BLUE-GREEN AND BENTHIC

A WORKSHOP ON MONITORING, MITIGATION, AND MANAGEMENT OF CYANOBACTERIA IN ATLANTIC CANADA

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FINAL REPORT

CONTENTS

ORGANIZING COMMITTEE

Rob Jamieson, Lindsay Johnston, & Audrey Hiscock

Daniel Beach & Pearse McCarron

Wendy Krkosek

Cameron Deacoff

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WORKSHOP SUMMARY

Since the 2018 Atlantic Canadian Cyanobacteria Workshop, we have seen a rapid increase in the number of waterbodies (recreational and drinking water supplies) under public advisories, exposing gaps in local capacity for surveillance, notification, and mitigation. The aim of this workshop was to disseminate local expertise, promote the coordination of research programs between participants, and inform future monitoring strategies and areas of research.

The workshop provided a forum for academic, government, and industrial researchers to connect with regulators, operators, and practitioners and share novel findings and on-going research into benthic and planktonic proliferations of cyanobacteria across Atlantic Canada.

This report contains key findings from the workshop, challenges related to the complexity of cyanobacteria, and outstanding research questions that should be addressed in future efforts.

PRESENTATIONS

- Provincial Perspectives: Presentation and panel discussion with representatives from Atlantic provincial agencies on regional approaches to monitoring/managing cyanobacteria risk
  - Cameron Deacoff (Nova Scotia Environment and Climate Change)
  - Cindy Crane (PEI Department of Environment, Energy and Climate Action)
  - Adrian Rogers (Government of Newfoundland and Labrador, Department of Environment and Climate Change)
- Meghann Bruce (Canadian Rivers Institute): What we are learning about cyanobacterial mat proliferation from field studies in the Fredericton region of the Wolastoq
- Janice Lawrence (University of New Brunswick): Exploring the potential for anatoxin-a production in benthic cyanobacterial mats in New Brunswick using genetic approaches
- Daniel Beach (National Research Council): Analytical methods and reference materials for cyanotoxins
- Lindsay Johnston (Dalhousie University): Seeking cyanos: a survey of Nova Scotia's surface waters
- Wendy Krkosek (Halifax Water)/Nicole Taylor (City of Moncton): Drinking water utility cyanobacteria strategies: overview of recent experience, monitoring and current challenges from Halifax Water and the City of Moncton
- Lindsay Anderson (Dalhousie University): Passive sampling: Lessons learned and implementing a multiplex strategy
- Josh Kurek (Mount Allison University): Tracking eutrophication archived within lake sediments using geochemistry and bioindicators

KEY FINDINGS & LESSONS LEARNED

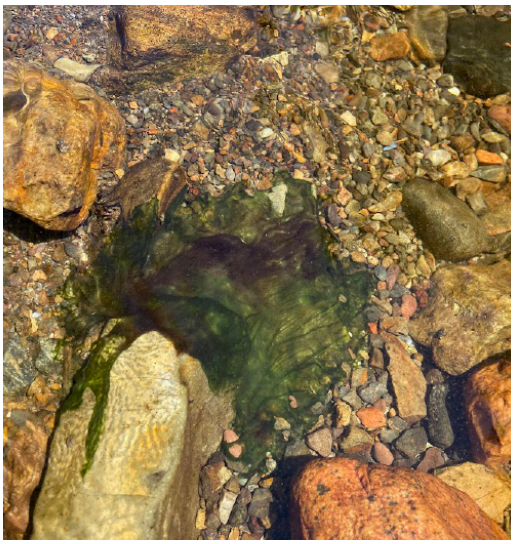
Planktonic and benthic cyanobacteria proliferations are increasingly reported across the Atlantic region

