Citizen Science Water Quality Monitoring for Prairie Lakes
A Guide

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Master of Water Security Project by:

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Preface

This project is part of a Master of Water Security program at the University of Saskatchewan. This project started as a request by the Crystal Lake Hamlet Board. They reached out to the University of Saskatchewan to get help determining some issues with their lake. They were put in touch with Dr. Helen Baulch to monitor and test the water quality, quantity and clarity in the lake. Some of the groups major concerns have to do with changes occurring in the lake over time as well as the longevity of the viability of the lake into the future.

Although this started as the concerns of one group the project has expanded. Kathrine Finn from the North Saskatchewan River Basin has an interest in implementing a citizen science monitoring program into the lakes in the North Saskatchewan River Basin.

This works has been expanded to not just include these small exclusive regions in Saskatchewan but the entire prairie region. The lakes in Saskatchewan are unique because of the geology of the land. Not everything is the same across Manitoba, Saskatchewan and Alberta but there are similarities that may be able to help community groups to monitor their own water resources.

This guide is just meant to be a first step and a place for citizens who are interested in water quality monitoring and citizen science in the prairies. This document should be used as a starting point for groups to get involved and to monitor what is important for their lakes. This document contains valuable resources but other resources can also be found through the local, provincial and

federal governments as well as other abundant sources that are being created and updated frequently.

Introduction

Monitoring for water quality is an important task for the people residing near various water bodies, as it can help to understand the current state of the ecosystem. Over time monitoring can indicate changes occurring to the ecosystem. This knowledge can help to inform decision making and environmental management. It is not possible for all bodies of water to be monitored by professional scientists. That is where you, as a citizen, come in. This guide can be used as a tool to create a citizen science water quality monitoring program in your community. In this document, I have worked to include important variables to monitor and understand the health of your lake and provide information to help you learn more about each of these variables. This guide was created for the prairie region; it is a unique region for numerous reasons noted in section #1.3.

The goal of this manual is to give people a resource from which to build a monitoring program, focused on areas important to their specific water body, community engagement level, and financial capacity. As a starting point, further engagement of scientists and government is recommended to help maximize the benefits of your monitoring and best use of this guide in order to create a robust program going forward for your lake. There are a variety of other resources available on the Internet and it is my hope that this is just one piece of the puzzle that will help you in creating a water quality monitoring program that is right for

your community. As this document is part of a Master project at the University of Saskatchewan I will not be updating this after my graduation. However, this data is also available in the form of a Prezi with the hope that information can be updated or expanded upon where possible. ((((PREZI LINK))))

Guide based on user interest

If you are interested in one of the topics in blue check read more in in the grey sections below.			
Fish	**Water Quality**	**Swimming**	**Climate Change**
-Aquatic Species Native & Invasive section #7	**-Water Clarity section #3**	**-Changing Shorelines section #8**	**-Changing Shorelines section #8**
-Dissolved Oxygen & Temperature section #5	**-Nutrients- Total Phosphorus & Total Nitrogen section #6**	**-Health Threats section #2**	**-Weather section #10**
-Macrophytes section # 9	**-Cyanobacteria Blooms section #4**	**-Cyanobacteria Blooms section #4**	**-Cyanobacteria Blooms section #4**

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#1. What is Citizen Science?

Citizen science is the way in which regular citizens can make contributions to the scientific community. Citizen scientists work regular jobs and have other activities and commitments, but in their spare time, they are able to collect scientific data that can be helpful in creating or participating in a citizen science program. Citizen science programs can focus on any topic. Many successful citizen science programs that have occurred in the past have focused on ornithology also known as bird watching, or botany, the study of plants, and water quality monitoring[1].

Water quality monitoring programs have been successful in many different regions in North America and around the world. Places such as Waikato Region New Zealand[2], multiple lakes and counties in Ontario[3],[4], Michigan[5], Minnesota[6], Missouri[7] and many other places. Each program monitors things that are important to their

[1] Jeffrey P. Cohn, "Citizen Science: Can Volunteers Do Real Research?," *BioScience* 58, no. 3 (March 1, 2008): 192–97, doi:10.1641/B580303.
[2] Waikato Regional Council, "Shoreline Change," *Waikato Regional Council*, accessed July 19, 2017, https://www.waikatoregion.govt.nz/environment/environmental-information/environmental-indicators/coasts/shoreline-change-report-card/.
[3] Federation of Ontario Cottagers' Association, "A Shoreline Owner's Guide to Helathy Waterfronts," accessed July 19, 2017, https://foca.on.ca/wp-content/uploads/2014/05/Watershed_booklet_FULL_2011_with_covers-1.pdf.
[4] Muskoka Watershed Council, "Muskoka Watershed Council," accessed February 7, 2017, http://www.muskokawatershed.org/upcoming-meetings/.
[5] Michigan Clean Water Corps, "Aquatic Plant Identification & Mapping," accessed July 19, 2017, https://micorps.net/wp-content/uploads/CLMP-AqPlant-FactSheet.pdf.
[6] Minnesota Pollution Control Agency, "History of the Secchi Disk," *Minnesota Pollution Control Agency*, November 16, 2009, https://www.pca.state.mn.us/water/history-secchi-disk.
[7] "The Lakes of Missouri Volunteer Program," *The Lake of Missouri Volunteer Program*, 2016, http://www.lmvp.org/index.htm.

specific environment (e.g., tidal reaches in New Zealand) but most also engage some key parameters that are of common interest across lakes.

