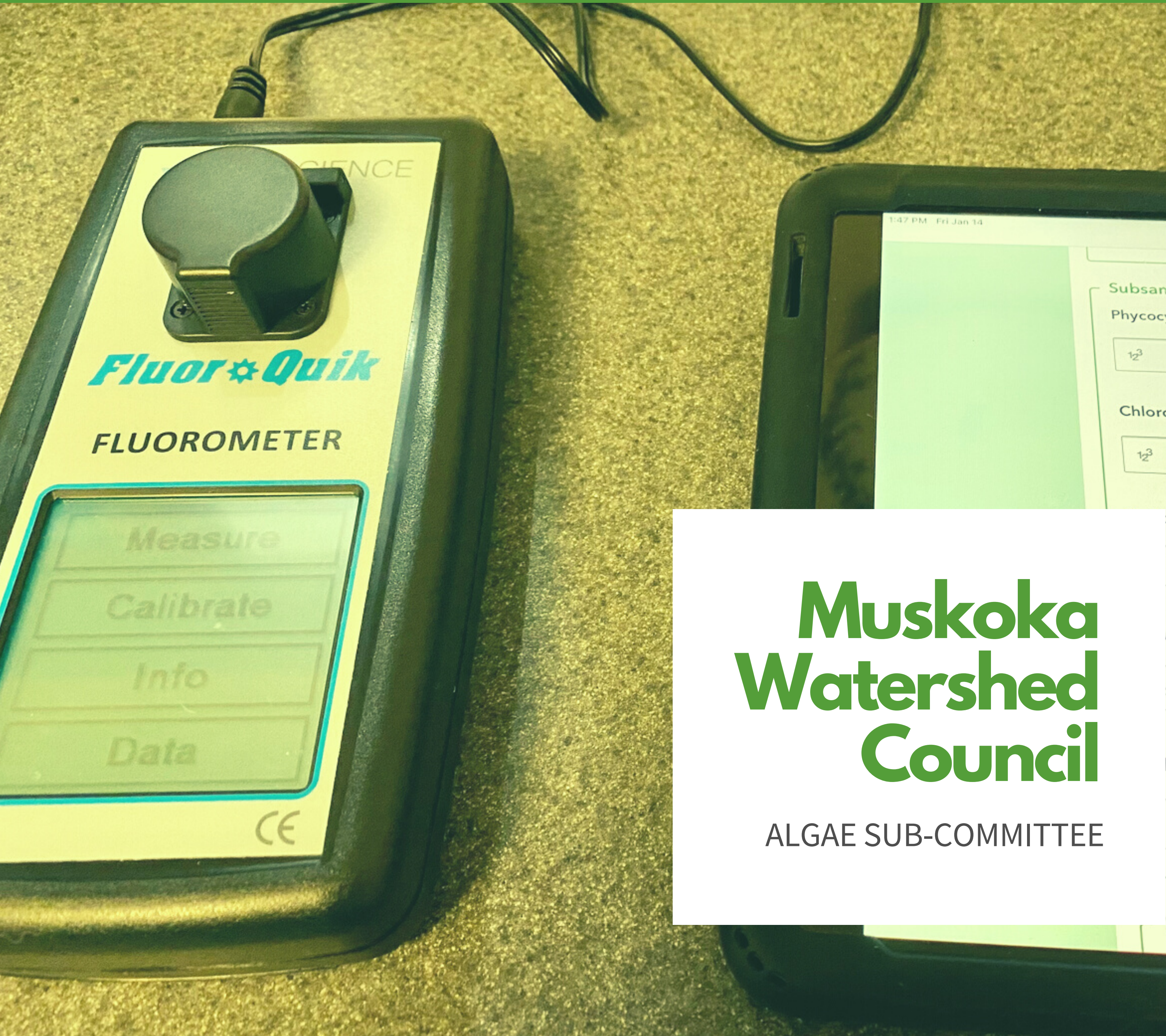
# Algae Monitoring Program

# 2021 Final Report

JUNE 2022

PILOT PROJECT




## Muskoka Watershed Council

ALGAE SUB-COMMITTEE

## Executive Summary

Muskoka Watershed Council established the Algae Sub-committee in April 2017 to investigate the development of a citizen science algae monitoring program in order to build an understanding of algae and algal blooms in Muskoka. Recent confirmation of blue-green algal blooms in area lakes, and a growing impression among the public that algae are more abundant than they used to be, have contributed to a growing concern about the future impacts of algal blooms in Muskoka.

Algae are an essential component of lake ecosystems and should always be present, but without information on the occurrence of algae in our lakes, or on how abundances vary through the seasons, among years, or across lakes, mechanisms or management procedures to control lake algae cannot be devised. This project is a first step in building that needed information.

Modelled closely on the Cyanobacteria Monitoring Collaborative's (CMC) algae monitoring program, the Algae Sub-committee devised a pilot project to be undertaken on a limited number of lakes in Muskoka to:

- Develop methods for fluorometric analysis of phytoplankton for use by lake associations interested in adding this to current water quality monitoring;
- Undertake explicit evaluations to ground-truth methods used;
- Develop information materials and a presentation on algae for delivery to lake associations and others; and
- Communicate these efforts to other lake associations across Muskoka during the year.

The pilot project was a two-year initiative that began in 2019 and concluded in 2021 (2020 was cancelled due to COVID-19). Year 1 of the pilot project (2019) focused on evaluating the sampling methodology outlined in the protocol manual (V.1), testing the effectiveness of the collection and analysis equipment, and comparing two sample collection methods. These were a) collection of a sample integrated through the water column to twice the measured secchi depth (2xSecchi), and b) collection of a sample integrated through the water column to a standard depth of 3 meters using a polypropylene tube of that length (IT). An analysis of the data obtained using the two methods showed that they are comparable, therefore in year two the 2xSecchi method was used as the only collection method. Results for the Year 1 pilot project are available in the interim report available at www.muskokawatershed.org/wp-content/uploads/AlgaeMonitoringProgram-2019Report-September2020.pdf. Year 2 of the pilot project (2021) continued to refine the sample collection and analysis methodology, and incorporated ad-hoc sampling of algal blooms if they occurred. This document will report the findings for Year 2 of the pilot project.

## Contents

## Introduction

Phytoplankton, a type of algae, are a diverse group of mid-water, microscopic, single-celled or colonial, photosynthesizing organisms that are found at the base of every lake food web. Through photosynthesis, they use solar energy, carbon dioxide and water to build organic molecules that allow for their own growth and provide food to zooplankton, and ultimately to fish and other animals. In the process of photosynthesis, they generate significant amounts of oxygen that is released to the atmosphere. Every second breath you take provides you with oxygen originally placed into the atmosphere by phytoplankton in lakes and oceans.

Unfortunately, on occasion, conditions can be particularly favorable for algal growth and reproduction. At these times, algal populations can become quite large, resulting in a visible scum on the lake surface. These algal blooms can develop over just a few days and can disappear just as fast as algal cells die and decompose. Severe blooms can deplete a lake of oxygen when decomposing, leading to fish kills and other serious disruptions to the lake ecosystem. They can also prove noxious, in appearance as well as odor, degrading our enjoyment of our lakes. In rare instances, the bloom-causing species produce toxins that can cause serious health risks to people and animals drinking or bathing in the water.

The identification of phytoplankton is a demanding, specialized task, as is the task of determining phytoplankton abundance by counting cells in water samples. Fortunately, photosynthesis requires specific pigments that also happen to be fluorescent molecules. By measuring absorbance due to fluorescence at a given wavelength, it is possible to quantify the amount of a specific pigment in a water sample. This value is a reliable index of the abundance in the sample of the phytoplankton containing that pigment.

The pigment, chlorophyll *a*, is present in the cells of all algae that occur in Muskoka area lakes; the pigment, phycocyanin, is present in all cells of cyanobacteria (also known as blue-green algae). By quantifying fluorescence of chlorophyll *a* in a water sample, it should be possible to provide an index of the amount of all phytoplankton species combined (including blue-green algae). Similarly, by quantifying fluorescence of phycocyanin it should be possible to provide an index for the amount of blue-green algal species present in that water sample. This is the approach being used in this project.

