Algae Monitoring Program

2022 Final Report

MAY 2023

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 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 program 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 that was undertaken on a limited number of lakes in Muskoka in 2019 and 2021. Following the successful conclusion of the pilot project, the MWC Algae Monitoring Program was opened to additional interested organizations. Seven organizations joined the program in 2022 for a total of 12 lake associations participating (11 provided data in 2022).

The objectives of the Algae Monitoring Program are to:

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

This report presents the data collected and analysed in 2022. As more lakes are added, and as we collect data at each lake over multiple years, it is beginning to appear that a simple relationship between algal abundance, as measured by pigment fluorescence in frozen water sample, will not exist. Our 11 lakes differ in average levels of phycocyanin fluorescence through the late summer and fall suggesting they carry different average abundances of blue-green algae. But the four lakes that reported apparent blue-green algae blooms in 2022 (only three of which were confirmed by the Ministry of the Environment, Conservation and Parks) did not show similar patterns of average fluorescence, nor of trends through the season leading up to and through the time of the bloom. Blue-green algae bloom occurrence seems likely to be determined by a number of factors specific to a lake, the time of year, and the weather at that lake, of which blue-green algal abundance is just one. Further years' data should help clarify these results. No blooms of other types of algae were reported, and levels of chlorophyll *a* fluorescence were more consistent among lakes and through the sampling period than was the case for phycocyanin fluorescence.

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Introduction

The phytoplankton, or mid-water algae, are a diverse group of 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 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 algal 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. Instead, this program aims to monitor all algae combined, and all blue-green algae combined, using fluorometric techniques.

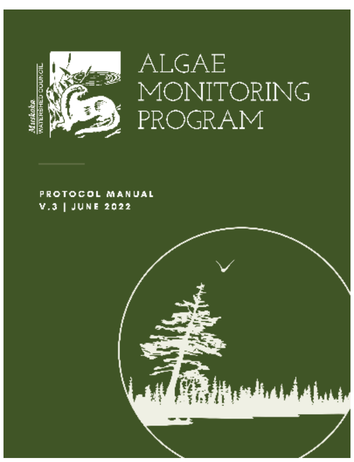
Following the successful completion of a pilot project in 2019 and 2021, the MWC Algae Monitoring Program was opened to interested organizations. The objectives of the program are to:

- 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, 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 consider the different environmental conditions present in Muskoka.

The MWC Algae Monitoring Program Monitoring Protocol Manual (v3) (https://www.dropbox.com/s/h6ssb1r4ohzujm8/AlgaeMonitoringProgram-Manual_v.3-June2022.pdf?dl=0) contains detailed instructions on the collection and analysis of algae samples for both offshore and nearshore samples.

Results

The data collected during the 2022 sampling season are available in Figures 1-4, and the 11 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 algae 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 abundances of the algae.

All analyses of the fluorescence data have used the means of three subsamples taken from each of the frozen, stored and then 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

Figures 1-4 present graphs of phycocyanin fluorescence (Figs. 1, 2) and chlorophyll *a* fluorescence (Figs. 3, 4) for the 11 lakes sampled in 2022. Notice in viewing Figures 1 and 2, that the phycocyanin fluorescence values vary greatly among lakes (the vertical axis on the individual plots are very different). The average levels of fluorescence and the details of the trend through time vary among lakes. In Figures 3 and 4, differences among lakes in chlorophyll *a* fluorescence are less pronounced, but some differences in the vertical axis are still present. Using a standard vertical axis for all figures would have made it difficult to show the fluctuations through time for many lakes.

It's also important to remember, in viewing these figures, that the fluorescence recorded is not a direct measure of the number of algal cells in the water. Across all lakes, fluorescence values for phycocyanin are much greater than fluorescence values for chlorophyll *a*, but that does not mean that blue-green algae were more abundant than algae of other types. Fluorescence of a pigment such as phycocyanin or chlorophyll *a* depends on the wavelength of light used to stimulate it. The fluorometer being used in this project is designed specifically for the field detection of blue-green algal blooms. It generates a single wavelength of light for chlorophyll *a*, and another single wavelength for phycocyanin. The wavelength used for phycocyanin produces high levels of fluorescence when phycocyanin is present in the sample; the wavelength used for chlorophyll *a* produces somewhat lower levels of fluorescence for typical abundances of chlorophyll *a*. With these caveats, let's look at Figures 1-4.

Blue-Green Algae

Fluorescence of phycocyanin is an index of the abundance of blue-green algae in a water sample. Figures 1 and 2 show that phycocyanin fluorescence levels vary, often markedly, through the sampling period for all lakes. Blue-green algae are present at every sample date, but their abundances vary seasonally in every lake.

The seasonal trends from lake to lake are not the same. In a few lakes (Brandy, Menominee), blue-green algae appear to have become less abundant as the season progressed. In others (Leonard, Rosseau, Three Mile), blue-green algae appear to have become more abundant towards the end of the sampling period. And in others (Kawagama, Mary, Peninsula, Six Mile, Stewart, and Vernon), there is no obvious increasing or decreasing trend in blue-green algal fluorescence. In addition, as already noted, there are big differences among lakes in the levels of fluorescence – blue-green algae appear to be more abundant in some lakes than others.

For lakes that were sampled in 2019 and 2021, the seasonal patterns also differ among years. Only Lake Rosseau has consistently shown an increasing trend in 2019, 2021 and 2022, although Three Mile showed an upward trend in 2021 and 2022, with the 2019 data less clear. We will require more years of data before we can discern whether there is reliable year-to-year similarity within a lake, in seasonal trend in phycocyanin fluorescence and therefore in blue-green algae abundance.

