Monitoring Water Bodies with Harmful Algal Blooms: A Canadian Landscape Scan

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Research summary

In addition to their impact on environmental health, algal blooms on freshwater lakes and rivers are a concern for the households, businesses and governments that rely on them as sources of raw water and for recreational and aesthetic enjoyment. Algal blooms refer to any mass growth of planktonic or benthic algae, which may be dominated by cyanobacteria (so-called "blue-green algae"[1]) or by eukaryotic algae (Watson *et al*., 2015; Watson and Boyer, 2015).

Excess phosphorus in water - due primarily to run-off of fertilizers from agricultural land but also to sewage treatment plant effluent and urban stormwater run-off – has been identified as a key driver of algal blooms, as phosphorus is essential for all plant growth. Climate change is another driving factor, as warmer water increases plant reproduction rates. Invasive species are yet another driver. Zebra mussels, for example, clarify water through their filter-feeding, allowing light to penetrate more deeply into the water column and promoting plant growth (Pick, 2016).

The concern with algal blooms has several dimensions. Planktonic blooms dominated by cyanobacteria may produce toxins, such as the liver toxins known as microcystins, that can be harmful and even lethal to humans, livestock, pets, birds, fish and other wildlife. Non-toxic "nuisance" blooms are also a concern. Blooms of the benthic filamentous green algae *Cladophora*, for example, commonly foul shorelines of freshwater lakes with dense, rotting algal mats that can clog municipal and industrial water intakes, impair water quality and inshore habitat and pose microbial health risks to wildlife and humans (International Joint Commission, 2014). The bacterial degradation of beached *Cladophora* generates foul odours from the production of methyl sulphides and other organic compounds (Watson, 2004). The blooms may impart unpleasant tastes and odours to water, requiring higher levels of treatment if the water is to be used for human consumption. Together, hazardous and nuisance algal blooms may be referred to as HNABs.

HNABs have been found to impose significant economic costs in the few instances where this has been studied. Smith *et al.* (2019) report that the long-term costs imposed on users of Lake Erie's ecological goods and services due to the blooms that regularly impact the lake are likely

[1] Cyanobacteria, or "blue-green algae" are not, strictly speaking, algae but, in fact, a type of bacteria.

to amount to $5.3 billion if nothing is done to reduce phosphorus loadings to the lake. The greatest costs were found to be imposed on tourism operators ($2.2 billion) and so-called "non-users" who value the lake for its intrinsic worth ($1.8 billion). Property owners, recreational users, commercial fishers and water treatment plants were also found to suffer significant costs. Though similar estimates are not available for other Canadian freshwater bodies impacted by HNABs, it seems safe to say that the costs would be several times this amount if estimates for all freshwater bodies were available.

Though Lake Erie is arguably the best-known Canadian lake touched by HNABs, HNABs occur on a large and increasing number of freshwater bodies in Canada (Winter *et al.*, 2011; Pick, 2016). This "rise of slime" has been most dramatic in the large, inland lakes found along the edge of the Canadian Shield: Lake Champlain, Lake Ontario, Lake Erie, Lake of the Woods and Lake Winnipeg. Lake Winnipeg has had the dubious distinction of being called "Canada's sickest lake" (Pick, 2016). Many smaller lakes are also affected (Winter *et al.*, 2011).

In spite of the increasing extent and seriousness of the issue, an estimate of the total number of freshwater bodies affected by HNABs across the country is not available today. No monitoring is done by the federal government and the approaches taken to monitoring by provincial agencies[2] vary widely. Moreover, current monitoring approaches do not lend themselves to estimation of the total number of water bodies affected or to an understanding of the severity of the blooms in terms of area affected, duration or concentration of algae and/or toxins.

Monitoring by provincial agencies relies in the first instance on the reporting of suspected blooms by concerned third parties. The agencies will then – depending on the jurisdiction – dispatch an inspector to confirm the presence of the bloom through water sampling and testing or simply take note of the report.[3] Obviously, water bodies with blooms that go unreported (either because they are not visited by people or because the bloom goes unnoticed or unreported for some other reason) cannot be identified as impacted. Given this, it is all but impossible that the number of water bodies identified as impacted in a given year would equal the actual number of impacted water bodies, as some of those impacted will almost certainly go unreported.

