0, 8.0 (8.0)	30.4	7.6
May 31	11:17	151	>depth	17.2	-	-	-
June 17	11:17	168	>depth	18.7	10.4, 11.0 (10.7)	33.7	9.1
June 27	11:12	178	>depth	23.5	-	-	-
July 14	10:58	195	>depth	23.8	10.0, 10.0 (10.0)	-	-
August 1	11:33	213	>depth	24.8	-	-	-
August 15	11:40	227	>depth	22.4	9.8, 9.6 (9.7)	-	-
September 1	12:15	244	>depth	20.1	-	-	-
September 15	11:22	258	>depth	16.2	8.4, 8.2 (8.3)	-	-
September 30	11:46	273	>depth	14.1	-	-	-
October 18	11:05	291	>depth	8.2	6.8, 6.6 (6.7)	-	-

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 16	11:46	136	3.4	10.4	13.0, 12.4 (12.7)	28.4	3.6
May 31	11:26	151	>depth	15.8	-	-	-
June 17	11:39	168	>depth	18.2	10.0, 9.8 (9.9)	27.3	3.8
June 27	11:28	178	>depth	22.5	-	-	-
July 14	11:12	195	>depth	24.8	9.2, 10.4 (10.3)	-	-
August 1	11:43	213	>depth	25.0	-	-	-
August 15	11:57	227	>depth	23.0	12.2, 11.4 (11.8)	-	-
September 1	12:28	244	>depth	21.0	-	-	-
September 15	11:34	258	>depth	17.3	9.6, 9.8 (9.7)	-	-
September 30	12:06	273	>depth	17.8	-	-	-
October 18	11:23	291	>depth	10.8	8.8, 8.6 (8.7)	-	-

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 16	11:55	136	>depth	10.8	8.8, 8.6 (8.7)	27.9	3.6
May 31	11:40	151	>depth	16.9	-	-	-
June 17	11:51	168	>depth	18.2	10.6, 9.6 (10.1)	27.5	4.0
June 27	11:45	178	>depth	23.0	-	-	-
July 14	11:28	195	>depth	23.6	9.0, 8.8 (8.9)	-	-
August 1	11:54	213	>depth	24.3	-	-	-
August 15	12:12	227	>depth	22.1	9.2, 9.4 (9.3)	-	-
September 1	12:28	244	>depth	21.0	-	-	-
September 15	11:47	258	>depth	16.2	8.2, 8.2 (8.2)	-	-
September 30	12:15	273	>depth	15.2	-	-	-
October 18	11:33	291	>depth	8.0	8.4, 8.0 (8.2)	-	-

Temperatures taken 1 m from bottom. B= bottom temperature

Weather Conditions 2019

Date	Day of Year	Weather Conditions
May 16	136	Light rain on precious three days. High water levels on lake. Partly cloudy, but fairly bright. Air temperature: 10C.
May 31	151	Minor quantity of rain during past week; none over three days previous to sampling. Water levels remain high. Moderate pollen storm; no wind, sunny day with no clouds. Air temperature 12 to 15C.
June 17	168	No rain 24 hours previous to sampling; 26 mm of rain fell on four days previous to that; of that 15 mm two days previous to sampling. Clear and sunny with no wind. Air temperature: 20C.
June 27	178	High winds (40 km/hr. day before sampling, no rain during previous four days. Full sun day with no wind. Full sun day with no wind. Air temperature ranged from 15 to 20C.
July 14	195	Over cast skies; Air temperature 19 to 22C; Very windy previous day; 18 mm rain evening before sampling and 11 mm two days prior to that. Wind from 0 to 5 km/hr.
August 1	213	Air temperature from 20-24C; Full sun, no wind; 23 mm rain 2 days prior to sampling, otherwise, ten days of hot (>30C) dry weather.
August 15	227	Air temperature: 21-23C; Full sun day with no wind. No rain for previous 5 days. From Aug 5 to 9, 5.6 cm of rain fell.
September 1	244	Air temperature 10-15C; Full sun with no wind. 11 mm rain three days before sampling. Weather clear and calm since rainfall. Mats of tape grass seen on parts of the lake, Eurasian milfoil taking over shorelines.
September 15	258	Air temperature 13-15C; wind < 5 km/hr;5 mm rain on Sept 14; very windy (15 km/hr) for three previous days. Sunny weather with some clouds.
September 30	273	Air temperature 8 – 13 C; wind from 5 to 10 km/hr; full sunshine; no rain for 4 days prior to sampling. Lots of polysaccharide foam on lake, especially Hayes Bay.
October 18	291	Air temperature 7 – 8 C; wind from North about 15 km/hr; 32 mm rain two days prior to sampling. Cloud overcast conditions.