- There is growing evidence that planktonic and benthic cyanobacteria are present in lakes and rivers throughout the Atlantic region.
- Due to a lack of historical baseline information, it is difficult to confirm if the frequency of cyanobacterial proliferations is increasing, especially benthic cyanobacteria. However, our understanding and awareness of cyanobacterial proliferations has improved. This increased awareness of cyanobacteria may have led to increased public reporting.
- Historically, conditions that favour cyanobacteria have been assumed to be slow, stagnant, nutrient rich and warm waters that had discoloration or odours. However, recent monitoring in Atlantic Canada has indicated that the conditions for cyanobacteria proliferation are highly variable, particularly with respect to benthic cyanobacteria.
- Studies in New Brunswick show that benthic cyanobacteria are growing in rivers that are not necessarily nutrient rich. Hydrologic characteristics might be more of a controlling factor as there is evidence that benthic mats are forming in areas with rocky substrate and flowing water, which are also periodically exposed and submerged.
- Results from a study of numerous rivers across Nova Scotia showed that river-lake systems in the province could be prone to the proliferation of benthic cyanobacteria. The study also demonstrated that varying hydrologic regimes may be linked to benthic cyanobacteria presence.
- In lake systems, nutrient loading is still an important risk factor. Additional research in Nova Scotia has highlighted the importance of surrounding land-use on cyanobacteria proliferations. Road salt run-off in highly urbanized areas can lead to prolonged stratification (occurring earlier and lasting longer), resulting in anoxic conditions at the bottom of the lake and subsequent phosphorous (P) release from the sediment. Following lake turnover, the internal P load is mixed and available for cyanobacteria. As such, lakes that may have unfavourable conditions for cyanobacteria in upper levels of their water column, may show favourable conditions after lake turnover.

Factors influencing the proliferation of benthic cyanobacteria are not the same as planktonic cyanobacteria

- The appearance of benthic and planktonic cyanobacteria, and the factors that contribute to their proliferation, are different. The factors which influence the proliferation of benthic cyanobacteria are still highly uncertain. Additionally, cyanobacteria mats are highly variable in appearance, species present, toxin producing potential, etc.
- In the Wolastoq, it was determined that cyanobacterial mats had varying physical characteristics at different times of the year. The appearance of the mats also depended on the environmental conditions. For example, mats appeared green and bubbly and formed on the riverbed rocks in early spring. However, in late spring, the same mats transitioned to a golden-brown colour and eventually detached and became buoyant. A similar observation was reported at Shubenacadie Grand Lake, where cyanobacteria mat samples, collected from the same site, had very different physical characteristics.
- Further, determining the toxin production within cyanobacterial mats is also a complex problem, as it can vary with the species of cyanobacteria, and even over time within the same mat. Results from the Wolastoq monitoring program identified two predominant strains of a single species of cyanobacteria, that varied with respect to a few genes – one sub-species contained the anaC gene (the anatoxin-producing gene), where the other did not. Although the two strains of cyanobacteria were of the same species, one presents much higher public health risks than the other.

Toxin producing benthic cyanobacteria found across the region
Top and bottom right photos provided by Meghann Bruce.



Multi-faceted monitoring strategies are needed to understand and assess cyanobacterial risks