Figure 1: *Plots showing the level of phycocyanin fluorescence at offshore and nearshore sites for each sampling date on each of Brandy Lake, Kawagama Lake, Leonard Lake, Mary Lake, Menominee Lake and Peninsula Lake. Offshore sites have ID codes ending in* ***o****; nearshore sites have ID codes ending in* ***n****. In some lakes more than one* ***o*** *or* ***n*** *site was sampled. Note that the vertical axes on the individual plots are scaled differently – these lakes differ substantially in their average levels of phycocyanin fluorescence. Level of fluorescence is an index of blue-green algal abundance, not a direct measure of algal cell abundance in the sample. Data plotted are in Appendix 1, Tables A1 to A6. The plots for Leonard Lake and Mary Lake include a background tint showing the period commencing with the sighting of a bloom. The red line is the date SMDHU posted an advisory confirming a cyanobacterial bloom. In no case was the bloom resolved before the end of our sampling period but the presence of the background tint does not mean a bloom was visible during that entire period (see text for details).*

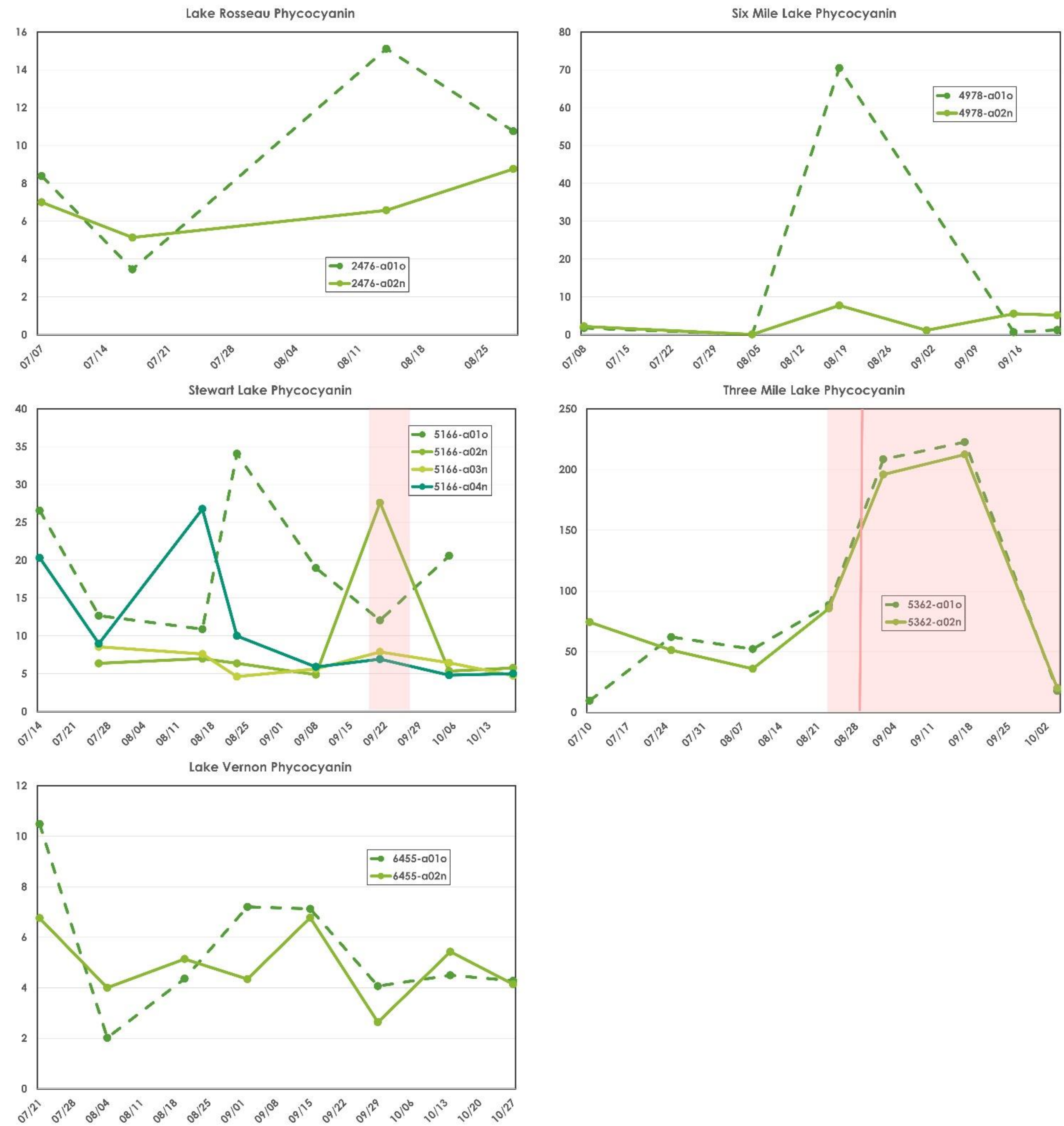


Figure 2: *Plots showing the level of phycocyanin fluorescence at offshore and nearshore sites for each sampling date on each of Lake Rosseau, Six Mile Lake, Stewart Lake, Three Mile Lake, and Lake Vernon. Offshore sites have ID codes ending in* ***o****; nearshore sites have ID codes ending in* ***n****. In some lakes more than one* ***o*** *or* ***n*** *site was sampled. Note that the vertical axes on the individual plots are scaled differently – these lakes differ substantially in their average levels of phycocyanin fluorescence. Level of fluorescence is an index of blue-green algal abundance, not a direct measure of algal cell abundance in the sample. Data plotted are in Appendix 1, Tables A7 to A11. The plots for Stewart Lake and Three Mile Lake include a background tint showing the period commencing with the sighting of a bloom. The red line is the date SMDHU posted an advisory confirming a cyanobacterial bloom. In no case was the bloom resolved before the end of our sampling period but the presence of the background tint does not mean a bloom was visible during that entire period (see text for details).*