Benefits of Citizen Science

Collecting data as a citizen scientist can be beneficial to those directly monitoring the ecosystem as well as the broader scientific community. There are many things that can bring a group together to allow for a successful water-monitoring program. These keys to success can include a sense of self-reliance; communities can collect their own data and not have to rely on the government or private contractors. As new technologies emerge, it is becoming more affordable for technology to be at the fingertips of the user, making monitoring more accessible in all locations[8]. There are many different videos on the Internet that detail the proper methods of correct sampling techniques. The low costs of many of these technologies allow for any group or individual to afford technologies that would allow for accurate sample collection and water quality monitoring[9]. If citizen scientists did not perform research it may not be performed at all[10]. Canada is a vast country with a sparse population making some areas difficult to access. With estimates of 2 million[11] lakes across the country it is not possible for all these lakes to be monitored by scientists. It also means that there are a limited number of

[8] Vincent Devictor, Robert J. Whittaker, and Coralie Beltrame, "Beyond Scarcity: Citizen Science Programmes as Useful Tools for Conservation Biogeography," *Diversity and Distributions* 16, no. 3 (2010): 354–62.
[9] Ibid.
[10] Cohn, "Citizen Science."
[11] Farrell M. Boyce, "Lake," *The Canadian Encyclopedia*, March 4, 2015, http://www.thecanadianencyclopedia.ca/en/article/lake/.

scientists compared to locations therefore, it would not be possible for scientists to monitor the entire country. It would also be very costly for them to travel back and forth between some of these more remote communities so citizen science can supplement the gaps where scientists are unable to do research.

Citizen science records can also help to note cross cutting research that would not always be noted by professional scientists. In the case of the Christmas Bird Count, citizen scientists were counting birds across North America and noting the times and locations in which these birds were seen[12]. Unbeknownst to them they were not only collecting data on bird sighting's but also changing climate and weather patterns. This research may not have been collected if only performed by a professional scientist. Similar work is underway monitoring for how climate change is impacting lakes in the northern hemisphere. The cycles for freeze thaw patterns are changing as a result of climate change[13], but it is difficult to say how climate change will impact individual lakes therefore it is up to the individuals on a given lake to monitor the ice time to understand how climate change will impact any given lake[14].

#1.1 Challenges of Citizen Science

Although, there are many opportunities for success within citizen science there are some pitfalls that can cause challenges for citizen scientists. These include

[12] "Bird Studies Canada," *Bird Studies/ Etudes D'Oiseaux Canada*, accessed February 7, 2017, http://www.birdscanada.org/volunteer.jsp.
[13] Ice Watch, "Icewatch Engaging Citizens in Science," *IceWatch*, accessed July 29, 2017, https://www.naturewatch.ca/icewatch/.
[14] Ibid.

challenges in collecting accurate data, maintaining data through time, having adequate energy and number of interested participants[15]. There can also be problems with accuracy if there is bias by the citizen scientists collecting the data. If the community is monitoring their water quality it is likely because they question the quality of their water.

There can also be questions as to the longevity of the program. If there are a few key community members who propel the program forwards but leave it after moving from the area, it is difficult to say if the program will continue[16]. To ensure that a program is successful, it is best that the program is intergenerational, inclusive of a variety of engaged member and programs that are accessible to all[17].

Another challenge of citizen science is that not all research can be done by citizen scientists. In some cases, samples must be sent to a professional laboratory for testing. However, this is not always possible because of geographic restrictions, time-sensitivity of some samples, and financial limitations. Finally, some things are just difficult to test for – creating a gap between what a citizen science would ideally know and monitor if professional scientists cannot be employed to help.

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[15] Janis L. Dickinson, Benjamin Zuckerberg, and David N. Bonter, "Citizen Science as an Ecological Research Tool: Challenges and Benefits," *Annual Review of Ecology, Evolution, and Systematics* 41 (2010): 149–72.
[16] Greg Newman et al., "The Future of Citizen Science: Emerging Technologies and Shifting Paradigms," *Frontiers in Ecology and the Environment* 10, no. 6 (2012): 298–304.
[17] Ibid.

#1.2 How to Create a Citizen Science Program that Works for Your Community

If you are interested in citizen science here are some links to help you learn more.

1. https://scistarter.com/citizenscience.html

   This link includes a TED talk on the benefits of citizen science and helps readers to understand the basics of what different components are brought together to perform citizen science research.

2. https://www.nationalgeographic.org/encyclopedia/citizen-science/

   This link talks about different examples of citizen science and how it can be possible even in urban environments. It then dives into the history of citizen science. It also talks about the role that technology plays in data collection.

3. http://www.citizensciencecenter.com/citizen-science-definition/

   This link discusses some frequently asked questions around citizen science programs.

4. http://publications.gc.ca/collections/collection_2011/ec/En1-28-1-1999-12-1-eng.pdf

   The link above is a special edition of an insert into a scientific journal that specifically talks about citizen scientists that are volunteering in the Canadian environment and outline their contributions.

These resources are more specific as to what will help you to determine how to create a water quality monitoring program that works for your community.

5. https://terra.nasa.gov/citizen-science/water-quality

NASA produced this link, in the webpage, it discusses the successes associated with citizen science monitoring water quality in the United States.

6. https://www.evergreen.ca/downloads/pdfs/watershed-toolkit/waterMonitoring_FINAL.pdf

   This link can help you to create your own citizen science water monitoring program. It can help you to pick your site and determine some of the parameters that should be monitored.