In addition, comparison of the number of bodies impacted from year-to-year cannot be relied upon as a gauge of changing severity, since the likelihood of reporting blooms will increase over time as citizens become more aware of HNABs and their impacts on human and environmental health. Population growth will also tend to drive reports upward, both because there are more people to notice blooms and because people encroach on previously pristine parts of the environment as the population grows. Changes in agencies' approaches to monitoring can also render comparisons over time unmeaningful (see, for example, the discussion of Quebec's monitoring program below).

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[2] No monitoring is done by any territorial agencies.

[3] This is especially the case in instances where blooms are reported on water bodies for which blooms have been regularly confirmed in the past.

The monitoring approaches taken by provincial agencies across the country and the type of data currently available are outlined below. The approaches are heterogenous and no province provides anything today that could be taken as an accurate estimate of the total number of impacted water bodies within its boundaries. Many provinces monitor and report blooms only for provincially managed beaches. Some provinces (and all territories) provide no quantitative information at all. Given this, there is no possibility of estimating the total number of freshwater bodies impacted by HNABs in Canada based on data available today.

In order to estimate the total number of impacted water bodies, either the federal or provincial/territorial governments would have to establish statistically valid water-quality monitoring programs. Such programs would have to select random and representative samples of water bodies for standardized monitoring over time. The programs would then have to be permanently funded and staffed so monitoring could be carried out as designed. With such programs in place, it would be possible to establish both a statistically valid estimate of the total number of impacted water bodies across the country as well as to assess the trend in this figure over time. To date, only one province (Ontario) has implemented anything resembling such a system, though it falls short of what would be required (see the discussion below).

Newfoundland and Labrador: In Newfoundland and Labrador (NL), monitoring of HNABs is carried out by staff of the Water Resources Management Division of the Department of Municipal Affairs and Environment. The Department responds to citizen reports of possible HNABs by sending inspectors to take water samples, which are sent for analysis to the York Durham Regional Environmental Lab in Ontario. The first confirmed HNABs in NL occurred in several "ponds" (lakes) near St. John's, possibly as a result of a large influx of nutrients due to heavy rains following tropical storm Chantal on August 1, 2007. Since then, those water bodies and a few others in which blooms have since been reported and confirmed have been monitored each summer. In total, 11 water bodies have been inspected and found to have HNABs in various years since 2007. The number of bodies with confirmed blooms has varied from a low of zero (2010 and 2011) to a high of four (2007). All of the water bodies with confirmed blooms have been located on the Avalon Peninsula near St. John's, where population density is the greatest in the province. Annual reports on HNAB occurrences from 2017 to 2018 are available from the website of the Department of Municipal Affairs and Environment.

Prince Edward Island: Monitoring of HNABs in Prince Edward Island (PEI) is carried out by the Department of Environment, Water and Climate Change. Monitoring began in 2004, when a bloom was confirmed in the Murray River. Since then, eleven blooms have been confirmed in five different water bodies, with no more than two blooms in any given year and none in the years 2006, 2007, 2009, 2011, 2012, 2014 and 2017. PEI's monitoring approach relies on response to public reporting of possible blooms. A summary of confirmed blooms from 2004 to 2018 is available on the Department's website.

Nova Scotia: The Government of Nova Scotia provides no public information on the occurrence of HNABs in the province.

New Brunswick: When an HNAB report by a member of the public is confirmed through testing by the New Brunswick Department of Environment and Local Government, the impacted water body is added to a running list maintained on the Department's website as a public advisory.[4] The advisory remains on the list indefinitely as a warning to "visitors to be aware that [a bloom] could possibly recur since the area has had blue-green algae blooms in the past. Future sampling of the area [is] not undertaken to rescind any advisories due to the unpredictability of blue-green algae blooms." As of 2019, 16 water bodies were included on the HNAB public advisory list, with the earliest bloom reported in 2008 and the most recent addition in 2019. Blooms were also added in 2010, 2015, 2017 and 2018.