## Objectives

Muskoka Watershed Council initiated this program in order to gain a greater understanding of algae by harnessing the efforts of volunteers to collect data on the distribution, abundance and seasonal cycles of phytoplankton across Muskoka area lakes so that, over time, it may be possible to identify conditions favoring algae blooms, detect trends in phytoplankton abundance, and provide management advice. Monitoring at species level, tracking the abundance of individual species of algae, while ideal, is well beyond the capacity of a routine, citizen-led monitoring program. During the open water season, the overall abundance of phytoplankton will sometimes be made up predominantly of certain algal species while at other times the abundance will be predominantly of different algal species. Tracking abundance of individual species would require microscopic counting and identification of algal cells in water samples. This program aims to monitor all algae combined, and all blue-green algae combined, using fluorometric techniques.

Year 2 (2021) of the pilot project was undertaken in collaboration with the following five lake associations:

- Brandy Lake Association | Brandy Lake
- Leonard Lake Stakeholders' Association | Leonard Lake
- Muskoka Lakes Association | Clark Falls (Lake Rosseau near Windermere)
- Peninsula Lake Association | Peninsula Lake
- Three Mile Lake Association | Three Mile Lake

The purpose of the pilot project was to:

- Develop methods for fluorometric analysis of phytoplankton for use by lake associations interested in adding this to current water quality monitoring;
- Undertake explicit evaluations to ground-truth methods used;
- Develop information materials and a presentation on algae for delivery to lake associations and others; and
- Communicate these efforts to other lake associations across Muskoka during the year.

Following successful completion of the pilot project, the objectives of an ongoing Algae Monitoring Program would be to:

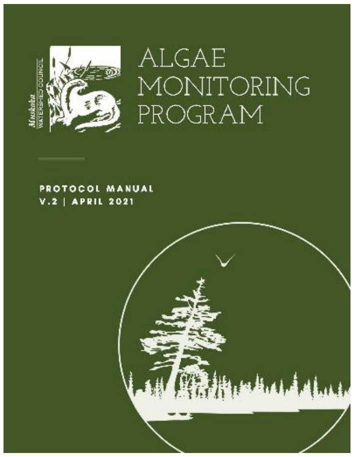
- Expand phytoplankton monitoring to interested lake associations across Muskoka as an addition to their existing water quality efforts;
- Develop information materials and presentations on algae for delivery to lake associations and others;
- Continue to collaborate with select lake associations on additional algal sampling to address specific issues of prevalence and/or causation of algal nuisance blooms;
- Evaluate the program in 2026 and decide whether to continue beyond that date; and
- Communicate these efforts to other lake associations across Muskoka.

## Background

The MWC Algae Monitoring Program is being undertaken in recognition of the growing concern across Muskoka regarding potentially toxic algal blooms on our lakes. While blooms remain rare in Muskoka, and toxic blooms even rarer, this concern is understandable given the potential for serious health risks, and more generally the aesthetic and environmental consequences of algal blooms. As well, climate change seems likely to exacerbate problem algal blooms across Muskoka. At present, there is only limited information on algae in our lakes, yet it seems possible that the army of dedicated citizen scientists who currently monitor water quality across Muskoka could make a significant contribution towards building a richer database concerning local algal populations.

In designing the sampling program for the pilot project, we relied extensively on the experience of a group operating across the New England states to track the incidence of blue-green algal blooms. With leadership provided by the University of New Hampshire and the U.S. Environmental Protection Agency, and drawing upon a 30+ year history leading citizen science monitoring of lake water quality, the 'Cyanobacteria Monitoring Collaborative' (CMC) provides a web-based program to aid citizen groups exploring blue-green algae.

While the CMC protocol formed the basis of MWC's procedures for collecting algae samples, on the advice of the scientists on MWC's Algae Sub-committee, some modifications were made to take into account the different environmental conditions present in Muskoka.




The MWC Algae Monitoring Program Monitoring Protocol Manual (v2) (https://www.dropbox.com/s/716984zc8u0jk00/AlgaeMonitoringProgram-Manual_v.2-April2021.pdf?dl=0) contains detailed instructions on the collection of algae samples for both offshore and nearshore samples, as well as the collection protocol in the event of an algal bloom.

In addition to the regular sampling efforts, one "special collection" protocol was undertaken; triplicate samples were collected from all sites once during the field collection season to assess the patchiness in distribution of algae in the water column of the lake.

## Ad-hoc Bloom Sampling Pilot

An ad-hoc bloom sampling protocol was developed for Year 2 of the pilot project to enable lake associations to document any significant blooms that occur on their lake in a consistent but flexible way by:

1. recording information about the extent and duration of the bloom, whether it moves over time, and the weather conditions at the time it occurred; and
2. collecting samples for fluorometric analysis over its course.

The ad-hoc bloom sampling protocol was to be undertaken in the event that a significant algal bloom occurred in the lake and is reported to the MECP Public Pollution Reporting hotline for confirmation. This protocol does NOT replace formal reporting of the bloom to the MECP, nor will the data collected be used to support or contradict the findings of regulatory authorities.

## Equipment and Protocol Adjustments

As the pilot progressed there were some minor adjustments made to the sample analysis protocol. These changes will be incorporated into the next version of the Protocol Manual.

## Results

The data collected during the 2021 sampling season are available in Figures 1-5, and the five tables in Appendix 1. The fluorometer (FluoroQuik™ Phycocyanin & Chlorophyll-a Dual-Channel Fluorometer (FQD-PC-CHL/IV-RATIO-C)) outputs data as phycocyanin (PC), chlorophyll *a* (CHL), and the ratio PC:CHL. This ratio has been found useful by lake biologists because it emphasizes changes in the relative proportions of blue-green to other algae and can indicate when algae with phycocyanin are dominating the community. Fluorescence results should be considered as indices of abundance rather than actual abundance of the algae.

All analyses of the fluorescence data have used the means of three subsamples taken from each of the thawed water samples as the best estimate of fluorescence of that water sample. These means are the values reported in Appendix 1.

## Trends in Algal Abundances Through the Season

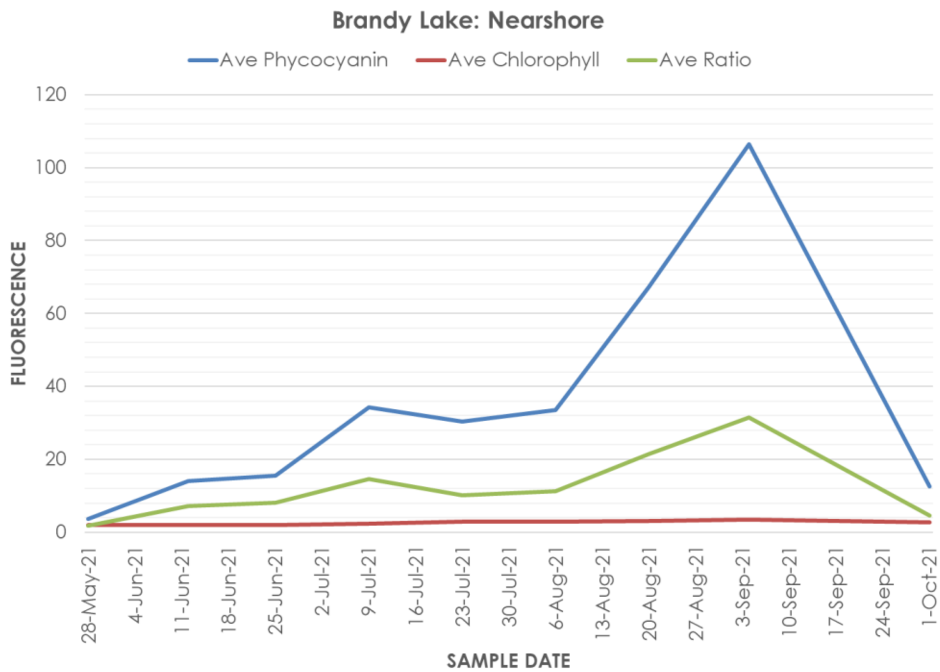
In Figures 1-5, for convenience, the three sets of data (mean values from three subsamples of water) are plotted on the same y-axis as trend lines through the season. These trends can be compared with each other or between lakes, so long as the relative heights of the trend lines are not interpreted to mean anything about actual abundance of blue-green or other algae. (To clarify, the trend line for phycocyanin is usually well above that for chlorophyll *a* (and the ratio trend may be higher still), but that does not mean that blue-green algae were more abundant than algae of other types.)