7. http://www.catchmentbasedapproach.org/images/PDFS/CaBACitizenScienceVolunteerMonitoringLOWRES.pdf

   This link can help a community to compare prices of different equipment and let the purchaser know the main differences besides price associated with each piece of equipment.

8. http://www.tu.org/sites/default/files/offline/science/WaterQualityV2.pdf

   This document walks the reader through the purpose of citizen science and water quality monitoring and its importance. It then goes on to help the user create their own program by focusing on what there is interest in and what can be monitored. It also gives helpful tips on how to stay safe and get accurate results while monitoring. The document also goes into the different parameters you could measure and what impact they have on the aquatic ecosystem.

#1.3 What makes the prairie region unique?

The hydrology of the prairies is that of fill and spill in low-laying areas[18] the prairies also experience a wet-dry cycle that causes variability [19]. The land here can also be saline, meaning that there is a larger concentration of salt found in the soils in parts of the prairies[20], this can also contribute to higher salinity in lakes. The prairie region also has a high nutrient level in the soil, which can create blooms without human inputs. These blooms can occur also because a majority of prairie lakes are shallow, which can be very helpful in creating ideal conditions for a bloom to occur. As these factors compound to make ideal situations for algal blooms to occur it is important that there is a lake management program in place to monitor and manage the lake health.

The prairie region does not get much rainfall throughout the year. Most of the precipitation falls in the winter in the form of snowfall. That is where much of the moisture comes from for the entire year[21]. The topography of their area is predominantly grains and grasses with sparse shrubbery[22]. Many nutrients were

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[18] McGill University, "Canadian Biodiversity: Ecozones: Prairies," *Canadian Biodiversity*, accessed July 24, 2017, http://canadianbiodiversity.mcgill.ca/english/ecozones/prairies/prairies.htm.
[19] Jen Gerson, "Why Exactly Are Floods Soaking Saskatchewan and Manitoba? And Are They Here to Stay?," *National Post*, July 2, 2014, http://nationalpost.com/news/canada/why-exactly-are-floods-soaking-saskatchewan-and-manitoba-and-are-they-here-to-stay.
[20] William M Last and Fawn M Ginn, "Saline Systems of the Great Plains of Western Canada: An Overview of the Limnogeology and Paleolimnology," *Saline Systems* 1 (November 18, 2005): 10, doi:10.1186/1746-1448-1-10.
[21] Ibid.
[22] Ibid.

left in the soil from the last glaciation period, giving us the geographic landscape we are accustomed to now[23]. As the land is high in nutrients it can cause problems with nutrient loading in the water bodies[24]. The area is also dominated by agriculture allowing for more nutrient run off to occur and cause further nutrient loading in the water bodies. This region is also relatively water insecure making it important that the water resources present can be managed properly[25].

#1.4 Types of lakes commonly found in the prairies

There are two types of lakes that are commonly found in the prairie region. These types of lakes are dimictic also known as seasonally stratified lakes and polymictic lakes. Dimictic lakes are often deeper; therefore, they can have problems with the cycling of nutrients and oxygen in the lower levels of the lake[26], particularly during summer. They are mixed twice a year during spring melt and again at the end of fall. Polymictic lakes are more common in the prairies as they are identified as shallow lakes that experience levels of mixing at any point in the year[27]. Although, these lakes are less likely to have oxygen related problems in summer as a result of the shallowness of the water and lack of stratification, they are subject to more frequent oxygen problems in winter, which can lead to fish kills.

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[23] Ibid.
[24] D. Schindler and W.F. Donahue, "An Impending Water Crisis in Canada's Western Prarie Provinces," *Proceedings of the National Academy of Science of the United States of America* 103, no. 19 (2006): 7210–16.
[25] Ibid.
[26] The Scientific Fisherman, "Lake Classification by Mixing," *The Scientific Fisherman*, March 5, 2014, http://thescientificfisherman.com/lake-classification-mixing/.
[27] Ibid.

Following this section the paper will discuss some parameters that can be monitored by citizen scientists. These parameters are important specifically for monitoring in the prairie region because of the unique geographic and climate factors that influence the area. These parameters include, aquatic plants, weather, changing shorelines, health risks, total dissolved solids, macrophytes, water clarity, total nutrients, cyanobacteria blooms and total oxygen and temperature.

#1.5 Winter Safety Procedures

Continuing citizen science monitoring into the winter can be an affective way of understanding the lake and the changes it experiences throughout a whole year. However, there are many difficulties associated with monitoring parameters in the winter months when there is likely a layer of ice covering the body of water. Therefore, certain safety precautions should be used when attempting to preform winter monitoring. It is best for those who are comfortable with being on the ice to monitor in the winter season. This likely means ice fishers should be the ones conducting the data because of their knowledge of the winter ice layer on their lake as well as their tools that are used for ice fishing can also be deployed for conducting monitoring parameters on the water. Monitoring in the winter can be especially important in prairie lakes because they are generally shallow. Understand the exchange of oxygen between the atmosphere and the water in the winter can help to gain insights into how the ecosystem functions.

Safety is a top priority when dealing with nature at all times, but more precaution should be taken in the winter months as sub-zero temperatures can be dangerous very quickly. Thus, it is important to follow safety procedures such as

checking the ice thickness, which should be thicker than 15 cm[28] and should also pay attention to any warning signs or advisories posted by local health or weather authorities[29]. Avoiding rivers, open water, thin ice and quick moving water can also help to ensure safety[30]. It is important that one never ventures out onto the ice alone, a buddy system should be utilized at all times[31]. Wearing a cold suit and a personal flotation device can help to protect oneself in case of contact with sub-thermal water[32]. It is also advised that rescue equipment should be carried at all times, which includes rope and a phone in a waterproof container to call for help[33].