Quebec: Quebec has the most comprehensive reporting on HNABs. Each year, it produces an updated on-line summary table of the water bodies in each region of the province that have been reported and confirmed as impacted by HNABs. The current summary covers the period 2004 to 2017. In addition to this summary table, the province produces a detailed report on HNABs each year.

In spite of this high-quality reporting, it remains impossible to determine either the total number of freshwater bodies impacted by HNABs in Quebec or the evolution of the situation. To quote the Quebec Ministry of Sustainable Development, Environment and Climate Change:

> "Interannual fluctuations - downward or upward - in the number of water bodies where the [Ministry] confirms the presence of a bloom of blue-green algae cannot be interpreted as improvements or deteriorations in situation. The fluctuations recorded do not depend solely on environmental and weather conditions; they also depend on citizens' willingness to report the presence of cyanobacterial water blooms and changes to the Ministry's monitoring procedures. In addition, it should be noted that the [Ministry] does not have information on the duration, extent and intensity of blooms during the season." (Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques du Québec, 2016; p. 7. Free translation by the author.)

The "changes to the Ministry's monitoring procedures" alluded to above have been significant. Whereas the Ministry responded to all reports of possible HNABs in prior years by sending an inspector to verify the bloom, beginning in 2013 inspectors were only sent in cases where the bloom was reported on a water body that was not subject to "recurring" blooms[5] or a water body that was considered "sensitive"[6]. Beginning in 2016, only reports of possible blooms on sensitive water bodies were followed up with a visit. The impact of these changes can be seen, for example, in the reduction in the number of water bodies visited and confirmed as impacted

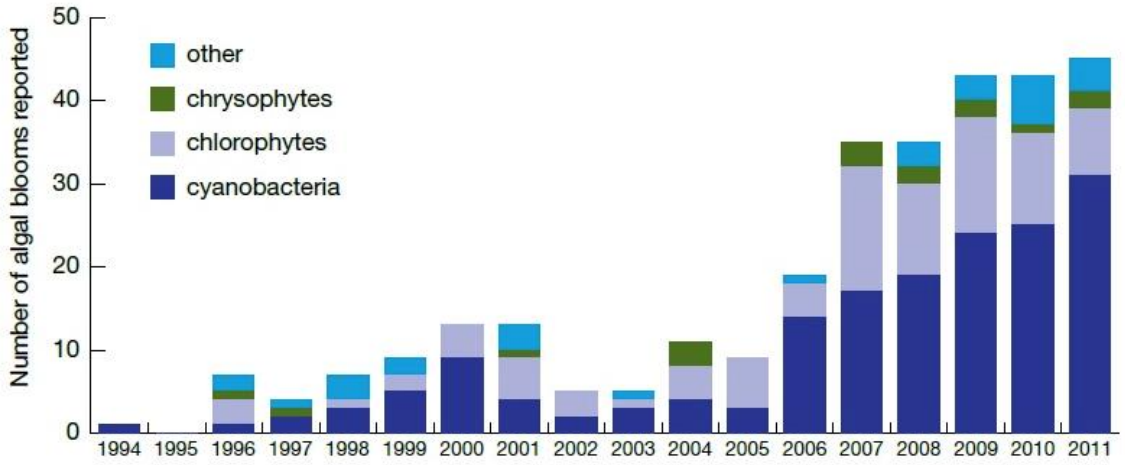
[4] It is not clear whether inspectors are dispatched to confirm the bloom through sampling and testing or whether a citizen report is sufficient for the advisory to be issued.
[5] Recurring blooms are those that have occurred in at least three of the last six years.
[6] For example, because the water body had never been reported in the past, because it was subject to an inter-jurisdictional agreement of some sort or because it was the source drinking water.

after 2012. In that year, 213 water bodies reported to have been impacted were visited to confirm the presence of blooms. By 2015, the number of water bodies visited was just 72 (Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques du Québec, 2016; p. 7).

Ontario: The Ontario Ministry of the Environment, Conservation and Parks has a protocol in place for responding to reports of suspected HNABs. It involves collaboration between local health units and medical officers of health to manage blooms, including screening of water samples to identify potential toxins.