All Algae

Chlorophyll *a* fluorescence is an index of total algal abundance including blue-green algae. Figures 3 and 4 summarize fluorescence values for all 11 sampled lakes through the sampling period. In contrast to the results for phycocyanin, chlorophyll *a* fluorescence shows little if any trend through the sampling season on any of the lakes (Three Mile Lake reveals a possible slight downward trend). Temporal variation was rarely two-fold, usually much less. In addition, there is much more consistency among lakes in fluorescence levels for chlorophyll *a*. Most lakes show fluorescence of less than 1.0, with Menominee Lake and Brandy Lake a little above 1.0, and Three Mile Lake around 3.0 to 4.0.

These data suggest that total algal abundance does not vary much through the season, nor very greatly from lake to lake. What does vary is the relative proportion of blue-green algae to other types of algae. Blue-green algae are proportionately much more abundant in some lakes at some times than at others.

Chlorophyll *a* fluorescence levels in previous years for the lakes sampled in 2019 or 2021also revealed little evidence of any trend through the sampling period in each year, and level of fluorescence was again mostly around 1.0.

Summary on Seasonal Trends in Fluorescence Results

It is too early to draw any firm conclusions concerning the temporal trends, average levels, or differences among lakes or years in the fluorescence data. A couple more years of monitoring will be needed before any definitive patterns start to emerge.

The results obtained to date, however, do suggest that a simplistic notion that algal abundances through the season might be used to infer whether a lake is likely to experience a blue-green algal bloom is unlikely to be confirmed. Algal populations experienced different patterns of change in abundance from lake to lake but results so far do not suggest it will be easy to identify lakes prone to algal blooms.

Average Levels of Phycocyanin Fluorescence in Late Summer and Fall

Blue-green algae typically bloom in late August through November in our lakes. To explore whether lakes that experienced blue-green algal blooms tended to exhibit higher levels of phycocyanin fluorescence during this time of year, we examined the mean and the maximum fluorescence values recorded for each sampled lake, from August 15th to whenever sampling ceased on that lake. The results are in Figures 5 and 6 for offshore sites and nearshore sites respectively.

There is considerable similarity between Figures 5 and 6. Mean values at the offshore site in each lake are close to mean values at nearshore sites in the same lake. Overall, the lakes appear to fall into three groups.

The first group of lakes has low average levels of phycocyanin fluorescence (<10) at offshore and nearshore sites. This group includes Leonard Lake, Mary Lake and Lake Vernon. Six Mile Lake would have been included in this group except for a single high fluorescence value on August 19th at the offshore site.

The second group has intermediate average values of phycocyanin fluorescence at both offshore and nearshore sites. Included are Brandy Lake, Kawagama Lake, Menominee Lake, Peninsula Lake, Lake Rosseau, Six Mile Lake and Stewart Lake. For these lakes, mean fluorescence levels at offshore sites ranged from 10 to 43. Nearshore mean fluorescence values were slightly lower, ranging from 4.7 to 40 (although only the Six Mile Lake site, the Lake Vernon site and one of the Stewart Lake nearshore sites had values below 8.7).