#2. Health Threats

Key points

This section reflects health risks associated with recreational water activities and is focused on microbial risks. Further health threats are discussed in section #3. Cyanobacteria blooms.

1. https://www.saskatchewan.ca/residents/health/understanding-the-health-care-system/saskatchewan-health-regions/regional-public-health-inspectors

[28] "Ice Fishing - Canadian Red Cross," *Red Cross Canada*, July 31, 2017, http://www.redcross.ca/training-and-certification/swimming-and-water-safety-tips-and-resources/swimming--boating-and-water-safety-tips/ice-fishing.
[29] Ibid.
[30] Ibid.
[31] Ibid.
[32] Ibid.
[33] Ibid.

This link gives a list of the different public health authorities in Saskatchewan and how to contact the public health inspector in your region.

2. https://www.gov.mb.ca/health/rha/contact.html

This link helps to identify the health authorities in Manitoba and how to contact the inspector in your area.

3. http://www.albertahealthservices.ca/zones/zones.aspx

The link above identifies the different health regions in Alberta and can bring the user to the correct web page for their region.

Beach Monitoring

Ensuring the safety of swimming in a lake is important to cottage owners and day visitors alike. Monitoring for bacterial and fecal contaminants is not something that can be done easily by citizen science groups, thus it is best for citizen scientists to collect samples that can be analysed by a professional laboratory. It is important to test for microbes and fecal contaminants, as these are some types of bacteria that can make swimmers feel ill. In the case that professional testing are able to take place to monitor for bacteria or fecal coliforms that could be harmful to human health laboratories in Saskatchewan can test for these contaminants. There are higher risks for bacterial or fecal water contamination after rainfall events. After large rainstorms water could be tested for these risks to ensure swimmer safety. The government of Saskatchewan website has a list of the different water quality parameters that water samples can be tested for. The costs of each type of testing is listed on their website and packages to test multiple parameter can also be purchased. The website also has information on the best practices to get the most

accurate sample data, including how to prepare samples and how to transport them to the laboratory.

1. https://www.saskatchewan.ca/residents/environment-public-health-and-safety/environmental-health/water-quality-and-testing/getting-water-tested

   This link can help citizens scientists to understand what their water can be tested for and how samples can be taken.

2. http://lakewatch.ifas.ufl.edu/pubs/circulars/Circ106BacteriaLR.pdf

   The link gives a brief description of what bacteria is and what bacterial strains are important to monitor for swimmer safety.

3. https://www.theswimguide.org/

   This link helps citizens to understand the swimming safety of the beaches in their area.

#3. Water Clarity

Key points

Water clarity is an important measure, it can impact your enjoyment of the lake, and also reflects the overall health of a lake, and how that may be changing. Cottagers often value clear waters, but lakes are known to change in clarity rapidly, for example, as a result of nutrient pollution. Water clarity is expected to change seasonally and is typically at its lowest in summer, and after storms. Testing can be

done easily, inexpensively and accurately using a secchi disk which is a simple, centuries-old technology.

What is it?

Water clarity refers to the depth in which sunlight can penetrate the water[34]. Water clarity is impacted by the amount of suspended particles in the water body, including algae, cyanobacteria, and suspended particles resulting from riverine inflows, and windstorms[35]. In shallow waters, certain types of fish and invertebrates can also impact the number of suspended particles at a given point. Humans can impact the water clarity by the amount of boat activity that occurs in the lake.

Why do we measure it?

Water clarity is a key indicator of ecosystem health, which many cottagers care about, it is easy to measure and can be tracked through time. Declining water clarity can affect the growth of rooted aquatic plants. While some cottagers do not like aquatic plants – they serve an important role in helping to keep the water clear – so the loss of water clarity and associated loss of aquatic plants can lead to very rapid deterioration of lake transparency, a major concern to cottagers.

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[34] Moriya Rufer, "Monitoring Water Clarity," *Minnisota Pollution Control Agency*, accessed July 12, 2017, http://www.pelicanlakemn.org/Education/Lake_Learning/monitoring_water_clarity.htm.
[35] Ibid.

How do we measure it?

Secchi Disks

Secchi disks are a disk that is attached to the bottom of a rope; they are divided into quarter sections that are coloured black and white alternatively. The disk is lowered into the water when the disk is no longer visible the depth is noted[36]. The disk is then raised until it is visible again this depth is noted[37]. The average of these two depths are taken to determine the transparency of the water in the location[38]. These measurements should be taken from the sunny side of the boat[39]. If measurements are taken from the shade side, they are more susceptible to errors[40]. Measurements should be taken frequently throughout the spring to fall of the water body as the clarity can change frequently.

Here is a how to video that demonstrates how samples should be taken;

https://www.youtube.com/watch?v=XYjh6sD6Bqk

Chlorophyll A

Chlorophyll A is an essential component in photosynthesis. Chlorophyll A is measured in water to get an understanding of the cumulative algal biomass present

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[36] Michigan Clean Water Corps, "Secchi Disk Transparency," *Michigan Clean Water Corps*, accessed July 10, 2017, https://micorps.net/wp-content/uploads/CLMP-Secchi-FactSheet.pdf.
[37] Ibid.
[38] Ibid.
[39] North American Lake Managment SOciety, "Secchi Disk Procedures Used in Several State Programs," *The Secchi Dip-In*, March 31, 2015, http://www.secchidipin.org/index.php/monitoring-methods/the-secchi-disk/secchi-disk-procedures-used-in-several-state-programs/.
[40] Ibid.

in the water body. The total amount of chlorophyll A is related to the productivity of the lake. This can be measured by sampling the upper portion of the water column, where sunlight can still penetrate to get samples of the amount of algal growth occurring in this area[41]. Chlorophyll A samples must be analysed in a laboratory[42], and the laboratory can inform you of the best practices on how to prepare samples for increased accuracy. Contact your local laboratory services for further information before collecting your first sample.