The Ministry does not publish annual data on the number of water bodies impacted by HNABs. However, until 2014, irregular reports on water quality in Ontario were published that included information related to HNABs and their causes. The 2012 version of this report provided a summary of the trends in reporting of algal blooms to the provincial government from 1994 to 2011 (Figure 1). It noted an overall increase in the number of blooms reported (and, presumably, confirmed through testing), with reports of cyanobacterial blooms accounting for the largest share in most years. An update of these figures (Holeton *et al.*, 2017) showed that the upward trend in the number of reported blooms that began around 2005 ended in 2012 and then began again in 2015.

Figure 1 – Number of reports of algal blooms received by the Ontario government, 1994-2011



Source: Ontario Ministry of Environment and Climate Change, 2012. *Water Quality in Ontario Report 2012*. Figure 3.18. Available at https://www.ontario.ca/page/water-quality-ontario-report-2012.

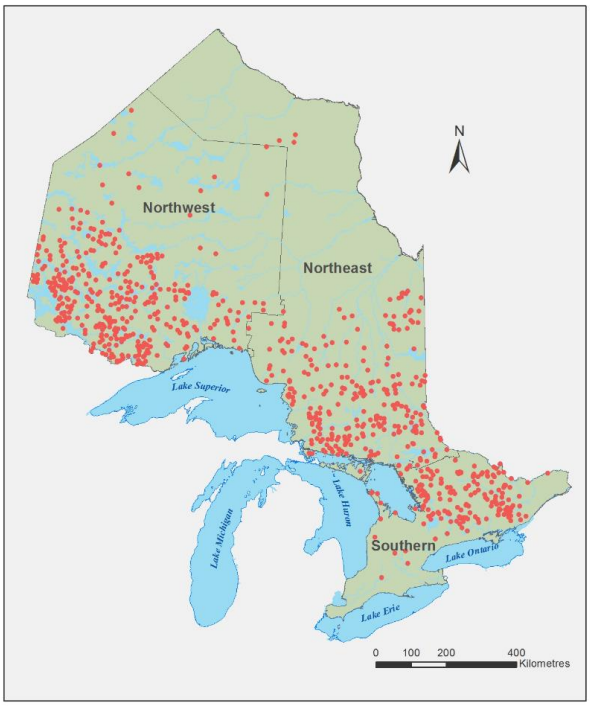
From 2008-2012, the Ontario government undertook the first cycle of its Broad-scale Monitoring Program for water quality, designed primarily to evaluate the state of the province's fisheries. Water quality data were collected from a representative sample of lakes following standardized protocols. The number of lakes included in the program was sufficient for managing and reporting on fisheries in each of the province's fish management zones, though it represented a relatively small percentage of the total number of lakes in Ontario

(Figure 2). Detailed information regarding fish species and communities, physical and chemical water characteristics, invasive species, and fishing effort were collected for each lake sampled. Though the presence of HNABs was not one of the variables monitored, results from the first cycle show that 7% of lakes had total phosphorus concentrations of more than 20 micrograms/litre, the level above which appearance of HNABs is more common (Figure 3).[7]

The government of Ontario has conducted two further cycles of the Broad-scale Monitoring Program since 2012, though it has not published the results in a report as was done with the first cycle. Those wishing to access the data from the more recent cycles must apply through the Dorset Environmental Science Centre and must agree to use of the data for research purposes only.

Notwithstanding the fact that the Broad-scale Monitoring Program does not directly monitor the presence of HNABs, the program is, in principle, exactly the kind needed to assess water quality in a manner that is statistically robust and comparable over time. It would be valuable, then, for the provincial government to provide more ready access to the program's findings. The trend in phosphorus concentrations would provide useful, if only indicative, information regarding the potential threats Ontario's freshwater lakes face from algal blooms.

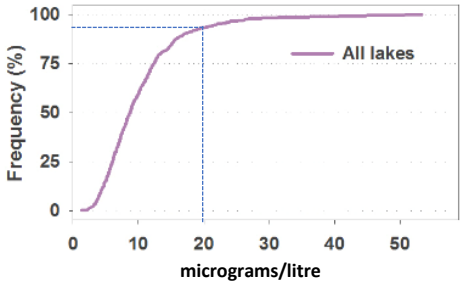
Figure 2 – Lakes sampled in the first cycle of Ontario's broad-scale monitoring program



Source: Government of Ontario, 2014; Figure 11.