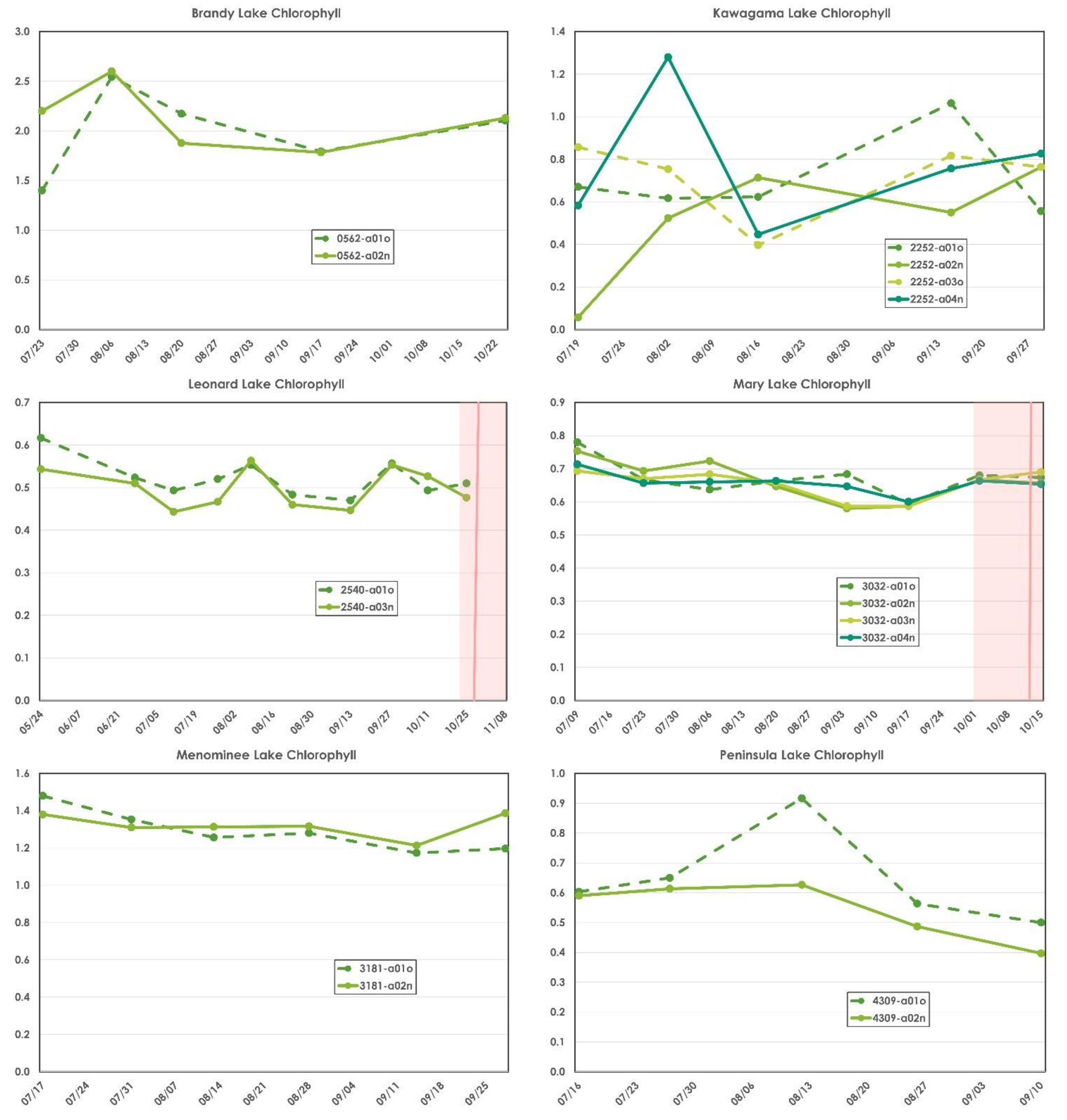


Figure 3: *Plots showing the level of chlorophyll a fluorescence at offshore and nearshore sites for each sampling date on each of Brandy Lake, Kawagama Lake, Leonard Lake, Mary Lake, Menominee Lake and Peninsula Lake. Offshore sites have ID codes ending in* ***o****; nearshore sites have ID codes ending in* ***n****. In some lakes more than one* ***o*** *or* ***n*** *site was sampled. Note that the vertical axes on the individual plots are scaled differently – these lakes differ substantially in their average levels of chlorophyll a fluorescence. Level of fluorescence is an index of algal abundance, not a direct measure of algal cell abundance in the sample. Data plotted are in Appendix 1, Tables A1 to A6. The plots for Leonard Lake and Mary Lake include a background tint showing the period commencing with the sighting of a bloom. The red line is the date SMDHU posted an advisory confirming a cyanobacterial bloom. In no case was the bloom resolved before the end of our sampling period but the presence of the background tint does not mean a bloom was visible during that entire period (see text for details).*

Figure 4: *Plots showing the level of chlorophyll a fluorescence at offshore and nearshore sites for each sampling date on each of Lake Rosseau, Six Mile Lake, Stewart Lake, Three Mile Lake, and Lake Vernon. Offshore sites have ID codes ending in* ***o****; nearshore sites have ID codes ending in* ***n****. In some lakes more than one* ***o*** *or* ***n*** *site was sampled. Note that the vertical axes on the individual plots are scaled differently – these lakes differ substantially in their average levels of chlorophyll a fluorescence. Level of fluorescence is an index of algal abundance, not a direct measure of algal cell abundance in the sample. Data plotted are in Appendix 1, Tables A7 to A11. The plots for Stewart Lake and Three Mile Lake include a background tint showing the period commencing with the sighting of a bloom. The red line is the date SMDHU posted an advisory confirming a cyanobacterial bloom. In no case was the bloom resolved before the end of our sampling period but the presence of the background tint does not mean a bloom was visible during that entire period (see text for details).*

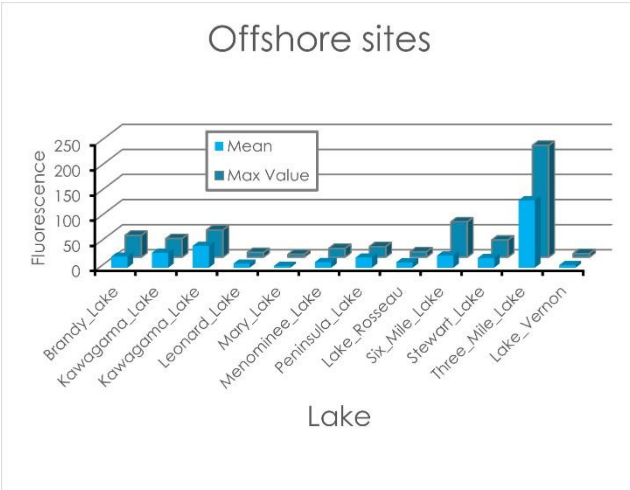


Figure 5: *Mean phycocyanin fluorescence and maximum phycocyanin fluorescence between 15 August and end of sampling period for all offshore sites on each lake.*