Data management

The measurements taken from the secchi disk reading should be kept on digital and hard copy sources. Both the averaged depth as well as the lowest depth and highest depth should be recorded. This information can also be input into the GLEON Lake Observer App that can be downloaded for free from the Apple store or the Google play store. Chlorophyll A measurements can be kept as a digital record form that is sent from the laboratory that tested the sample. It is important that date be accessible and easy to understand so that other users can interpret the data and data can easily be compared between measurements.

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[41] Kenneth Dunton, "Water Column Chlorophyll a Extraction," Texas Parks and Wildlife, (July 2004), http://tpwd.texas.gov/landwater/water/habitats/seagrass/media/QAPP/Chlorophyl_a_protocol.pdf.

[42] EPA, "Standard Operating Procedure for Chlorphyll a Sampling," March 2013, https://www.epa.gov/sites/production/files/2017-01/documents/sop-for-chlorophyll-a-201303-5pp.pdf.

Costs

Secchi disks are relatively inexpensive and can be used repeatedly[43]. Chlorophyll A testing can differ at each lab and each year. The link below is to the Saskatchewan laboratories that lets users know the price of testing different water quality parameters. https://www.saskatchewan.ca/residents/environment-public-health-and-safety/environmental-health/water-quality-and-testing/testing-scope-and-service-charges

Resources and other groups

Other citizen science monitoring programs use secchi disks to monitor the water clarity of the water body they are observing. Here are some helpful links to other cottager associations that monitor water clarity.

1.http://www.pelicanlakemn.org/Education/Lake_Learning/monitoring_water_clarity.htm

This link discusses the functionality of the secchi disk and how it can be used. It explains in simple language the science behind the secchi disk.

2. https://micorps.net/wp-content/uploads/CLMP-Secchi-FactSheet.pdf

The link below is from the Michigan Clean Water Corps. They have a citizen science program in the state, the link is a fact sheet produced by the agency to help citizen scientists to take secchi disk readings.

3. https://www.pca.state.mn.us/water/history-secchi-disk

[43] Fondriest Environmental, "Watermark Professional Secchi Disc Kit," *Foundriest Envrionmental*, accessed July 19, 2017, http://www.fondriest.com/watermark-77914.htm.

Below is a link that identifies the history of the secchi disk and its use and development throughout time.

#4. Cyanobacterial Blooms

Key points

Cyanobacteria are also referred to as blue-green algae. In some cases, cyanobacteria can be toxic to humans. In other cases cyanobacteria can cause unpleasant taste and odour as well as major changes to the water body. Cyanobacteria can occur when there is nutrient loading in the water body combined with warmer than average temperatures. Cyanobacteria blooms have become more intense and more frequent over time due to nutrient loading and seasonal warming[44], but cyanobacteria blooms can be a result of natural processes. As the prairies experience high levels of nutrients naturally blooms can occur without human influence[45].

What is it?

Cyanobacteria are a concern because they can be toxic, and can have negative impacts on aesthetic quality of a lake, and its ecology [46]. Cyanobacteria include a

[44] ORD US EPA, "Harmful Algal Blooms & Cyanobacteria," Overviews and Factsheets, *US EPA*, (June 6, 2014), https://www.epa.gov/water-research/harmful-algal-blooms-cyanobacteria.
[45] Ibid.
[46] H.R. Hunter, "Cyanobacteria and Human Health," *The Pathological Society of Great Britain Anf Ireland* 36 (1992): 301–2.

variety of species, not all of which are harmful to humans. Even species that can be harmful, may not always produce toxins. As a result, it is extremely difficult to make the distinction between harmful and safe cyanobacteria without performing tests, thus, if a cyanobacteria bloom is occurring, humans should avoid using the water source for drinking as well as recreation until the water can be tested[47]. Blooms are likely to occur in the summer season in many nutrient rich prairie lakes, as conditions are right for blooms to grow rapidly when water temperatures are high.

Why do we measure it?

Monitoring for cyanobacteria is important for a number of reasons. First, it can be harmful to human and animal health. It can also reduce the opportunities for recreation and change property values[48]. Cyanobacteria blooms are also expected to get worse as climate change progresses. Thus, it is important to understand and note warning signs that could cause blooms in the future.

How do we measure it?

Properly measuring and identifying the types of cyanobacteria present in a bloom is an important but difficult task. Many different cyanobacteria look similar to one another and may only be differentiated by using microscope and a trained professional. Since this is not always possible it is still important to keep records of what is occurring in the water body

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[47] Ibid.
[48] Hilary Snook, Shane Brandt, and Jeff Hollister, "Cyanobacteria Monitoring Collaborative," *Cyanobacteria Monitoring Collaborative*, accessed August 15, 2017, https://cyanos.org/.

1. http://epa.ohio.gov/portals/35/hab/HAB_Report_Form.pdf

This link is to a form that should be filled out if you suspect a bloom to be occurring. Though this form is produced in partnership with the government of Ohio the questions on the form are still relevant to blooms occurring in the prairies.