[7] Government of Ontario, 2014, *Water Quality in Ontario 2014 Report.* Available at: https://www.ontario.ca/page/water-quality-ontario-2014-report.

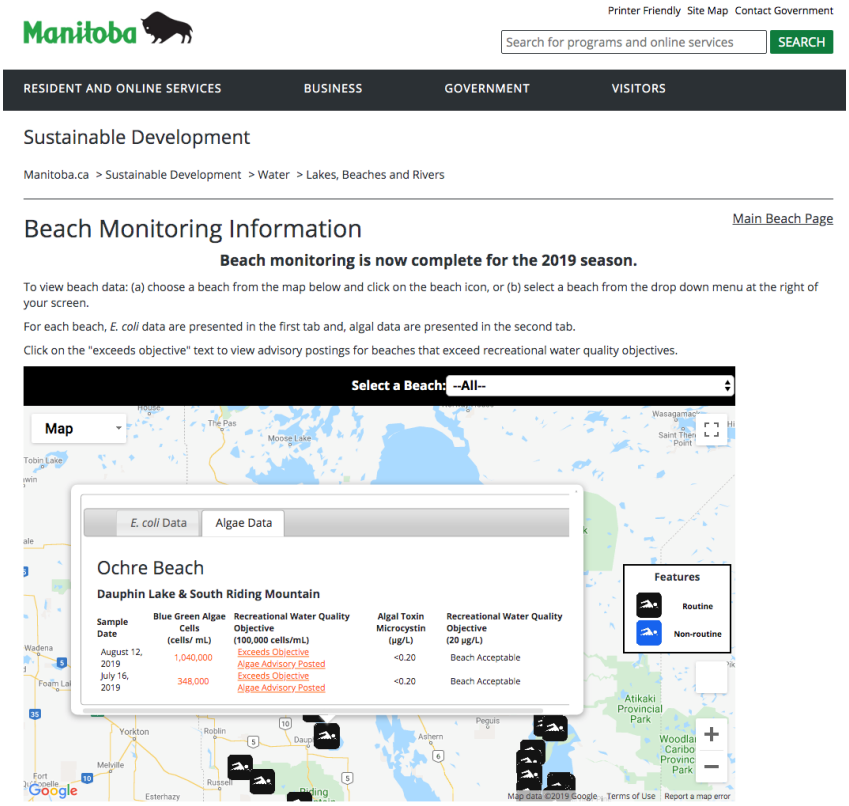
Figure 3- Total phosphorus in lakes monitored in the first cycle of Ontario's broad-scale monitoring program, 2008-2012



Source: Government of Ontario, 2014; Figure 13a.
Note: 93% of lakes are found to the left of the 20 micrograms/litre point on the x-axis.

Manitoba: The Manitoba Department of Sustainable Development regularly monitors about 60 beaches across the province for the presence of cyanobacterial blooms. Testing is also carried out on other water bodies in response to reports of possible blooms. During the summer season, the province maintains an on-line list of water conditions at provincial beaches that includes information on cyanobacterial blooms (sampling date, algae cell counts, toxin concentrations and adherence with recreational water quality objectives). In order to find the information for a given beach, visitors to the site must click on the appropriate icon (Figure 4). No annual summary of HNABs occurrences on provincial beaches is provided and no information is provided on HNABs occurring on water bodies other than provincial beaches. A weekly summary of beach conditions is published during the summer season.

Figure 4 – Example of beach monitoring information provided by the Government of Manitoba



Source: https://gov.mb.ca/sd/waterstewardship/quality/beach_table.html

Saskatchewan: The Saskatchewan Ministry of Environment provides an cyanobacterial bloom fact sheet on its website that notes that "during the warm summer months, many Saskatchewan lakes may suddenly take on a green soupy appearance." The fact sheet provides additional information on cyanobacterial blooms, including what they are, what to do if exposed, using/consuming contaminated water and/or fish and so on. No mention is made of a protocol for reporting suspected blooms. Unlike other provinces, Saskatchewan does not typically issue bloom advisories for specific water bodies. Rather, when climatic conditions (temperature) are favourable for bloom formation, the government will issue a blanket, province-wide advisory warning citizens to avoid swimming in or drinking water where blooms are occurring. These advisories typically note that cyanobacterial blooms are common during calm, hot weather in areas of the province with lakes and reservoirs are shallow and slow moving and where sufficient nutrients are found (see, for example, the 2019 advisory). Such advisories appear to have been issued in 2014, 2018 and 2019 (based on on-line information). Advisories for specific water bodies are also issued when blooms are unusually severe (see, for example, this advisory from 1997).