- As there are many factors that influence the proliferation of cyanobacteria, taking a multidisciplinary approach to monitoring and problem solving is important. This should also include dissemination of knowledge to other communities/groups experiencing similar challenges.
- Community watershed groups can assist with sampling and monitoring, land-use planning, and are a valuable connection between stakeholders and the government, particularly in rural areas.
- Communicating the risk of cyanobacteria to the public is also very important. Provinces are trying to make use of limited resources for monitoring by engaging the public. This highlights the need for continued public outreach and education to ensure that citizens are equipped with the most up-to-date information regarding cyanobacteria identification and risk factors.
- There is a need for increased knowledge sharing to ensure that researchers are operating with the most current information and are building upon the efforts of others (e.g., through events such as conferences). As cyanobacterial proliferations tend to reoccur seasonally at sites, a database compiling those locations could help to target future monitoring and mitigation efforts.
- Multi-disciplinary approaches are needed to fully assess and understand cyanobacteria proliferations in Atlantic Canada. There are a variety of monitoring approaches that can be used to identify cyanobacteria and assess risk:
    - Visual inspection
    - Microscope examination
    - Molecular detection methods such as PCR based method and DNA sequencing
    - Cyanotoxin Analysis
    - Remote sensing of blooms using satellite imagery and drones
- Passive samplers, like Solid Phase Adsoprtion Toxin Tracking (SPATT), may be useful for monitoring purposes. Passive samplers have been employed in the Atlantic region to detect concentrations of toxins below the minimum detection level of grab sampling techniques in lake waters and drinking water supplies. This provides the potential to identify cyanobacteria presence early and reduce the risk to the public.
- Many of these monitoring approaches should be used in combination. Researchers in New Brunswick took a collaborative approach to their monitoring program, including consideration of water quality parameters, the physical riverbed characteristics, and multiple methods for identification of cyanobacteria and toxins (e.g., qPCR for detection of toxin producing genes, culturing of cyanobacteria samples for full genetic analysis).
- The lack of baseline or long-term datasets can be partially addressed by complimentary areas of research to understand how watersheds and lakes have changed over time. The application of paleolimnology (i.e., studying lake sediment cores) can be helpful in establishing long term trends in environmental states in the absence of long term water quality monitoring.
- Monitoring is resource intensive, thus establishing baseline conditions will require considerable time and resources. Conferences and seminars such as the Atlantic Canada Cyanobacteria Workshop facilitate information sharing and advance the movement towards establishing a baseline.

CHALLENGES

The complexity of cyanobacteria proliferations and stressors causing toxin production make prediction of hazardous events difficult.

- Cyanobacteria are complicated organisms and the stressors that cause the production and release of cyanotoxins are not well understood.
- Slight genetic differences in strains of the same species can cause significant differences in the response of the cyanobacteria and its potential to produce toxins. This was shown in cyanobacteria strains found in NB.

Monitoring Strategies

- Current monitoring strategies are resource intensive to the extent that most provincial governments in Atlantic Canada are not actively monitoring for cyanobacteria, but instead rely heavily on public reports of potential proliferations.
- There are no established national guidelines that can be referenced when planning monitoring activities related to cyanobacteria and the associated risk to public health. There is a lack of guidance on what to test for, when tests should be done, and where to do the tests. Risk based guidelines from WHO and associated documentation are broadly applicable in the region (Chorus, I. & Welker, M., 2021).
- There is a lack of real-time monitoring and turn-around times are too slow for risk-based assessment of conditions. The long turn-around times (up to 2 weeks for microcystins, which is the only toxin that commercial labs currently test for) can present health and safety issues in the case of a toxin-producing cyanobacterial proliferations.
- Complexity of species, toxins, and matrices makes it hard to do one-size-fits-all analysis. The wide variation in physical and chemical characteristics of cyanotoxins make it extremely difficult to analyze all toxins with one technique. As such, toxins with similar structures, classes, and behaviours are often grouped together, and those that do not fit into similar classes (e.g., saxitoxin) are ignored for the ease of monitoring. This does not signify that those ignored toxins pose a lower risk.
- There is a need to determine what is normal and/or safe levels of cyanobacteria with the tools and measurement techniques that we are using to collect data. There is also a lack of actual public health guidelines for many toxins. Current regulations by Health Canada indicate a Maximum Allowable Concentration of 1.5 ug/L total (intra- and extra-cellular) microcystins (MCs) in the Canadian Drinking Water Guidelines. Total MCs is not currently a parameter that can be easily measured; thus, regulations are ahead of analytical techniques. However, it was identified that regulations are needed to drive analytics and research to more advanced states. It is difficult to have the resources needed to develop analytical methods if there are not regulations supporting the advancement. Further, certified reference materials needed for quality assurance and control purposes (which are crucial to enable accurate comparisons among studies) are limited and NRC is currently working toward solutions to this challenge.
- Benthic cyanobacteria are difficult to monitor, especially when reliance is on visual inspection by the public. Monitoring programs across Atlantic Canada have determined that cyanobacterial proliferations present in many different physical forms, thus identifying requires extensive knowledge of a wide range of cyanobacteria species. For this reason, more effort is needed to understand what these proliferations look like.