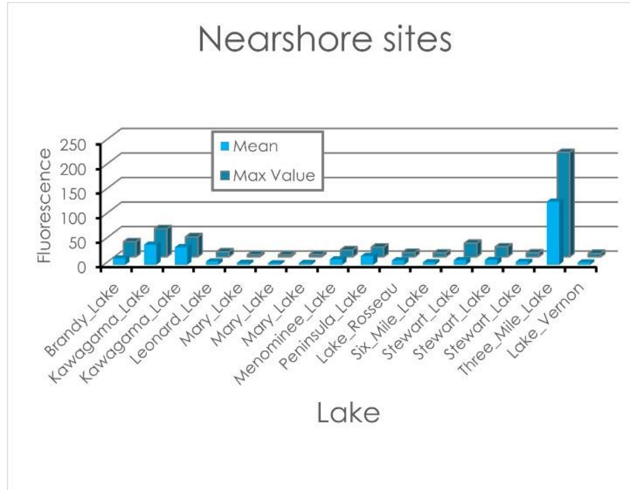


Figure 6: *Mean phycocyanin fluorescence and maximum phycocyanin fluorescence between 15th August and end of sampling period for all nearshore sites on each lake.*

The third group includes only Three Mile Lake with mean fluorescence values at both offshore and nearshore sites above 120. Three Mile Lake had a bloom that commenced in mid August and persisted through the remainder of the sampling period. It will be interesting to see if these three groupings of lakes persist in subsequent years.

Reported and Confirmed Blooms in 2022

In 2022, visible blooms were reported on Leonard Lake, Mary Lake, Stewart Lake and Three Mile Lake. In all cases, the following steps were taken. Blooms were reported to Ministry of Environment, Conservation and Parks (MECP) for testing and confirmation. If microscopic analyses revealed species of blue-green algae to be present and if algal density was such to constitute a bloom, toxicity testing was done, and, if a bloom was confirmed, the Simcoe Muskoka District Health Unit (SMDHU) issued a public notice of a blue-green bloom. Regardless of whether toxicity was detected, the bloom status remained in place until later in the season when SMDHU declared the bloom resolved. None of the blooms on lakes participating in this program in 2022 had detectable levels of toxicity.

There are inevitable delays in these inspection/evaluation procedures. The initial sighting of an apparent bloom precedes the public notice of a toxic bloom by 2-3 days, sometimes more, and the announcement by SMDHU that the bloom has been resolved often comes weeks or months after any visible evidence of algae has disappeared. This situation becomes more problematic if a lake is exhibiting transient blooms.

At Leonard Lake, small, transient blooms persisting 1-2 days were observed on July 16th, August 23rd, and October 6th. These were reported but had dissipated before MECP staff arrived to take samples. A fourth bloom was sighted on October 25th which remained visible until November 5th; MECP confirmed this bloom on October 28th and SMDHU issued a public notice although levels of toxin were not above the critical level. Resolution of this spill did not occur until December 13th.

A visible bloom was reported on Three Mile Lake on August 23rd. On August 29th, MECP confirmed a blue-green algal bloom with levels of cyanotoxin above the criterion and SMDHU posted an advisory for the lake. The bloom remained visible until after October 4th, the final monitoring date of the year for our program on this lake. SMDHU resolved this bloom December 14th.

On Mary Lake a visible bloom was reported on October 2nd. SMDHU issued the public notice confirming a toxic bloom on October 13th. The visible bloom had dissipated by the final monitoring date of the year on this lake, October 15th. SMDHU announced the bloom resolved on December 13th.

On Stewart Lake, routine weekly water testing by staff at the water treatment plant detected low levels of microcystin toxin in the water on September 6th and was duly reported to the MECP and SMDHU. Our volunteers reported a visible bloom on September 20th, however the weekly testing of water at the treatment plant was again yielding undetectable levels of toxin about the same time. SMDHU did not declare a bloom or issue a public notice.

Members of the public not associated with the MWC Algae Monitoring Program reported apparent blooms on Peninsula Lake on October 4th and on Menominee Lake on October 5th. In both cases, samples collected by the MECP revealed that algae were not present in a high enough abundance to indicate a bloom.

Discussion and Conclusions

Effectiveness of the Procedures Followed

The major change implemented in 2022 was to have individual lake associations responsible for the analyses in addition to the collection of water samples. This arrangement appears to have worked quite well, although some lake associations were late in getting their samples analysed. This delayed the preparation of this report.

A couple of lake associations had difficulty securing sufficient volunteer participation, especially later in the season. Given that blue-green algae tend to bloom well into the fall, it is important that sampling go into October, preferably past mid-month.

Based on the reasonable precision in the data collected in 2021, we did not include a collection of triplicate samples at any date in 2022 to evaluate sampling precision. This will likely be reinstated in 2023 as it is a good quality control procedure. Final decisions on any changes to the protocol and program design will need to be made before our planned training refresher workshop in spring 2023.

Patterns in Algae Abundance Through the Season and Across Lakes

With data available from 11 lakes this year, the impression gained in previous years that there would be substantial variation in pattern of fluctuations in abundance (as measured by fluorescence) was confirmed. We will need more years of data from these lakes in order to see if there are consistent patterns of either average abundance of blue-green algae or trend through time for individual lakes. That lakes differ substantially in abundance of blue-green algae through the season is interesting and raises questions about the factors responsible, but abundance through the season does not, at least with data now in hand, seem to predict the likelihood of a lake experiencing an algal bloom.

Blooms of algae other than blue-green algae, which tend to occur earlier in the summer months, have not yet been recorded on our monitored lakes. As well, the lower levels of fluorescence of chlorophyll *a* which the FluoroQuik™ instrument records, relative to the levels of fluorescence of phycocyanin, may make detection of trends in total algal abundance, or trends through time, more difficult. Since the major concern around algal blooms is the risk of blue-green algal blooms, that is a minor problem for this program.

In 2022, average levels of phycocyanin fluorescence from August 15th onwards suggested that the set of 11 lakes might fall into three categories. If this is confirmed in future years, it may be a way to categorize lakes of different types. Limited data on bloom occurrence in 2022 suggest, however, that any such categorization will not be correlated with risk of algal blooms in any simple way.