The data show the relative fluorescence of each pigment and provides an indication of how the blue-green and the total algal communities varied throughout the sampling season. The fluorometric readings obtained in the four lakes sampled both years showed generally similar patterns of variation through the season as in 2019. Chlorophyll *a* (CHL) values were consistently quite low and seasonal variation was rarely twofold, usually much less in the five lakes. Phycocyanin (PC) values were larger, varied at least 3-fold and usually about 10-fold. Phycocyanin values trended upwards through the season at least through September in three of the lakes, but this was not apparent in Leonard Lake or Peninsula Lake where phycocyanin values fluctuated with peaks both early and later in the season, much as all lakes had in 2019.

Bloom conditions were observed on Three Mile Lake between August 21 and 30, but while phycocyanin levels at the standard sampling sites were high at this time, they were not out of line with a seasonal upward trend, and thus do not provide any ‘signal’ of the moderately extensive bloom taking place in the north arm of the lake (the sampling sites are in the south-east arm). A bloom was also observed on Leonard Lake between August 18 and September 7, located close to the nearshore monitoring site. As on Three Mile Lake the PC values at the offshore site did not show any ‘signal’ of the bloom, however, samples at the nearshore site did show some elevated PC values during the period the bloom was visible. By August/September, PC values were substantially larger at both Three Mile Lake sites than were values obtained at Peninsula, Rosseau, or (with one exception) Leonard Lake. Phycocyanin values for Brandy Lake were comparable to those at Three Mile Lake. Lake characteristics such as depth and exposure to prevailing wind, and environmental factors such as turbidity, water temperature, and nutrient loading likely influence PC and CHL concentrations and help account for the differences in trends among lakes.

## Using the Ad-hoc Bloom Monitoring Protocol

Three Mile Lake and Leonard Lake each experienced a confirmed blue-green algae bloom in 2021 and the volunteers implemented the ad-hoc bloom sampling protocol (see data, Appendix 2). The results obtained provide useful guidance for how to improve the protocol for the future. Volunteers had some difficulty applying the protocol as written, but the larger issue is that the protocol does not result in adequate characterization of the location or extent of a bloom and of how this changed from day to day. Samples taken from near the bloom varied by over two orders of magnitude in each lake, and while variability over time was anticipated, it is not possible from the data collected to determine whether the variation seen among samples is due to small scale spatial patchiness in bloom density, or to rapid changes (<24 hours) in overall bloom density. Repeated sampling at the nearshore site in Leonard Lake during the nearly 3-week bloom period revealed a very similar pattern to sampling at the bloom sites nearby, while offshore samples remained much lower. These data indicate the highly variable nature of the bloom in time and space. There is a need to improve this protocol if data collected using it are going to provide a useful record of bloom behavior.



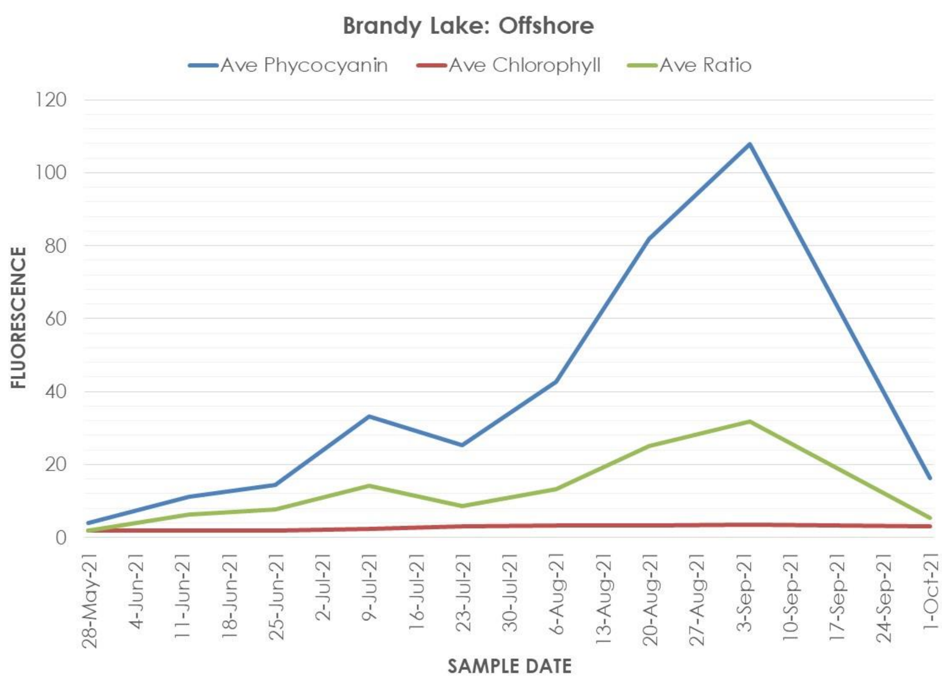
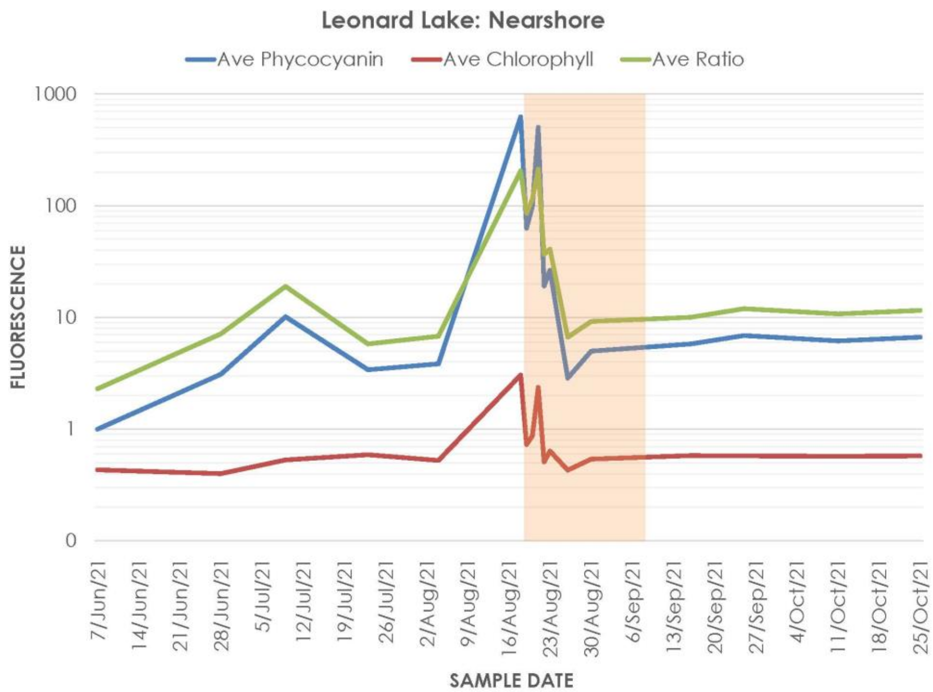




Figure 1: Chart with chlorophyll *a* and phycocyanin data for Brandy Lake in 2021 for the nearshore (top) and offshore (bottom) sites. The green line shows the ratio of phycocyanin to chlorophyll *a*.