2.http://www.clrma.org/files/springconference/CLRMA%20Luncheon.2015.HAB%20Guidance%20Document.pdf

This link can help individuals to understand what types of algae are present in the water body. There are multiple charts in the article that can help readers to form preliminary conclusions without the assistants of laboratories. It explains more about the types of algae that could be present in a bloom and helps the reader to understand which of these algae's are harmful to humans. This link also breaks down some easy ways to identify the different species.

Your local public health official is also a good source to reference as they may have advisories in place that negate the need for testing to occur. If information is not available samples can be taken and sent to laboratories to determine if a cyanobacteria bloom is occurring. It is best to contact your local laboratory to understand best practices for collecting samples.

Data management

These forms noted above should be collected over time to monitor for any changing trends in the water body. Your local laboratory or health authority should be contacted if you have serious health concerns about the bloom. Contacting a

laboratory to see if they would be able to test for cyanobacteria or cyanobacterial toxins could be a good step and helpful for your specific water body.

Costs

The costs of sampling and transportation of samples will depend of the laboratory selected and whether you are sampling for cyanobacteria, or toxins. Contact a laboratory for more details, although currently both suites of analysis tend to be expensive, and the risk associated with a bloom can change rapidly in time, making monitoring challenging, and potentially expensive.

Resources and other groups

Other citizen science monitoring programs participate in the HABS or Harmful Algal Bloom monitoring. To get more accurate data on the types of algae blooming in their water body and determining if the species is harmful, samples must be taken and examined by a laboratory. This is difficult as the time spent between sampling and testing is important, therefore a laboratory would have to be contacted before samples are taken to determine the best way to transport samples and the viability of the samples. Here are some helpful links to learn more about cyanobacteria.

1. http://www.muskokawatershed.org/wp-content/uploads/AlgaeIDSheet.pdf

   The link above is a fact sheet produced by a group in Muskoka. The fact sheet goes over the basics of cyanobacteria and the health risks associated with the bacteria.

2. https://cyanos.org/

Below is a link that is a world wide website and citizen science organization that informs users on the risks of cyanobacteria. It is a collaborative program that helps to monitor for signs of cyanobacteria blooms.

Health management

If a cyanobacteria bloom is suspected it is safest to stay out of the water body. Any vigorous exercise immediately next to the water should also be avoided as toxins, if present, could cause respiratory problems[49]. Cyanobacterial blooms are also a significant risk to pets and livestock.

Cyanobacteria can change the colour of the lake, as well as create a strong odour. It can also cause skin irritations on those who enter the water body. Many people will have no symptoms from exposure; others may have respiratory problems, rashes, or serious issues, for example with their livers[50].

#5. Dissolved Oxygen & Temperature

Key points

Dissolved oxygen in an important component of lake health. The dissolved oxygen in a lake affects the habitat available for fish with low dissolved oxygen contributing to fish kills in many lakes. Low dissolved oxygen in bottom waters can

[49] ORD US EPA, "Epidemiology & Health Effects of Cyanobacteria," Overviews and Factsheets, *US EPA*, (June 6, 2014), https://www.epa.gov/water-research/epidemiology-health-effects-cyanobacteria.
[50] Ibid.

also lead to greater nutrient release from the sediments – contributing to water quality problems. Finally, changes in dissolved oxygen in surface waters can reflect the productivity of a lake – providing important information about ecology, and changes in the lake productivity.

Temperature and dissolved oxygen are typically measured together as the temperature of the water impacts the density (hence stratification in the lake) and the solubility of oxygen[51]. It is important to identify what type of lake you are monitoring before taking measurements. As noted in the above in section #1.3, what makes prairie lakes unique there are two different types of lake classification, dimictic and polymictic. The type of lake you are monitoring will either have frequent mixing as is common with polymictic lakes or infrequent mixing that occurs in dimictic lakes. If a lake is classified as dimictic, the dissolved oxygen level should be tested in the late summer and the late winter when the lake would be stratified. If the lake is polymictic, testing can occur for frequently as the there is continuous movement in the lake that could create differing levels of dissolved oxygen at different points throughout the year[52]. To learn more about procedure in the winter refer to section #1.5.

What is it?

Dissolved oxygen is similar to the oxygen that would be found in the atmosphere but in dissolved quantities in the water. Much like terrestrial animals

[51] Michigan Clean Water Corps, "Dissolved Oxygen and Temperature," accessed July 19, 2017, https://micorps.net/wp-content/uploads/CLMP-DO-Temp-FactSheet.pdf.
[52] Fisherman, "Lake Classification by Mixing."

that can be found on land, the aquatic animals that live in the water depend on oxygen to survive. The variation in dissolved oxygen levels can impact the types of species that grow and thrive in a given environment[53].

Temperature has a very important impact on the dissolved oxygen amount in a water body. The temperature changes the water's ability to hold oxygen; it also impacts the productivity of the lake, which impacts the levels of dissolved oxygen[54], finally, temperature variation from top to bottom in a lake affect mixing. When a lake is layered with cold water at the bottom, oxygen depletion in those bottom waters may be more likely to occur. The dissolved oxygen level in the water body changes throughout the year as the biological productivity changes across seasons.

It is important to measure dissolved oxygen over the winter season as well because the ice acts as a barrier to gas exchange and can impact the amount of dissolved oxygen in the water body. Fish kills are relatively common in shallow prairie lakes in winter, particularly when there is heavy snow cover.

Why do we measure it?