Lessons Learned and Plans for 2023

Any relationship between risk of blue-green algal blooms and patterns of abundance in lakes or through the season is not going to be simple. We will require additional years of data and a greater number of lakes in the program to build a dataset likely to permit the teasing out of such patterns.

The procedures and the sampling protocol, as well as the analytical methodology, appear to be amenable to being executed by volunteer citizen scientists with minimal in-season guidance. There is a need for an annual training/refresher workshop each spring to keep lake association teams of volunteers up to date with the methodology and attending to the small but important details in applying the methods. There is also a need to stress to lake associations and directly to volunteer teams that the program needs sampling to continue as late into the fall as possible. While it is difficult to anticipate all details that should be recorded, the experience in 2022 suggests volunteers should record, and report, the details of any sightings of a bloom, reporting of that bloom and subsequent follow-up by MECP and SMDHU. Data publicly available on the websites of those agencies are quite limited, and our understanding of bloom occurrence, and potentially of its relationship to prior blue-green abundance derived from the fluorescence records, requires a bit more information than we have asked for (whether a bloom was present or absent at each sampling date).

Given the overall success, it is recommended that the Algae Monitoring Program be opened up to additional Muskoka area lake associations for the 2023 sampling season with the following considerations:

- The number of new lake associations able to participate in 2023 be capped at approximately eight (about eight new pairs of offshore/nearshore monitoring locations). This assumes the 12 participating lake associations will be continuing.
- The program will continue to 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 are required to purchase a "Sampling Kit" when they join the Algae Monitoring Program at a cost of approximately $250. The Sampling Kit includes 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. Costs for replacement items for lake associations already enrolled will be determined on a cost recovery basis.
- Lake associations will continue 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 is a one-time cost of approximately $3,000. MWC will continue to 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 will be required to submit all data by November 15th so the annual report can be produced in a timely manner. This did not happen in 2022 and caused significant delays.
- 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 have participated on the Algae Sub-committee. While it meets relatively infrequently now that the program is up and running, this group still provides valuable input on the annual reports and on any modifications made to the methods being used.

We are particularly grateful for the scientific expertise provided by Dr. 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 11 Lake Associations that sampled their lakes in 2022 (we look forward to the Ril Lake Association becoming an active participant in 2023). These citizen scientists donated their time, their ideas, and their enthusiasm to collect water samples and are 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 on Brandy Lake in 2022 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**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
0562-a01o	2022-07-23	No	31.14	1.40	22.23
0562-a01o	2022-08-06	No	59.18	2.54	23.19
0562-a01o	2022-08-20	No	43.51	2.17	20.01
0562-a01o	2022-09-17	No	15.69	1.79	8.72
0562-a01o	2022-10-24	No	6.78	2.10	3.22
0562-a02n	2022-07-23	No	35.43	2.20	16.10
0562-a02n	2022-08-06	No	49.69	2.60	19.14
0562-a02n	2022-08-20	No	30.65	1.88	16.33
0562-a02n	2022-09-17	No	6.71	1.78	3.76
0562-a02n	2022-10-24	No	1.99	2.13	0.93

Table A2. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Kawagama Lake in 2022 for the nearshore (2252-a02n, 2252-a04n) and offshore (2252-a01o, 2252-a03o) 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.

Kawagama Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
2252-a01o	2022-07-19	No	25.80	0.67	38.82
2252-a01o	2022-08-02	No	95.08	0.62	318.07
2252-a01o	2022-08-16	No	22.33	0.62	37.35
2252-a01o	2022-09-15	No	29.38	1.06	36.56
2252-a01o	2022-09-29	No	37.10	0.56	69.06
2252-a02n	2022-07-19	No	27.21	0.06	205.11
2252-a02n	2022-08-03	No	32.83	0.52	64.28
2252-a02n	2022-08-16	No	33.16	0.71	49.66
2252-a02n	2022-09-15	No	57.14	0.55	105.61
2252-a02n	2022-09-29	No	32.16	0.76	36.11
2252-a03o	2022-07-19	No	42.20	0.86	49.56
2252-a03o	2022-08-03	No	48.92	0.75	70.41
2252-a03o	2022-08-16	No	41.19	0.40	170.67
2252-a03o	2022-09-15	No	54.15	0.82	67.07
2252-a03o	2022-09-29	No	34.73	0.76	44.99
2252-a04n	2022-07-19	No	43.79	0.58	73.97
2252-a04n	2022-08-02	No	28.64	1.28	24.98
2252-a04n	2022-08-16	No	40.59	0.45	112.28
2252-a04n	2022-09-15	No	28.54	0.76	34.60
2252-a04n	2022-09-29	No	38.10	0.83	45.88

Table A3. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Leonard Lake in 2022 for the nearshore (2540-a03n) and offshore (2540-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.