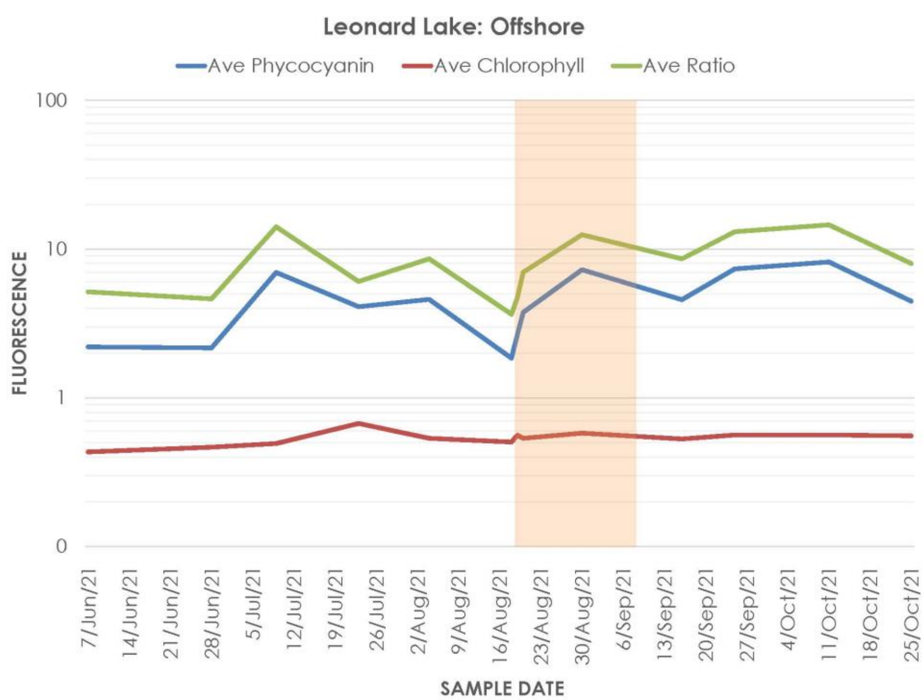
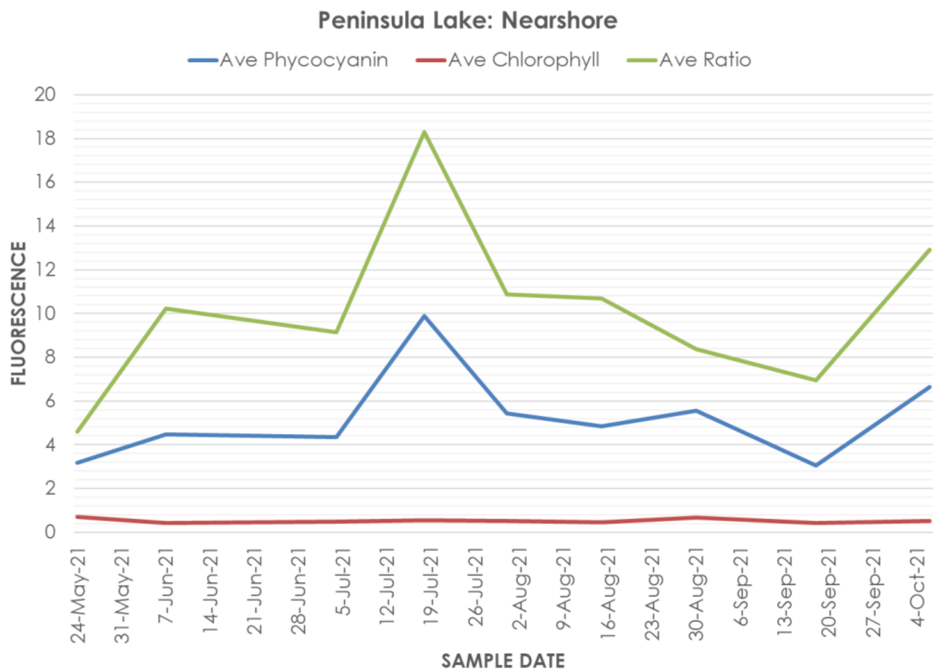




Figure 2: Chart with chlorophyll *a* and phycocyanin data for Leonard Lake in 2021 for the nearshore (top) and offshore (bottom) sites. The green line shows the ratio of phycocyanin to chlorophyll *a*. Due to high readings, the Y-axis is shown using a logarithmic scale. The shaded area shows the dates that Ad-hoc Bloom Sampling was conducted.



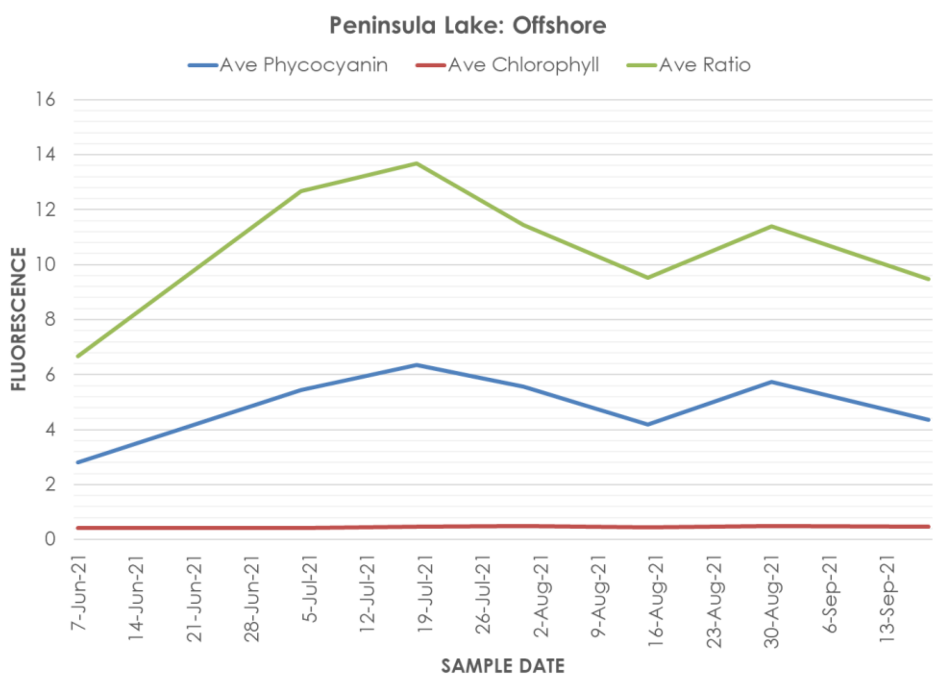
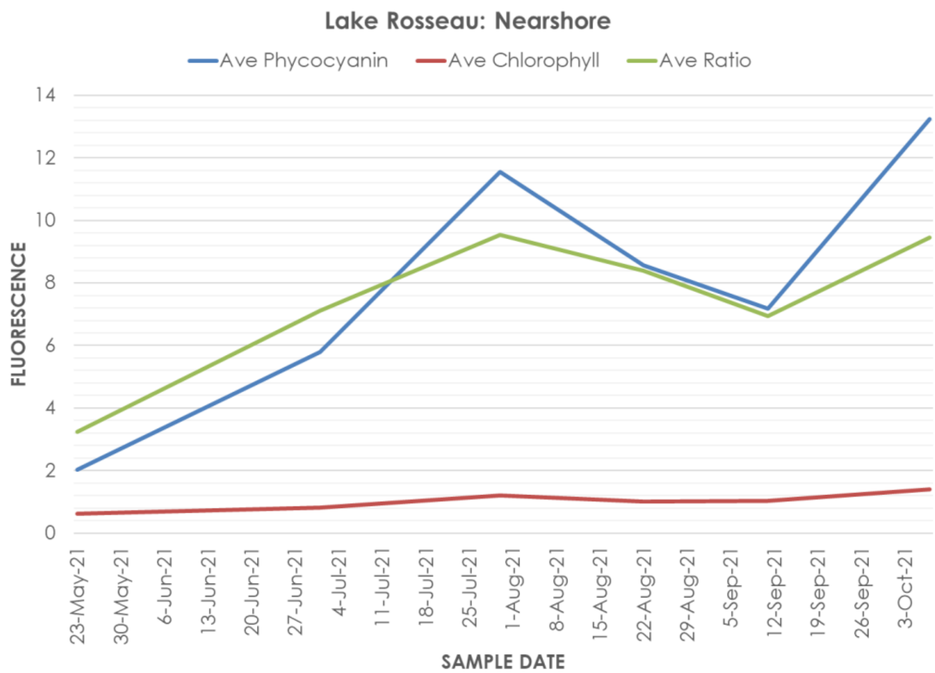




Figure 3: Chart with chlorophyll *a* and phycocyanin data for Peninsula Lake in 2021 for the nearshore (top) and offshore (bottom) sites. The green line shows the ratio of phycocyanin to chlorophyll *a*.