Measuring the dissolved oxygen content of a water body is an indicator of the health of the water body. By measuring the dissolved oxygen researchers are able to get an estimate of what type of aquatic life are able to live in the water body.

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[53] Fondriest Environmental, "Dissolved Oxygen," *Environmental Measurement Systems*, accessed July 19, 2017, http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/.
[54] Ibid.

How to measure?

Dissolved oxygen should be monitored in different frequencies depending on the type of lake being monitored. Dissolved oxygen should be monitored every 2 to 3 weeks from melt to first frost; this can vary from year to year because of the changing temperature.

Temperature should be taken alongside the dissolved oxygen measurements.

The type of sensor that is purchased can dictate the frequency of the measurements increments. In some cases a continuous sensor may be the best option but in other situations different sensors may be better for the needs of the community monitoring the water body.

Both the dissolved oxygen reading and the temperature should be recorded at approximately 1 meter above the bottom of the lake and near the surface. It should also be taken from a boat that is no longer running in the middle of the water body. This will reduce the amount of suspended solids that could interfere with the dissolved oxygen sensor.

Data management

Data that is collected using a dissolved oxygen sensor can be stored on a computer in a spread-sheet program in which numbers can be analyzed and compared to each other datasets from the same year and/or across years. Data can also be compared across lakes in the region

It is important to consistently monitor water temperature at the same time every day to ensure you obtain usable data. If temperatures that are taken in the

Commented [HB1]:

Here is my previous comment – which I don't tt think is fully addressed. If you don't understand my comments – we need to discuss via regular meetings. –

Again, question fo whether you're talking about continuous sensors, or profiles take for example with a YSI. See what other programs do – but YSI are tricky and expensive. Sensor more practical – but they provide very different data (Profile top to bottom vs. one location through time). You probably need to describe both.

Commented [HB2]: Most importantly…it is needed to understand the solubility as well….

Commented [HB3]: This comment from last version has not been addressed:

ensor data are tricky – there is much more to it than this – calibration, tracking fouling, frequent maintenance, etc.

morning are compared to temperatures taken in the afternoon, the variation in results can cause problems with results when compared with the dissolved oxygen level.

If sensor technology is being used to monitor the dissolved oxygen levels the proper instructions for terms of use of the sensor must be used and adhered to. This could mean calibration is needed or software updates or any form of maintenance associated with a sensor. This will be specific for what type of sensor is used. When the piece of equipment is purchased it is important to read the operating manual.

Costs

The prices of dissolved oxygen sensors can range greatly depending on the sophistication of the type of sensor needed. For a citizen science based program it is up to the group to decide the level of sophistication the technology they need is. They can also be limited by costs of the equipment and this can determine the equipment used. The price of the technology can range between $700 to $25,000. This is a link to different types of dissolved oxygen sensors, it can give an idea of what is right for your lake as well as the costs associated with it; https://www.analyticaltechnology.com/analyticaltechnology/gas-water-monitors/product.aspx?ProductID=1068 .

Resources and other groups

Other groups are likely to use a dissolved oxygen sensor and temperature probe as equipment for measurement. Here are some helpful links to other cottager associations that monitor dissolved oxygen and temperature:

1. https://micorps.net/wp-content/uploads/CLMP-DO-Temp-FactSheet.pdf
   This link is again from the Michigan Clean Water Corps. They have a citizen science program that monitors for water clarity. This sheet is for their citizen scientists to learn how to monitor for dissolved oxygen and temperature.
2. https://www.annapolisriver.ca/annapolis-river-guardians
   The Annapolis River Guardians is a project in the Annapolis Valley in Nova Scotia. They use dissolved oxygen as one of the assessment tools for their restoration project.

#6. Nutrients-Total Phosphorus & Total Nitrogen

Key points

Phosphorus and nitrogen are elements that can be responsible for eutrophication and cyanobacterial blooms. For example, phosphorus is linked to the large algal blooms in Lake Winnipeg[55]. Nitrogen is another element that can often be found in above average quantities because of the human application of nitrogen for fertilizers[56]. The nitrogen that is used as a fertilizer on land also acts as a fertilizer in the water and can cause increased plant and algae growth[57].

[55] Michigan Clean Water Corps, "Total Phosphorus," accessed July 19, 2017, https://micorps.net/wp-content/uploads/CLMP-TP-FactSheet.pdf.
[56] EPA, "Total Nitrogen," June 4, 2013, https://www.epa.gov/sites/production/files/2015-09/documents/totalnitrogen.pdf.
[57] Ibid.

What is it?

Phosphorus and nitrogen are naturally occurring nutrients that are essential for plant growth both on land and for aquatic plants[58]. Phosphorus is a necessary building block for aquatic plant life but there are other uses for phosphorus. Phosphorus can be used alone or in a combination with nitrogen and other elements as a fertilizer for residential use (e.g., lawn fertilizer) or on-farm operations. It is also released in human waste, which can be a concern in many cottage lakes where septic systems may not be adequate for nutrient removal. Although, nutrients are necessary for plant growth, it can become problematic when there is a surplus[59], leading to high algal biomass, declining water clarity, and cyanobacterial blooms.

Why do we measure it?

Nutrient pollution is the primary stressor affecting the water quality of lakes globally. Monitoring nutrients can help understand if and when problems are developing, and provide insight into how to manage them. Without measurements it is difficult to understand changes over time and what could be considered normal levels of nutrients in a given water body.

How do we measure it?