Leonard Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
2540-a01o	2022-05-24	No	3.97	0.62	6.43
2540-a01o	2022-06-27	No	4.37	0.52	8.40
2540-a01o	2022-07-11	No	3.37	0.49	6.97
2540-a01o	2022-07-27	No	4.57	0.52	8.77
2540-a01o	2022-08-08	No	5.37	0.55	9.73
2540-a01o	2022-08-23	Yes	8.70	0.48	18.00
2540-a01o	2022-09-13	No	6.20	0.47	13.23
2540-a01o	2022-09-28	No	9.40	0.56	16.90
2540-a01o	2022-10-11	No	8.93	0.49	18.17
2540-a01o	2022-10-25	Yes	6.90	0.51	13.53
2540-a03n	2022-05-24	No	3.70	0.54	6.83
2540-a03n	2022-06-27	No	6.53	0.51	12.63
2540-a03n	2022-07-11	No	2.73	0.44	6.17
2540-a03n	2022-07-27	No	3.73	0.47	8.03
2540-a03n	2022-08-08	No	3.27	0.56	5.80
2540-a03n	2022-08-24	Yes	4.03	0.46	8.77
2540-a03n	2022-09-14	No	4.13	0.45	9.27
2540-a03n	2022-09-28	No	8.50	0.55	15.40
2540-a03n	2022-10-11	No	10.07	0.53	19.13
2540-a03n	2022-10-25	No	5.87	0.48	12.33

Table A4. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Mary Lake in 2022 for the nearshore (3032-a02n, 3032-a03n, 3032-a04n) and offshore (3032-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.

Mary Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
3032-a01o	2022-07-09	No	5.92	0.78	7.59
3032-a01o	2022-07-23	No	4.01	0.67	6.00
3032-a01o	2022-08-06	No	3.82	0.64	6.00
3032-a01o	2022-08-20	No	3.88	0.66	5.84
3032-a01o	2022-09-04	No	3.70	0.68	5.54
3032-a01o	2022-09-17	No	2.80	0.59	4.72
3032-a01o	2022-10-02	Yes	5.68	0.68	8.35
3032-a01o	2022-10-15	No	2.68	0.67	3.98
3032-a02n	2022-07-09	No	6.70	0.75	8.88
3032-a02n	2022-07-23	No	3.28	0.69	4.73
3032-a02n	2022-08-06	No	4.78	0.72	6.61
3032-a02n	2022-08-20	No	3.70	0.65	5.72
3032-a02n	2022-09-04	No	3.34	0.58	5.74
3032-a02n	2022-09-17	No	4.30	0.59	7.33
3032-a02n	2022-10-02	Yes	4.12	0.67	6.17
3032-a02n	2022-10-15	No	2.92	0.66	4.44
3032-a03n	2022-07-09	No	2.98	0.69	4.29
3032-a03n	2022-07-23	No	5.02	0.67	7.49
3032-a03n	2022-08-06	No	3.70	0.68	5.41
3032-a03n	2022-08-20	No	3.52	0.66	5.30
3032-a03n	2022-09-04	No	3.46	0.59	5.96
3032-a03n	2022-09-17	No	2.74	0.59	4.65
3032-a03n	2022-10-02	Yes	3.28	0.67	4.91
3032-a03n	2022-10-15	No	4.42	0.69	6.40
3032-a04n	2022-07-09	No	3.40	0.71	4.76
3032-a04n	2022-07-23	No	4.96	0.66	7.55
3032-a04n	2022-08-06	No	3.52	0.66	5.34
3032-a04n	2022-08-20	No	2.80	0.66	4.22
3032-a04n	2022-09-04	No	2.80	0.65	4.33
3032-a04n	2022-09-17	No	3.52	0.60	5.86
3032-a04n	2022-10-02	Yes	1.96	0.66	2.95
3032-a04n	2022-10-15	No	3.88	0.65	5.94

Table A5. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Menominee Lake in 2022 for the nearshore (3181-a02n) and offshore (3181-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.

Menominee Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
3181-a01o	2022-07-17	No	32.41	1.48	21.87
3181-a01o	2022-07-31	No	18.85	1.35	13.97
3181-a01o	2022-08-13	No	14.84	1.26	11.78
3181-a01o	2022-08-28	No	17.44	1.28	13.61
3181-a01o	2022-09-14	No	8.35	1.17	7.11
3181-a01o	2022-09-28	No	7.57	1.20	6.32
3181-a02n	2022-07-17	No	28.33	1.38	20.53
3181-a02n	2022-07-31	No	19.62	1.31	14.96
3181-a02n	2022-08-13	No	24.54	1.31	18.66
3181-a02n	2022-08-28	No	13.93	1.32	10.60
3181-a02n	2022-09-14	No	8.07	1.21	6.64
3181-a02n	2022-09-28	No	10.98	1.39	7.93

Table A6. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Peninsula Lake in 2022 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**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
4309-a01o	2022-07-16	No	10.04	0.60	16.60
4309-a01o	2022-07-27	No	20.96	0.65	32.26
4309-a01o	2022-08-12	No	31.56	0.92	34.25
4309-a01o	2022-08-26	No	19.38	0.56	35.16
4309-a01o	2022-09-10	No	21.13	0.50	42.11
4309-a02n	2022-07-16	No	13.92	0.59	23.61
4309-a02n	2022-07-27	No	18.78	0.61	30.67
4309-a02n	2022-08-12	No	21.86	0.63	34.93
4309-a02n	2022-08-26	No	19.76	0.49	40.67
4309-a02n	2022-09-10	No	15.65	0.40	39.85

Table A7. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Lake Rosseau in 2022 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**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
2476-a01o	2022-07-07	No	8.39	0.70	11.54
2476-a01o	2022-07-17	No	3.46	0.40	8.72
2476-a01o	2022-08-14	No	15.12	0.56	63.38
2476-a01o	2022-08-28	No	10.76	0.54	18.82
2476-a02n	2022-07-07	No	7.00	0.89	7.69
2476-a02n	2022-07-17	No	5.14	0.74	6.71
2476-a02n	2022-08-14	No	6.58	0.72	9.09
2476-a02n	2022-08-28	No	8.77	0.84	9.81

Table A8. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Six Mile Lake in 2022 for the nearshore (4978-a02n) and offshore (4978-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.