Lack of Technical Guidance, Expertise, and Guidelines

- The overarching theme of provincial response to cyanobacterial blooms was found to be reactive instead of proactive. All three provincial representatives identified the lack of federal discussion and support on cyanobacterial bloom mitigation as a significant challenge.
- This presents challenges with respect to resources, as significantly more energy is required for each province to work independently. Technical support on sampling (how to do it, what to look for, expertise on taxonomy and toxicity, etc.) are lacking, and bloom management strategies or mitigation options would be highly beneficial.
- Accessible and reliable information on cyanobacterial proliferations is not reaching the public in appropriate time frames.
- The amount of knowledge on cyanobacteria has increased substantially over the last few decades, however, a lot of old assumptions, that have since been disproven, still exist (e.g., cyanobacteria only occur in stagnant, warm waters). Further, there is a lack of information on benthic cyanobacteria mats (outside of New Brunswick).
- There is also a lag between the emergence of higher quality information and information that reaches the public. There is significant research being done on the topics of cyanobacterial blooms, however it is often only presented in technical formats (e.g., reports, journal articles), which is not highly accessible to the greater public.
- Additionally, education of specific sectors (i.e., drinking water treatment, recreational) has been the primary focus, but other sectors (e.g., agriculture) have not been as informed but may still be vulnerable to the effects of cyanobacterial blooms.

A major finding from the workshop was that there is a lack of labs (commercial or otherwise) available to do analysis for cyanobacteria presence and toxin analysis.

Passive samplers (SPATT) used to monitor the concentration of cyanotoxins in various watersheds across the region

FUTURE RESEARCH QUESTIONS

MONITORING AND PREDICTION OF BLOOMS

A comprehensive understanding of risk factors is needed to predict cyanobacterial blooms in an accurate and timely manner. The conditions under which cyanobacteria are proliferating are highly variable, making it difficult to anticipate where they may occur. What are the similarities among sites where cyanobacterial blooms are known to have occurred that may be driving these proliferations? Are certain risk factors consistent among certain types of cyanobacterial growth?

Can we develop real-time monitoring technologies for cyanobacterial blooms? For toxins? If not, there is a need to build a toolbox for assessing risk in the absence of quantitative data and develop trigger points for action, as real-time monitoring technologies are lacking.

What role could drones play in monitoring strategies?

What is the best method to establish baselines to which bloom conditions can be compared? Paleolimnology? Extensive sampling immediately to compile baselines? A combination of different approaches?

MANAGEMENT OF INFORMATION AND PUBLIC OUTREACH

Can we develop a widespread database of cyanobacterial blooms, species, toxins, etc. for researchers, practitioners and the public?

What is the best method to disseminate such a database? What resources will be needed to sustain it? What is the best reporting structure?

What is the best method to communicate information to the public from a risk-based standpoint (i.e., communication of toxic blooms and risk)?

What is the best method to inform the public on appropriate methods to identify blooms?

IMPACTS ON AQUATIC LIFE, AGRICULTURE, AND FOOD INDUSTRIES

How do blooms and the presence of toxins impact aquatic organisms such as fish and invertebrates?

What are the impacts of cyanotoxins on agricultural industries? Could irrigation play a role in introducing toxins into food?

Do toxins bioaccumulate in animals consuming contaminated water or in aquatic species that are sources of food?

TOXICOLOGY

There is a lack of information on toxicology of chemicals produced by many cyanobacteria species. For example, many mechanisms and health impacts of toxins like beta-Methylamino-L-alanine (BMAA) and mixtures of anatoxins are unknown.

What are safe consumption limits for toxins (anatoxin-a, cylindrospermopsin, BMAA, saxitoxin, etc.)?