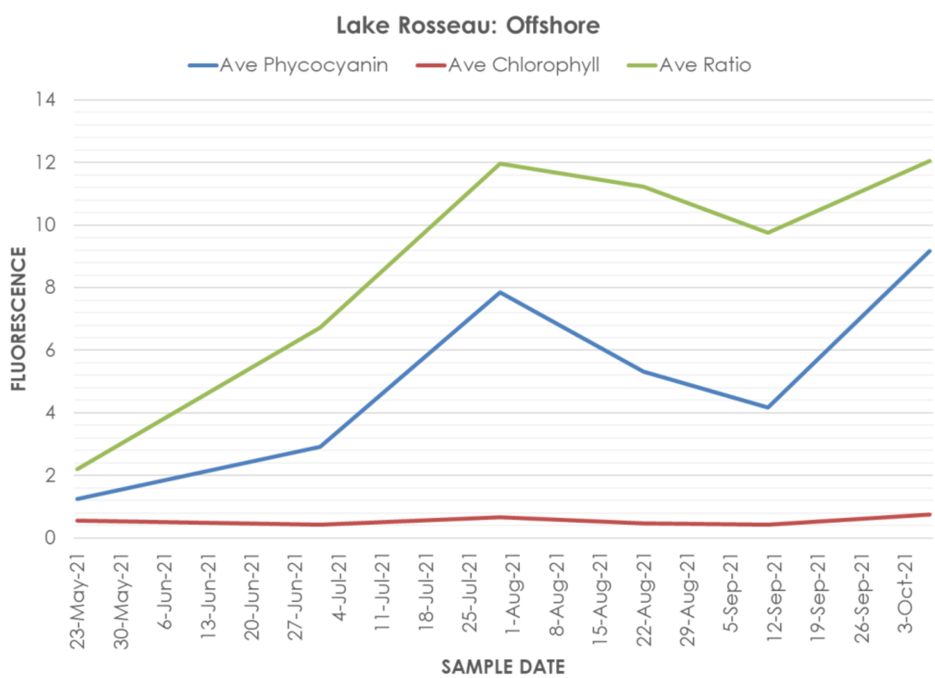
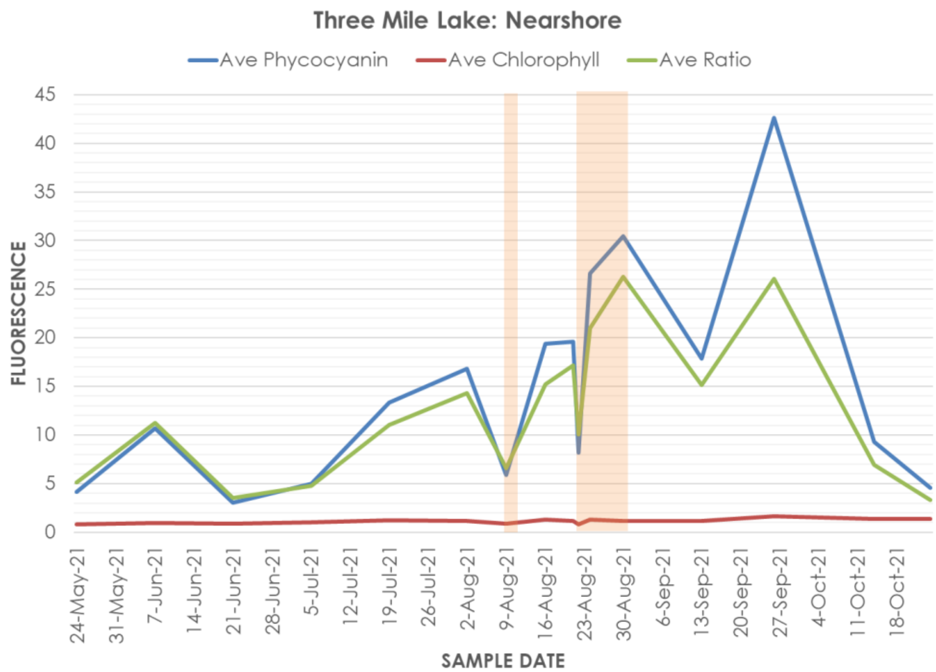




Figure 4: Chart with chlorophyll *a* and phycocyanin data for Lake Rosseau in 2021 for the nearshore (top) and offshore (bottom) sites. The green line shows the ratio of phycocyanin to chlorophyll *a*.



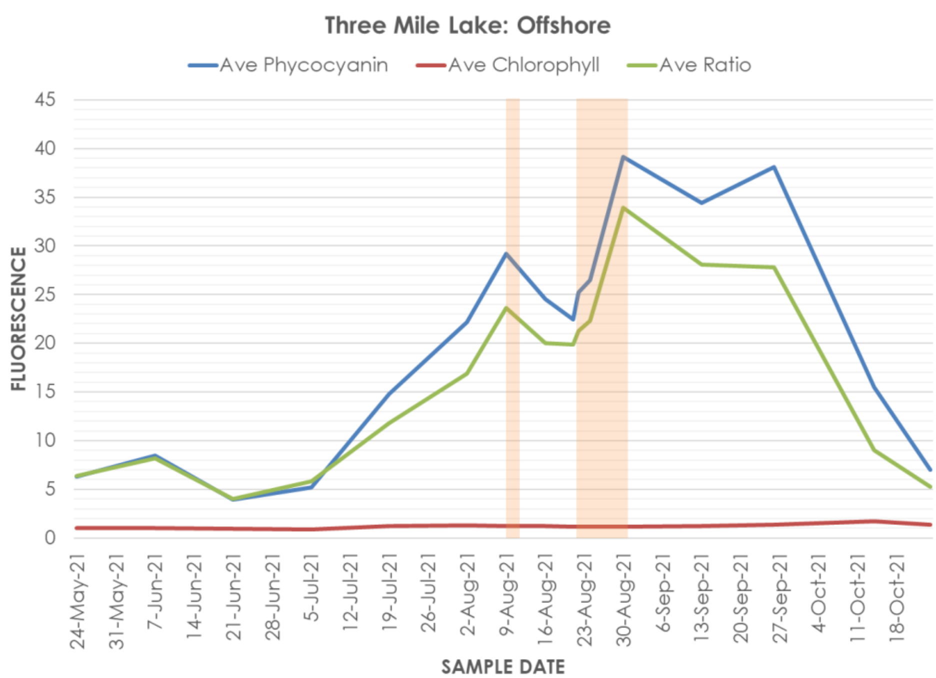




Figure 5: Chart with chlorophyll *a* and phycocyanin data for Three Mile Lake in 2021 for the nearshore (top) and offshore (bottom) sites. The green line shows the ratio of phycocyanin to chlorophyll *a*. The shaded area shows the dates that Ad-hoc Bloom Sampling was conducted.

## Analytical Precision and Small-scale Spatial Patchiness of Algae

Triplicate samples were collected during the regularly scheduled sampling event at the end of July/beginning of August and the data are included in the tables in Appendix 1. Using data from four lakes (we received only averaged data from one lake), we calculated the standard deviation of PC estimates among the three replicate subsamples from each water sample taken the day triplicate sampling was done. These ranged from 0.1 to 1.7 and averaged 0.82. They provide a measure of the precision of the analytical procedure.

We then examined the variation in mean PC estimates for the three samples taken at a site on that day and obtained standard deviations ranging from 0.036 to 3.04 and an average of 1.21. The similarity of these two averages – 0.82 and 1.21 – and the variation around each confirms that single samples of water provide a reasonable estimate of the abundances of algae at a site on a day. Small-scale spatial patchiness, which might be expected to lead to quite different amounts of algae collected in successive samples from the same site at a particular day, is not apparent. The patterns in variation through the season for each site can be confidently interpreted as real variation in algal abundances at each monitored site.