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.

Appendix 3 Summary of Artificial Materials Found in White Lake

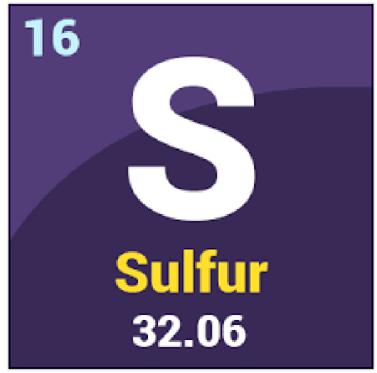
Table 1- Summary of artificial materials from ONSHORE White Lake sites on June 22 2019 (13:15-14:30)								
Sunny/Calm- Air 22C Water 20C								
Sample #	Location	Lat	Long	Fibres	Frag	Film	Total	Particle details
1a	Cedar Cove Resort	45.2612	76.507	3			3	2 Blue 1 Beige (natural)
1b				2			2	1 Blue 1 Blue (natural)
1c				2			2	1 Blue 1 Red
2a	Bayview Marina	45.3246	76.487				0	
2b				1			1	1 Red
3a	Bayview Lodge	45.3220	76.4824	2			2	2 Blue
3b				1			1	1 Blue
4	White Lake Outlet	45.3593	76.4976	4*			4*	2 Blue 2 bundles of clear fibres
5	White Lake Beach	45.3593	76.4976				0	
6a	Waba Cottage Museum	45.3613	76.505	6		1	7	5 Blue 1 Clear (large > 20mm) 1 Film Beige (2mm)
6b				2			2	1 Blue 1 Clear
7a	Private Dock (K. Krig)	45.2906	76.5215	3			3	3 Blue
7b				1			1	1 Blue
8a	Private Dock (S. Gottlieb)	45.2729	76.5513	2*			2*	1 Blue 1 Blue fibre bundle
8b				1			1	1 Black
			Total	30		1	31	

Table 2- Summary of artificial materials from ONSHORE White Lake sites on June 30 2019 (12:10-16:35)								
Overcast/Breezy- Air 17C Water 20C								
Sample #	Location	Lat	Long	Fibres	Frag	Film	Total	Particle details
1a	Cedar Cove Resort	45.2612	76.507		1		1	1 Fragment light blue
1b				4			4	2 Black 2 Blue
2a	Bayview Marina	45.3246	76.487	2			2	1 Blue 1 Orange (natural)
2b							0	
3a	Bayview Lodge	45.3220	76.4824	5*		1	6	2 Blue 1 Red 1 Black 1 Blue fibre bundle 1 Film blue
3b				6			6	3 Black 1 Blue 1 Red 1 Green
4a	White Lake Outlet	45.3593	76.4976			1	1	1 Film iridescent (paint?)
4b				1			1	1 Black
5a	White Lake Beach	45.3593	76.4976	3			3	2 Black 1 Blue
5b				1		2	3	1 Clear 2 Film iridescent (paint?)
6a	Waba Cottage Museum	45.3613	76.505	5	1		6	2 Blue 2 Red 1 Black 1 White spiral fragment
6b				2			2	1 Clear 1 Black
7a	Private Dock (K. Krig)	45.2906	76.5215			1	1	1 Film iridescent (paint?)
7b				1			1	1 Pink
8a	Private Dock (S. Gottlieb)	45.2729	76.5513				0	
8b							0	
			Total	30	2	5	37	