Six Mile Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
4978-a01o	2022-07-08	No	1.78	0.25	7.40
4978-a01o	2022-08-04	No	0.10	0.07	1.92
4978-a01o	2022-08-18	No	70.49	0.27	262.49
4978-a01o	2022-09-15	No	0.68	0.30	2.41
4978-a01o	2022-09-22	No	1.26	0.32	3.71
4978-a02n	2022-07-08	No	2.21	0.85	2.84
4978-a02n	2022-08-04	No	0.10	0.31	0.32
4978-a02n	2022-08-18	No	7.75	0.11	75.91
4978-a02n	2022-09-01	No	1.19	0.37	3.04
4978-a02n	2022-09-15	No	5.57	0.39	12.09
4978-a02n	2022-09-22	No	5.18	0.28	19.40

Table A9. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Stewart Lake in 2022 for the nearshore (5166-a02n, 5166-a03n, 5166-a04n) and offshore (5166-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.

Stewart Lake					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
5166-a01o	2022-07-14	No	26.58	1.17	22.66
5166-a01o	2022-07-26	No	12.68	0.95	13.34
5166-a01o	2022-08-16	No	10.89	0.83	13.17
5166-a01o	2022-08-23	No	34.08	1.03	32.96
5166-a01o	2022-09-08	No	18.97	0.91	20.68
5166-a01o	2022-09-21	Yes	12.06	0.85	14.21
5166-a01o	2022-10-05	No	20.59	0.90	22.80
5166-a02n	2022-07-26	No	6.38	0.73	8.74
5166-a02n	2022-08-16	No	6.99	0.71	9.91
5166-a02n	2022-08-23	No	6.38	0.58	11.04
5166-a02n	2022-09-08	No	4.88	0.70	6.93
5166-a02n	2022-09-21	Yes	27.61	0.90	30.55
5166-a02n	2022-10-05	No	5.36	0.69	7.77
5166-a02n	2022-10-18	No	5.77	0.63	9.14
5166-a03n	2022-07-26	No	8.56	0.88	9.69
5166-a03n	2022-08-16	No	7.61	0.74	10.25
5166-a03n	2022-08-23	No	4.62	0.47	13.22
5166-a03n	2022-09-08	No	5.63	0.67	8.37
5166-a03n	2022-09-21	Yes	7.88	0.71	11.06
5166-a03n	2022-10-05	No	6.45	0.68	9.47
5166-a03n	2022-10-18	No	4.75	0.63	7.54
5166-a04n	2022-07-14	No	20.32	1.02	19.88
5166-a04n	2022-07-26	No	8.97	0.80	11.21
5166-a04n	2022-08-16	No	26.79	0.99	26.90
5166-a04n	2022-08-23	No	10.00	0.77	12.97
5166-a04n	2022-09-08	No	5.90	0.72	8.22
5166-a04n	2022-09-21	Yes	6.93	0.71	9.73
5166-a04n	2022-10-05	No	4.81	0.64	7.38
5166-a04n	2022-10-18	No	5.02	0.58	8.62

Table A10. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Three Mile Lake in 2022 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**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
5362-a01o	2022-07-10	No	9.59	1.82	6.56
5362-a01o	2022-07-25	No	62.11	6.90	9.20
5362-a01o	2022-08-09	No	52.15	2.03	26.15
5362-a01o	2022-08-23	Yes	88.45	3.28	28.18
5362-a01o	2022-09-02	Yes	208.50	3.81	54.78
5362-a01o	2022-09-17	Yes	222.72	3.13	71.28
5362-a01o	2022-10-04	Yes	17.58	1.04	16.89
5362-a02n	2022-07-10	No	74.40	4.57	15.87
5362-a02n	2022-07-25	No	51.24	3.92	16.31
5362-a02n	2022-08-09	No	35.90	1.57	23.08
5362-a02n	2022-08-23	Yes	85.64	3.47	24.68
5362-a02n	2022-09-02	Yes	195.93	4.24	46.70
5362-a02n	2022-09-17	Yes	212.47	2.73	77.82
5362-a02n	2022-10-04	Yes	20.04	1.06	18.83

Table A11. Chlorophyll *a* (CHL) and phycocyanin (PC) data collected during routine sampling on Lake Vernon in 2022 for the nearshore (6455-a02n) and offshore (6455-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 Vernon					
Site	**Date**	**Bloom?**	**PC**	**CHL**	**PC:CHL**
6455-a01o	2022-07-21	No	10.49	0.94	11.18
6455-a01o	2022-08-04	No	2.02	0.80	2.50
6455-a01o	2022-08-20	No	4.36	0.70	6.23
6455-a01o	2022-09-02	No	7.21	0.83	8.63
6455-a01o	2022-09-15	No	7.13	0.82	8.63
6455-a01o	2022-09-29	No	4.07	0.82	4.97
6455-a01o	2022-10-14	No	4.50	0.83	5.43
6455-a01o	2022-10-27	No	4.28	0.83	5.18
6455-a02n	2022-07-21	No	6.76	0.80	8.44
6455-a02n	2022-08-04	No	4.00	0.70	5.59
6455-a02n	2022-08-20	No	5.14	0.67	7.67
6455-a02n	2022-09-02	No	4.34	0.78	5.39
6455-a02n	2022-09-15	No	6.78	0.75	8.98
6455-a02n	2022-09-29	No	2.64	0.72	3.58
6455-a02n	2022-10-14	No	5.43	0.80	6.77
6455-a02n	2022-10-27	No	4.14	0.80	5.11