Beginning in 2019, the province began providing weekly on-line water-quality monitoring reports for 67 public beaches. The reports provide information on e-coli and algal toxin concentrations for each beach, along with an indication of the beach's suitability for swimming (Figure 5).

Figure 5 - Example of beach monitoring information provided by the Government of Saskatchewan

Recreational Area	Location	Date	Sample Results (*E.coli* geometric mean; Microcystin composite sample)
Annie Laurie Beach	Annie Laurie Lake	09-Jul-2019	*E. coli* = 52.66/100mL; Microcystin <0.1 µg/L
Aspen Grove Beach	Blackstrap Lake	23-Jul-2019 14-Aug-2019	*E. coli* = 30.92/100mL; Microcystin <0.1 µg/L *E. coli* = 36.30/100mL; Microcystin <0.1 µg/L
Battlefords Provincial Park Public Beach	Jackfish Lake	09-Jul-2019	*E. coli* = 11.39/100mL; Microcystin <0.1 µg/L
Bird's Point Beach	Round Lake	17-Jun-2019 22-Jul-2019 12-Aug-2019	*E. coli* = 2.73/100mL; Microcystin <0.1 µg/L *E. coli* = 3.64/100mL; Microcystin <0.1 µg/L *E. coli* = 127.39/100mL; Microcystin <0.1 µg/L
B-Say Tah Beach	Echo Lake	27-Jun-2019 23-Jul-2019 22-Aug-2019	*E. coli* = 0.15/100mL; Microcystin <0.1 µg/L *E. coli* = 4.12/100mL; Microcystin <0.1 µg/L *E. coli* = 2.81/100mL; Microcystin <0.1 µg/L
Buffalo Pound Provincial Park Beach	Buffalo Pound Lake	24-Jun-2019 24-Jul-2019 19-Aug-2019	*E. coli* = 8.79/100mL; Microcystin <0.1 µg/L *E. coli* = 2.23/100mL; Microcystin <0.1 µg/ *E. coli* = 8.56/100mL; Microcystin 5.0 µg/

Alberta: The Government of Alberta publishes an on-line list of active health advisories by region that includes advisories related to cyanobacterial blooms. When a water body is identified as having a bloom, an advisory is issued to warn citizens to avoid contact. When the advisory is lifted, it is placed on a list of inactive advisories that dates back to 2011. A total of 21 cyanobacterial bloom advisories were issued for 2019. The corresponding figures for previous years were 2011: 7; 2012: 3; 2013: 6; 2014: 4; 2015: 5; 2016: 4; 2017: 5; 2018: 36. In some instances, more than one advisory was issued for the same water body in a given year.

British Columbia: The Government of British Columbia provides an on-line fact sheet on cyanobacterial blooms with some instructions on what to if a bloom is observed, including reporting to government in instances where dead or distressed animals are found along the shoreline of impacted water bodies. More general instructions for public reporting of suspected blooms are found elsewhere on the Government website. Beyond this, no systematic information is provided on HNABs in the province.[8]

Yukon: The Government of Yukon provides no public information on the occurrence of HNABs in the territory.

[8] There is, however, a wide range of reports available on the B.C. Government website that touch in one way or another on algal blooms. Many of these reports are out-of-date, highly scientific and specific to just one area of the province (e.g., a single watershed). Though they may offer some useful information on the occurrence of HNABs, they do not constitute the kind of synthesized, easily accessible information provided by other provinces.

Northwest Territories: The Government of the Northwest Territories provides no public information on the occurrence of HNABs in the territory.

Nunavut: The Government of Nunavut provides no public information on the occurrence of HNABs in the territory.

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