Table 3- Summary of artificial materials from OFFSHORE White Lake sites on July 13 2019 (13:30-15:15)								
Sunny/Slight to heavy chop/ 1-**2' waves and whitecaps later Air**- 26C								
Sample #	Location	Lat	Long	Fibres	Frag	Film	Total	Particle details
1	Donnely's Bay (Norway Pt. level)	45.3498	-76.5267	2			2	1 Black 1 Pink (thick 2mm)
2	Rocky Island	45.3355	-76.513	2			2	1 Blue 1 Black
3	Hayes Bay	45.3186	-76.4823				0	
4	Outer Hayes Bay	45.3223	-76.4926	2	1	1	4	1 Black 1 Blue 1 Green 1 Red (thick/solid)
5	Reids Bay	45.3108	-76.5125	2			2	2 Black
6	Channel west of Stanley Is.	45.2929	-76.5279	5			5	5 Black
7	Outer Pickerel Bay	45.2825	-76.509	2			2	1 Blue 1 Purple
8	Off NE Birch Is. (lake deep spot)	45.2767	-76.5344				0	
9	Channel west of Birch Is.	45.2758	-76.5429	3			3	1 Blue 1 Black 1 Clear
10	Channel west of McLuchlin's Is.	45.2702	-76.5524	1			1	1 Clear
11	Channel west of Hardwood Is.	45.2662	-76.5617	2			2	1 Blue 1 Black
12	Sunset Bay	45.2556	-76.598	1	1		2	1 Clear (natural) 1 Fragment clear tapered 'tube' shaped (20mm)
13	Picnic Point	45.2542	-76.5646	1			1	1 Black
14	Outer 3 Mile Bay	45.2624	-76.5413	1			1	1 Black
15	Inner 3 Mile Bay	45.2571	-76.4904				0	
16	Off Cedar Cove Resort	45.2594	-76.509	3			3	3 Blue
			TOTAL	27	2	1	30	

Table 4- Summary of artificial materials from OFFSHORE White Lake sites on July 18 2019 (13:10-15:25)								
Sunny/Calm to light chop later Air- 27C								
Sample #	Location	Lat	Long	Fibres	Frag	Film	Total	Particle details
1	Donnely's Bay (Norway Pt. level)	45.3498	-76.5267	2	1		3	2 Black 1 Red 1 White Fragment shard (3mm)
2	Rocky Island	45.3355	-76.513	3			3	2 Black 1 Red
3	Hayes Bay	45.3186	-76.4823				0	
4	Outer Hayes Bay	45.3223	-76.4926	3			3	3 Black
5	Reids Bay	45.3108	-76.5125	2			2	1 Black 1 Blue
6	Channel west of Stanley Is.	45.2929	-76.5279	1			1	1 Red
7	Outer Pickerel Bay	45.2825	-76.509	3			3	2 Black 1 Blue
8	Off NE Birch Is. (lake deep spot)	45.2767	-76.5344	1			1	1 White
9	Channel west of Birch Is.	45.2758	-76.5429	2			2	1 Black 1 Grey
10	Channel west of McLuchlin's Is.	45.2702	-76.5524	0			0	
11	Channel west of Hardwood Is.	45.2662	-76.5617	2			2	1 Blue 1 Black
12	Sunset Bay	45.2556	-76.598	2	2		4	2 Black 2 Red Fragments (2mm, 1mm)
13	Picnic Point	45.2542	-76.5646	1			1	1 Black
14	Outer 3 Mile Bay	45.2624	-76.5413	2			2	1 Black 1 Blue
15	Inner 3 Mile Bay	45.2571	-76.4904	1			1	1 Black
16	Off Cedar Cove Resort	45.2594	-76.509	2		1	3	2 Blue 1 White film (2mm)
			TOTAL	27	3	1	31	