LIST OF ATTENDEES

NAME	AFFILIATION
Lindsay Anderson	Dalhousie University
Kash Bahri	Dalhousie University
Garth Bangay	Sherbrooke Lake Stewardship Committee
Dan Beach	National Research Council Canada
Tessa Bermarija	Dalhousie University
Ben Bickerton	CBCL Limited
Alexandre Binette	City of Moncton
Paul Bjorndahl	Dalhousie University
Diane Botelho	Research and Productivity Council
Pierre Bouteiller	National Research Council Canada
Leah Boutillier	Dalhousie University
Michael Brophy	CBCL Limited
Clarke Brown	Dalhousie University
Meghann Bruce	Canadian Rivers Institute at UNB
Jessica Campbell	Halifax Water
Maryann Comeau	Bureau Veritas
Cindy Crane	PEI Department of Environment
Martin Croney	West Hants Regional Municipality
Cameron Deacoff	Nova Scotia Environment and Climate Change
Isobel DeMont	Dalhousie University
Casey Doucet	Dalhousie University
Stuart Downie	Dalhousie University
Maxime Edelblout	Biofluids and Biosystems Modelling Lab
Megan Elliott	SWEPS
Monica Forestell	SWEPS
David Foster	Dalhousie University
Melissa Fraser	CBCL Limited
Megan Fraser	Dalhousie University
Megan Fuller	Dalhousie University
Craig Gerrior	Town of New Glasgow - Water Treatment
Madison Gouthro	Dalhousie University
Catherine Graham	NS Department of Agriculture
Sara Habibi	Dalhousie University
Emalie Hayes	Dalhousie University
Audrey Hiscock	Dalhousie University
Maggie Hosmer	Dalhousie University
Yannan Huang	Dalhousie University
Rob Jamieson	Dalhousie University
Zhehan Jiang	Dalhousie University
Lindsay Johnston	Dalhousie University
Maria Joudrey	Halifax Water
Narges Karamizadeh	Dalhousie University
Jim King	Bureau Veritas

NAME	AFFILIATION
Wendy Krkosek	Halifax Water
Pawan Kumar	Dalhousie University
Josh Kurek	Mount Allison University
Barret Kurylyk	Dalhousie University
Janice Lawrence	University of New Brunswick
Qianhan Le	Dalhousie University
Amber LeBlanc	Dalhousie University
Jenna MacKinnon	National Research Council Canada
Ryan Malley	Dalhousie University
Hadi Matin Rouhani	Dalhousie University
Pearse McCarron	National Research Council Canada
Kayla McLellan	Dalhousie Faculty of Agriculture
Chris Miles	National Research Council Canada
Elizabeth Montgomery	Halifax Regional Municipality
Krysta Montreuil	Nova Scotia Environment and Climate Change
Eva Mooers	Province of Nova Scotia
Solenn Mordret	National Research Council Canada
Christina Mosher	Nova Scotia Environment and Climate Change
Lee-Ann Nunn	Municipality of East Hants
Amanda O'Neil	Halifax Water
Charlie Parent	Dalhousie University
Colin Poirier	Nova Scotia Environment and Climate Change
George Quinn	Dalhousie University
Cheryl Rafuse	National Research Council Canada
Colin Ragush	Sentry Water Technologies
Dave Redden	Dalhousie University
Attiq Rehman	RPC
Adrian Rogers	Government of Newfoundland and Labrador
Aryan Samadi	Dalhousie University
Jenacy Samways	Dalhousie University
Daniel Saunders	Dalhousie University
Qianbo Sheng	Dalhousie University
Lauren Somers	Dalhousie University
Amina Stoddart	Dalhousie University
Mark Sumarah	Agriculture and Agri-Food Canada
Meghan Swanburg	Acadia University
Crystal Sweeney	Dalhousie University
Ryan Swinamer	Dalhousie University
Nicole Taylor	City of Moncton
Cecilio Valadez Cano	University of New Brunswick
Matthew Walker	Dalhousie University
Emma Wattie	Halifax Regional Municipality
Paul Yoon	Dalhousie University
Lydia Zamlynny	National Research Council Canada
Mina Zareie	Dalhousie University
Liang Zhu	Environment and Climate Change Canada