## Recommendations

Overall, the 2-Year Pilot Project was a success. Volunteer citizen scientists were able to collect water samples using the protocol developed and to maintain the samples in a frozen condition until analysed. Two groups obtained fluorometers and other equipment and one of these groups also analysed their own samples. Their analytical results were not different from ours. Only the bloom protocol, developed and trialed on two lakes in 2021, was found wanting. Some changes to the data collected when monitoring a bloom will be made in the revised manual to be provided for 2022 so that it is possible to see, in the data, more detail of location, extent, and change over the monitoring period of a followed bloom. To be of long-term value, such information must be encoded in the data collected and archived and that is not yet the case.

Given the overall success, it is recommended that the Algae Monitoring Program be opened up to additional Muskoka area lake associations for the 2022 sampling season with the following considerations:

- The number of new lake associations able to participate in 2022 be capped at approximately 10 (about ten new pairs of offshore/nearshore monitoring locations). This assumes the five lake associations that participated in the pilot project will be continuing.
- The program be subscription-based, at a cost of $250 per year per association for up to four (2 pairs) of sites. This subscription fee will be used to cover the cost of coordinating the Algae Monitoring Program, providing training, QA/QC of analytical procedures and results, managing the data, and developing an annual report and story map for permanent online access to the data.
- Lake associations be required to purchase a "Sampling Kit" when they join the Algae Monitoring Program at a cost of approximately $250. The Sampling Kit will include the equipment needed to collect the water samples for analysis, including a composite sampler, Secchi disc, 20-meter calibrated line, thermometer, 500 ml and 125 ml bottles, clipboard, pencil, protocol manual and a supply of sample labels. The five lake associations that participated in the pilot project will receive the Sampling Kit at no charge.

- Lake associations be required to carry out fluorometric analysis of the water samples themselves and submit the data online to MWC using the online forms developed for that purpose. To accomplish this, lake associations will have the option of purchasing an "Analysis Kit" that includes a fluorometer and associated equipment, thermometer, thawing basin and heater. The Analysis Kit will cost approximately $3,000 and may be too expensive for some lake associations to afford. To offset this, MWC should have two Analysis Kits available for lake associations to borrow for short periods of time (7 days) to analyze their respective water samples. Because samples are frozen, analysis of accumulated samples need only be done perhaps twice per year.
- Lake associations be required to submit all data by November 15th so the annual report can be produced in a timely manner.
- The Algae Monitoring Program is to be evaluated annually; following the 2026 season a more detailed evaluation will be made before deciding whether to continue for a further period of years.

## Acknowledgements

MWC would like to thank all who participated on the Algae Sub-committee (Appendix 2) for providing input and assisting with the development of this pilot program.

We are particularly grateful for the scientific expertise provided by Claire Holeton, Dr. Andrew Paterson and Dr. Jim Rusak, who assisted MWC in adapting the CMC protocol for use in Muskoka area lakes and provided ongoing guidance.

No citizen science monitoring program can exist without the citizen scientists, so MWC would like to thank the many volunteers from the Brandy Lake Association, Leonard Lake Stakeholders' Association, Muskoka Lakes Association, Peninsula Lake Association, and Three Mile Lake Association (Appendix 3) for donating their time and enthusiasm to collect water samples and helping MWC discover and solve issues related to the protocol and equipment.

## Appendix 1: Fluorometric Data Collected by Lake During Routine Sampling

**Table A1.** Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling Brandy Lake in 2021 for the nearshore (0562-a02n) and offshore (0562-a01o) sites, as well as the ratio of phycocyanin to chlorophyll *a* (PC:CHL). All readings are averages of three subsamples analysed. This relative fluorescence is correlated to the amount of algae (CHL) and cyanobacteria (PC), but is not equivalent to the concentration of pigments or cells.

| **Brandy Lake** | | | | | |
|---|---|---|---|---|---|
| **Site** | **Date** | **Triplicate?** | **PC** | **CHL** | **Ratio** |
| 0562-a01o | 2021-05-28 | no | 3.88 | 1.98 | 2.0 |
| 0562-a01o | 2021-06-12 | no | 11.22 | 1.81 | 6.2 |
| 0562-a01o | 2021-06-25 | no | 14.27 | 1.88 | 7.6 |
| 0562-a01o | 2021-07-09 | no | 33.21 | 2.33 | 14.2 |
| 0562-a01o | 2021-07-23 | yes | 25.46 | 2.89 | 8.8 |
| 0562-a01o | 2021-07-23 | yes | 24.05 | 2.92 | 8.2 |
| 0562-a01o | 2021-07-23 | yes | 26.31 | 2.98 | 8.8 |
| 0562-a01o | 2021-08-06 | no | 42.68 | 3.21 | 13.3 |
| 0562-a01o | 2021-08-20 | no | 81.97 | 3.28 | 25.0 |
| 0562-a01o | 2021-09-04 | no | 107.80 | 3.39 | 31.8 |
| 0562-a01o | 2021-10-01 | no | 16.29 | 3.09 | 5.3 |
| 0562-a02n | 2021-05-28 | no | 3.64 | 1.94 | 1.9 |
| 0562-a02n | 2021-06-12 | no | 13.97 | 1.92 | 7.3 |
| 0562-a02n | 2021-06-25 | no | 15.62 | 1.94 | 8.0 |
| 0562-a02n | 2021-07-09 | no | 34.19 | 2.34 | 14.6 |
| 0562-a02n | 2021-07-23 | yes | 28.88 | 2.99 | 9.7 |
| 0562-a02n | 2021-07-23 | yes | 34.50 | 2.96 | 11.7 |
| 0562-a02n | 2021-07-23 | yes | 27.59 | 3.05 | 9.0 |
| 0562-a02n | 2021-08-06 | no | 33.58 | 2.98 | 11.3 |
| 0562-a02n | 2021-08-20 | no | 67.36 | 3.13 | 21.5 |
| 0562-a02n | 2021-09-04 | no | 106.34 | 3.39 | 31.4 |
| 0562-a02n | 2021-10-01 | no | 12.56 | 2.75 | 4.6 |

**Table A2.** Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Leonard Lake in 2021 for the nearshore (2476-a03n) and offshore (2476-a01o) sites, as well as the ratio of phycocyanin to chlorophyll *a* (PC:CHL). This relative fluorescence is correlated to the amount of algae (CHL) and cyanobacteria (PC), but is not equivalent to the concentration of pigments or cells. Note that while triplicate samples were collected analyzed on July 23, only the mean values of the analyses of all three samples were reported to us.

| **Leonard Lake** | | | | | |
|---|---|---|---|---|---|
| **Site** | **Date** | **Triplicate?** | **PC** | **CHL** | **Ratio** |
| 2540-a01o | 2021-06-07 | no | 2.20 | 0.43 | 5.2 |
| 2540-a01o | 2021-06-28 | no | 2.17 | 0.47 | 4.6 |
| 2540-a01o | 2021-07-09 | no | 6.97 | 0.49 | 14.1 |
| 2540-a01o | 2021-07-23 | yes | 4.10 | 0.67 | 6.1 |
| 2540-a01o | 2021-08-04 | no | 4.60 | 0.54 | 8.6 |
| 2540-a01o | 2021-08-18 | no | 1.85 | 0.51 | 3.7 |
| 2540-a01o | 2021-08-19 | no | 2.65 | 0.56 | 4.7 |
| 2540-a01o | 2021-08-20 | no | 3.75 | 0.54 | 7.0 |
| 2540-a01o | 2021-08-30 | no | 7.27 | 0.58 | 12.5 |
| 2540-a01o | 2021-09-16 | no | 4.57 | 0.53 | 8.6 |
| 2540-a01o | 2021-09-25 | no | 7.37 | 0.56 | 13.1 |
| 2540-a01o | 2021-10-11 | no | 8.20 | 0.56 | 14.6 |
| 2540-a01o | 2021-10-25 | no | 4.47 | 0.56 | 8.0 |
| 2540-a03n | 2021-06-07 | no | 1.00 | 0.43 | 2.3 |
| 2540-a03n | 2021-06-28 | no | 3.10 | 0.40 | 7.1 |
| 2540-a03n | 2021-07-09 | no | 10.15 | 0.53 | 19.0 |
| 2540-a03n | 2021-07-23 | yes | 3.40 | 0.59 | 5.8 |
| 2540-a03n | 2021-08-04 | no | 3.85 | 0.53 | 6.8 |
| 2540-a03n | 2021-08-18 | no | 626.00 | 3.05 | 205.0 |
| 2540-a03n | 2021-08-19 | no | 63.00 | 0.73 | 85.5 |
| 2540-a03n | 2021-08-20 | no | 99.00 | 0.88 | 115.3 |
| 2540-a03n | 2021-08-21 | no | 503.67 | 2.37 | 213.0 |
| 2540-a03n | 2021-08-22 | no | 19.07 | 0.51 | 36.7 |
| 2540-a03n | 2021-08-23 | no | 26.53 | 0.64 | 41.0 |
| 2540-a03n | 2021-08-26 | no | 2.87 | 0.43 | 6.7 |
| 2540-a03n | 2021-08-30 | no | 5.00 | 0.54 | 9.2 |
| 2540-a03n | 2021-09-16 | no | 5.80 | 0.58 | 10.0 |
| 2540-a03n | 2021-09-25 | no | 6.90 | 0.58 | 12.0 |
| 2540-a03n | 2021-10-11 | no | 6.17 | 0.57 | 10.8 |
| 2540-a03n | 2021-10-25 | no | 6.67 | 0.58 | 11.6 |