27.0 Sulphate



Sulphur is a non-metallic element. The three most important sources of sulphur for commercial use are elemental sulphur, hydrogen sulphide (H_2S, found in natural gas and crude oil) and metal sulphides such as iron pyrites. Hexavalent sulphur combines with oxygen to form the divalent sulphate ion (SO_4^{2-}). Sulphates occur naturally in numerous minerals, including barite ($BaSO_4$), epsomite ($MgSO_4 \cdot 7H_2O$) and gypsum ($CaSO_4 \cdot 2H_2O$). The reversible interconversion of sulphate and sulphide in the natural environment is known as the "sulphur cycle." Sulphate enters the lake by a variety of ways including dust in the atmosphere, minerals in the local rocks and from human activity.

Sodium, potassium and magnesium sulphates are all soluble in water, whereas calcium and barium sulphates and the heavy metal sulphates are not. Dissolved sulphate may be reduced to sulphide, volatilized to the air as hydrogen sulphide, precipitated as an insoluble salt or incorporated in living organisms.

Sulphate levels in Canadian lakes typically range from 3 to 30 mg/L. Recent data from Ontario show similar levels in small lakes (12.7 ± 11.3 µg/ml); sulphate concentrations were 7.6 µg/ml in Lake Superior at Thunder Bay and 19 mg/L in Lake Huron at Goderich.

The average daily intake of sulphate from drinking water, air and food is approximately 500 mg, with food being the major source. The objective for sulphate concentrations in drinking water is ≤500 µg/ml, based on taste considerations.

Sulphate (µg/ml or ppm) - 2019

Sampling Site	May 16 (day 136)	June 17 (day 168)	July 14 (day 195)
Three Mile Bay	3.7	3.7	-
N. Hardwood Island	3.8	3.6	3.3
Middle Narrows	3.3	3.6	3.5
Jacob's Island	3.3	3.4	-
The Canal	3.2	3.3	-
Hayes Bay	3.4	3.2	-
Village Basin	3.1	3.2	-
Average Values	3.4 ± .2	3.4 ± .2	3.4 ± .1

Sulphate (µg/ml or ppm) - 2018

Sampling Site	May 18 (day 133)	June 15 (day 166)	July 15 (day 196)
Three Mile Bay	4.0	3.0	3.0
N. Hardwood Island	4.0	3.0	3.0
Middle Narrows	4.0	3.0	3.0
Jacob's Island	3.0	3.0	3.0
The Canal	3.0	3.0	3.0
Hayes Bay	3.0	3.0	3.0
Village Basin	3.4	3.3	3.0
Average Values	3.5 ± .5	3.0 ± .1	3.0 ± 0

Sulphate (µg/ml or ppm) - 2017

Sampling Site	May 16 (day 136)	June 14 (day 165)	July 15 (day 196)
Three Mile Bay	-	4.8	3.9
N. Hardwood Island	5.0	4.8	4.0
Middle Narrows	4.8	4.6	3.9
Jacob's Island	4.5	4.6	3.8
The Canal	4.2	4.3	3.4
Hayes Bay	4.2	3.9	3.0
Village Basin	4.3	4.3	4.3
Average Values	4.5 ± .3	4.6 ± .2	3.9 ± .3

The average concentrations for sulphate for 2017, 2018, and 2019 are similar varying by only by about 1 ppm. Sulphate concentrations are very low owing to the very high concentration of calcium in the water. Calcium sulphate is very insoluble which means that most of the sulphate entering the lake would precipitate to the lake bottom as solid particles. Sulphate concentrations in White Lake are well below drinking water or even aesthetic concentrations levels and therefore should be of no concern to lake users.

Note: This section is included as an addendum because results for both 2018 and 2019 arrived late in the writing and editing process of this report.