**Table A3.** Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Peninsula Lake in 2021 for the nearshore (4309-a02n) and offshore (4309-a01o) sites, as well as the ratio of phycocyanin to chlorophyll *a* (PC:CHL). All readings are averages of three subsamples analysed. This relative fluorescence is correlated to the amount of algae (CHL) and cyanobacteria (PC), but is not equivalent to the concentration of pigments or cells.

| **Peninsula Lake** | | | | | |
|---|---|---|---|---|---|
| **Site** | **Date** | **Triplicate?** | **PC** | **CHL** | **Ratio** |
| 4309-a01o | 2021-05-24 | no | 2.80 | 0.69 | 4.1 |
| 4309-a01o | 2021-06-07 | no | 2.80 | 0.42 | 6.7 |
| 4309-a01o | 2021-07-04 | no | 5.44 | 0.43 | 12.7 |
| 4309-a01o | 2021-07-18 | no | 6.34 | 0.46 | 13.7 |
| 4309-a01o | 2021-07-31 | yes | 6.04 | 0.47 | 12.8 |
| 4309-a01o | 2021-07-31 | yes | 5.56 | 0.50 | 11.0 |
| 4309-a01o | 2021-07-31 | yes | 5.08 | 0.48 | 10.5 |
| 4309-a01o | 2021-08-15 | no | 4.18 | 0.44 | 9.5 |
| 4309-a01o | 2021-08-30 | no | 5.74 | 0.50 | 11.4 |
| 4309-a01o | 2021-09-18 | no | 4.36 | 0.46 | 9.5 |
| 4309-a02n | 2021-05-24 | no | 3.16 | 0.69 | 4.6 |
| 4309-a02n | 2021-06-07 | no | 4.48 | 0.44 | 10.2 |
| 4309-a02n | 2021-07-04 | no | 4.36 | 0.48 | 9.1 |
| 4309-a02n | 2021-07-18 | no | 9.88 | 0.54 | 18.3 |
| 4309-a02n | 2021-07-31 | yes | 5.26 | 0.45 | 11.6 |
| 4309-a02n | 2021-07-31 | yes | 6.52 | 0.54 | 12.4 |
| 4309-a02n | 2021-07-31 | yes | 4.48 | 0.52 | 8.7 |
| 4309-a02n | 2021-08-15 | no | 4.84 | 0.45 | 10.7 |
| 4309-a02n | 2021-08-30 | no | 5.56 | 0.66 | 8.4 |
| 4309-a02n | 2021-09-18 | no | 3.04 | 0.44 | 6.9 |
| 4309-a02n | 2021-10-06 | no | 6.64 | 0.51 | 12.9 |

**Table A4.** Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Lake Rosseau in 2021 for the nearshore (2476-a02n) and offshore (2476-a01o) sites, as well as the ratio of phycocyanin to chlorophyll *a* (PC:CHL). All readings are averages of three subsamples analysed. This relative fluorescence is correlated to the amount of algae (CHL) and cyanobacteria (PC), but is not equivalent to the concentration of pigments or cells.

| Lake Rosseau | | | | | |
|---|---|---|---|---|---|
| **Site** | **Date** | **Triplicate?** | **PC** | **CHL** | **Ratio** |
| 2476-a01o | 2021-05-23 | no | 1.24 | 0.56 | 2.2 |
| 2476-a01o | 2021-07-01 | no | 2.92 | 0.43 | 6.7 |
| 2476-a01o | 2021-07-30 | yes | 7.42 | 0.66 | 11.2 |
| 2476-a01o | 2021-07-30 | yes | 6.76 | 0.69 | 9.8 |
| 2476-a01o | 2021-07-30 | yes | 9.34 | 0.63 | 14.8 |
| 2476-a01o | 2021-08-22 | no | 5.32 | 0.47 | 11.2 |
| 2476-a01o | 2021-09-11 | no | 4.18 | 0.43 | 9.8 |
| 2476-a01o | 2021-10-07 | no | 9.16 | 0.76 | 12.0 |
| 2476-a02n | 2021-05-23 | no | 2.02 | 0.62 | 3.2 |
| 2476-a02n | 2021-07-01 | no | 5.80 | 0.82 | 7.1 |
| 2476-a02n | 2021-07-30 | yes | 11.58 | 1.20 | 9.7 |
| 2476-a02n | 2021-07-30 | yes | 11.52 | 1.26 | 9.1 |
| 2476-a02n | 2021-07-30 | yes | 11.52 | 1.17 | 9.8 |
| 2476-a02n | 2021-08-22 | no | 8.56 | 1.02 | 8.4 |
| 2476-a02n | 2021-09-11 | no | 7.18 | 1.03 | 6.9 |
| 2476-a02n | 2021-10-07 | no | 13.23 | 1.40 | 9.4 |

**Table A5.** Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Three Mile Lake in 2021 for the nearshore (5362-a02n) and offshore (5362-a01o) sites, as well as the ratio of phycocyanin to chlorophyll *a* (PC:CHL). All readings are averages of three subsamples analysed. This relative fluorescence is correlated to the amount of algae (CHL) and cyanobacteria (PC), but is not equivalent to the concentration of pigments or cells.

| Three Mile Lake | | | | | |
|---|---|---|---|---|---|
| **Site** | **Date** | **Triplicate?** | **PC** | **CHL** | **Ratio** |
| 5362-a01o | 2021-05-24 | no | 6.34 | 0.99 | 6.4 |
| 5362-a01o | 2021-06-07 | no | 8.44 | 1.03 | 8.2 |
| 5362-a01o | 2021-06-21 | no | 3.94 | 0.97 | 4.0 |
| 5362-a01o | 2021-07-05 | no | 5.20 | 0.89 | 5.9 |
| 5362-a01o | 2021-07-19 | no | 14.82 | 1.25 | 11.8 |
| 5362-a01o | 2021-08-02 | yes | 20.45 | 1.26 | 16.2 |
| 5362-a01o | 2021-08-02 | yes | 22.09 | 1.31 | 16.8 |
| 5362-a01o | 2021-08-02 | yes | 23.93 | 1.36 | 17.6 |
| 5362-a01o | 2021-08-09 | no | 29.18 | 1.23 | 23.6 |
| 5362-a01o | 2021-08-16 | no | 24.54 | 1.23 | 20.0 |
| 5362-a01o | 2021-08-21 | no | 22.46 | 1.13 | 19.9 |
| 5362-a01o | 2021-08-22 | no | 25.21 | 1.18 | 21.3 |
| 5362-a01o | 2021-08-24 | no | 26.49 | 1.19 | 22.3 |
| 5362-a01o | 2021-08-30 | no | 39.14 | 1.15 | 33.9 |
| 5362-a01o | 2021-09-13 | no | 34.43 | 1.23 | 28.1 |
| 5362-a01o | 2021-09-26 | no | 38.10 | 1.37 | 27.8 |
| 5362-a01o | 2021-10-14 | no | 15.49 | 1.71 | 9.0 |
| 5362-a01o | 2021-10-24 | no | 7.00 | 1.34 | 5.2 |
| 5362-a02n | 2021-05-24 | no | 4.12 | 0.81 | 5.1 |
| 5362-a02n | 2021-06-07 | no | 10.67 | 0.95 | 11.2 |
| 5362-a02n | 2021-06-21 | no | 3.04 | 0.87 | 3.5 |
| 5362-a02n | 2021-07-05 | no | 5.02 | 1.05 | 4.8 |
| 5362-a02n | 2021-07-19 | no | 13.35 | 1.21 | 11.1 |
| 5362-a02n | 2021-08-02 | yes | 18.37 | 1.25 | 14.7 |
| 5362-a02n | 2021-08-02 | yes | 13.29 | 1.02 | 13.1 |
| 5362-a02n | 2021-08-02 | yes | 18.73 | 1.23 | 15.2 |
| 5362-a02n | 2021-08-09 | no | 5.92 | 0.89 | 6.6 |
| 5362-a02n | 2021-08-16 | no | 19.40 | 1.27 | 15.2 |
| 5362-a02n | 2021-08-21 | no | 19.59 | 1.14 | 17.1 |
| 5362-a02n | 2021-08-22 | no | 8.20 | 0.82 | 10.1 |
| 5362-a02n | 2021-08-24 | no | 26.61 | 1.27 | 21.0 |
| 5362-a02n | 2021-08-30 | no | 30.46 | 1.16 | 26.3 |
| 5362-a02n | 2021-09-13 | no | 17.88 | 1.18 | 15.1 |
| 5362-a02n | 2021-09-26 | no | 42.62 | 1.63 | 26.1 |
| 5362-a02n | 2021-10-14 | no | 9.31 | 1.34 | 6.9 |
| 5362-a02n | 2021-10-24 | no | 4.60 | 1.37 | 3.3 |

## Appendix 2: Fluorometric Data Collected During Ad-hoc Bloom Sampling by Lake

| Lake | Collection Date | Site Description | Site Coordinates | Collection Method | PC | CHL | Ratio |
|---|---|---|---|---|---|---|---|
| Leonard | 2021-08-18 | Boat Launch | 45.06353, -79.44124 | Composite | 11.70 | 0.53 | 22.0 |
| Leonard | 2021-08-18 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 4648.00 | 17.25 | 269.0 |
| Leonard | 2021-08-19 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 955.33 | 4.53 | 210.7 |
| Leonard | 2021-08-19 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 131.50 | 0.97 | 136.0 |
| Leonard | 2021-08-20 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 62.67 | 0.75 | 83.0 |
| Leonard | 2021-08-20 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 1285.00 | 5.40 | 238.0 |
| Leonard | 2021-08-20 | 4 properties NW of Bloom | 45.07181, -79.45350 | Composite | 34.00 | 0.57 | 58.0 |
| Leonard | 2021-08-21 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 215.67 | 1.33 | 161.7 |
| Leonard | 2021-08-21 | 4 properties NW of Bloom | 45.07181, -79.45350 | Composite | 647.00 | 2.97 | 217.7 |
| Leonard | 2021-08-21 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 3084.00 | 11.97 | 258.0 |
| Leonard | 2021-08-22 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 113.67 | 0.87 | 129.7 |
| Leonard | 2021-08-23 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 374.33 | 2.00 | 187.0 |
| Leonard | 2021-08-23 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 18.17 | 0.62 | 28.9 |
| Leonard | 2021-08-23 | 4 properties NW of Bloom | 45.07181, -79.45350 | Composite | 9.57 | 0.57 | 16.6 |
| Leonard | 2021-08-23 | Boat Launch | 45.06353, -79.44124 | Composite | 8.40 | 0.61 | 13.8 |
| Leonard | 2021-08-23 | Boat Launch | 45.06353, -79.44124 | Scoop | 1373.00 | 5.83 | 235.7 |
| Leonard | 2021-08-26 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 17.70 | 0.49 | 36.0 |
| Leonard | 2021-08-26 | Boat Launch | 45.06353, -79.44124 | Scoop | 6.27 | 0.58 | 10.9 |
| Leonard | 2021-08-30 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 6.00 | 0.51 | 11.7 |
| Leonard | 2021-08-30 | Bloom - West Shore | 45.07097, -79.45164 | Scoop | 6.40 | 0.52 | 12.3 |
| Leonard | 2021-08-30 | 4 properties NW of Bloom | 45.07181, -79.45350 | Composite | 16.53 | 0.55 | 29.8 |
| Leonard | 2021-08-30 | Boat Launch | 45.06353, -79.44124 | Scoop | 9.50 | 0.58 | 16.2 |
| Leonard | 2021-09-07 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Scoop | 40.45 | 0.66 | 60.2 |
| Leonard | 2021-09-07 | 2540-a03n: 2 properties N of Bloom | 45.07112, -79.45269 | Composite | 13.87 | 0.57 | 23.4 |
| Three Mile | 2021-08-09 | North Hammel's Bay | 45.19482, -79.48215 | Scoop | 25.09 | 0.84 | 30.0 |
| Three Mile | 2021-08-10 | North Hammel's Bay | 45.19482, -79.48215 | Scoop | 19.77 | 0.84 | 23.5 |
| Three Mile | 2021-08-21 | South Hammel's Bay | 45.18466, -79.46557 | Scoop | 37.06 | 0.79 | 46.9 |
| Three Mile | 2021-08-22 | South Hammel's Bay | 45.18466, -79.46557 | Scoop | 32.66 | 0.77 | 42.4 |
| Three Mile | 2021-08-22 | Main Basin | | Scoop | 53.62 | 1.29 | 41.5 |
| Three Mile | 2021-08-23 | Main Basin | | Scoop | 15.00 | 1.02 | 14.8 |
| Three Mile | 2021-08-23 | South Hammel's Bay | 45.18466, -79.46557 | Scoop | 23.81 | 0.90 | 26.5 |
| Three Mile | 2021-08-25 | Main Basin | | Scoop | 102.74 | 2.34 | 43.9 |
| Three Mile | 2021-08-30 | South Hammel's Bay | 45.18466, -79.46557 | Scoop | 15.43 | 0.42 | 37.1 |

## Appendix 3: Participants of the Muskoka Watershed Council Algae Sub-committee

| Name | Affiliation |
|---|---|
| **Chair**: Dr. Peter F Sale | Muskoka Watershed Council |
| Chris Cragg | Muskoka Lakes Association |
| Christy Doyle | Muskoka Watershed Council |
| Rob Fullerton | Three Mile Lake Association |
| Ken Harper | Peninsula Lake Association |
| Claire Holeton | Ministry of the Environment, Conservation & Parks |
| Dr. Neil Hutchinson | Hutchinson Environmental Sciences Ltd. |
| Jim Marshall | Peninsula Lake Association |
| Christiane Masters | District Municipality of Muskoka |
| Dr. Andrew Paterson | Ministry of the Environment, Conservation & Parks |
| Carmen Pereira | Queen's University |
| Dr. Ken Riley | Leonard Lake Stakeholders' Association |
| Dr. Jim Rusak | Ministry of the Environment, Conservation & Parks |
| Dr. Ryan Sorichetti | Ministry of the Environment, Conservation & Parks |
| Wendy Somerville | Peninsula Lake Association |
| Rob Tanner | Three Mile Lake Association |
| Kevin Trimble | Muskoka Watershed Council |
| Bill Walker | Three Mile Lake Association |
| Susan Walker | Three Mile Lake Association |
| Rebecca Willison | Muskoka Watershed Council |

## Appendix 4: Volunteers participating in the 2021 MWC Algae Monitoring Pilot Project

### *Brandy Lake Association*

- Andy von Bredow
- Derek Stevens
- Kevin Trimble

### *Leonard Lake Stakeholders' Association*

- Esther Giesbrecht
- Bill Heatlie
- Betty Isbister
- Bruce McNeely
- Ken Riley

### *Muskoka Lakes Association*

- Chris Cragg
- Jane Schipper
- Stuart Schipper

### *Peninsula Lake Association*

- Gary Depew
- Ken Harper
- Marianne Harper
- Wendy Somerville

### *Three Mile Lake Association*

- Christine Condy
- Greg Weston