Total phosphorus and total nitrogen can be measured by taking a sample of the water into a bottle that is one to two feet below the surface of the water. The

[58] Michigan Clean Water Corps, "Total Phosphorus."
[59] Ibid.

sample is taken with the opening of the bottle facing upwards to let the water flow in[60]. These samples must be taken using clean bottles as to not contaminate the sample. The sample should also be taken over the middle of the lake so that suspended sentiments that can be stirred up in shallow water are not collected. Samples should be taken at equal intervals over the year, ideally including the winter. The value of the total phosphorus and total nitrogen can change drastically over the course of one year especially depending on the type of lake being monitored, as noted in the, *what is unique in the prairies*, section #1.3 These samples to be tested would have to be sent to a laboratory for independent testing.

Data management

Results of the testing will be sent back from the laboratory noting the concentrations of total phosphorus and total nitrogen. These results should be kept together to create a picture of what the levels look like at similar points in the year over multiple seasons.

Costs

Costs will vary depending on the laboratory chosen to perform the sample analysis. Small clean containers for collecting water samples can be bought in bulk online at a reduced price, but are typically provided by the laboratory.

[60] Ibid.

Resources and other groups

Other citizen science groups typically monitor phosphorus, although monitoring nitrogen is also recommended in the prairies. Here are some helpful resources to continued reading and what other groups do.

1. https://www.ec.gc.ca/eaudouce-freshwater/default.asp?lang=En&n=0A77A85E-1&printfullpage=true

   The link below is to the federal government page of Environment and Climate Change Canada. It explains the impacts of phosphorus in aquatic ecosystems.

2. http://publications.gc.ca/site/eng/99345/publication.html

   This link notes the impact of nutrients and their impact on the environment. It focuses on phosphorus and nitrogen and their occurrence in the environment and water bodies in the country.

3. https://micorps.net/wp-content/uploads/CLMP-TP-FactSheet.pdf

   This resource is from the Michigan Clean Water Corps. It is a fact sheet informing their citizen scientists how to monitor for nutrients in the lakes.

#7. Aquatic Plants- Native & Invasive Species

Key points

Aquatic plants are a natural part of many lakes, they help stabilize sediments and improve water quality while providing important habitat for wildlife. The

introduction of new plant species (invasives); can be a major issue, and, many cottagers worry about extensive plant growth, making it an important parameter to monitor. Though plants are important, it is necessary to have the right types of plants in the water body and on land around the aquatic ecosystem. Invasive species are plants, animals and invertebrates that are naturally occurring in other parts of the world but not native to the prairie region[61].

What is it?

Aquatic plants are an essential component of the lake body ecosystem, they provide nutrients to the invertebrates and fish in the water body as well as providing an ideal habitat for fish to reproduce and lay eggs. Some plants can become aggressive and become a dominant feature of the waterway, this can happen with native and invasive plants.

Invasive species are organisms that are native to one part of the world but are not native to other parts of the world. When invasive species are transferred to other parts of the world intentionally or unintentionally, they can out compete the native species in the region because they are not exposed to the same predators[62].

[61] National Oceanic and Atmospheric Administration US Department of Commerce, "What Is an Invasive Species?," July 6, 2017, https://oceanservice.noaa.gov/facts/invasive.html.
[62] Ibid.

Why we measure it?

It is important to be cautious of invasive species because once they are present in a new ecosystem, it can be impossible to remove them and it can forever alter the ecosystem and food chains in the area.

Invasive species are an emerging issue in the prairie region, as people become more mobile, organisms from different areas travel with them[63]. Different parts of Canada have already had negative experiences because of the aggressiveness of invasive species.

These invasive species can be transferred on water sport vehicles and water toys. You can reduce the risk of transporting invasive species by rinsing all instruments that were exposed to a water body before moving and transporting the instruments to a new body of water. They must also be left to dry out of the water for 24 hours before entering a new water body or otherwise decontaminated.

1. http://www.environment.gov.sk.ca/Default.aspx?DN=f261b408-d5e3-4a45-831a-c81e5d33a636

   This link can be helpful for understanding how to properly clean drain and dry boating equipment as well as invasive threats in Saskatchewan.

2. http://invasivespeciesmanitoba.com/site/

   This link will aid people in understanding invasives threats in Manitoba. It lists the major plants of concern in Manitoba and best practices to avoid transportation.

[63] Ibid.

3. https://www.abinvasives.ca/

This link is for invasive species in Alberta. The link identifies the major threats to Alberta and prevention practices for reducing risk of transporting invasive species.

These groups give guidance on how to reduce risk of invasive species transportation as well as a number of the invasive species that are of special concern in the provinces and who to get in contact with if you discover a potential invasive species.

How we measure it?

Monitoring of aquatic plants and invasive species can be a difficult process. The first step in monitoring these plants is determining what the origin of the plant is. Having a data base of the plants native to the water body will protect the ecosystem as cottage owners and citizen scientists become familiar with the native plants it becomes easier to spot invasive plant species when they are introduced.

Small samples of plants could be taken out of the water and identified by using any type of native plant species guide. Once identified it is important to note the location and frequency of each plant. This can be done by noting on a map where species can be found. A different map should be used each year to note any variation in the population over time. To get more specifics on the abundance of a plant a cross sections of the lake can take place[64]. Depending on the water body size there would be variation in the appropriate number of samples. Locations for frequency

[64] Michigan Clean Water Corps, "Aquatic Plant Identification & Mapping."

should be spread out to note different populations in the water body. At each site a centre should be picked and noted with GPS coordinates to keep sampling consistent[65]. From that point, a count should take place of the frequency of a given plant. Looking 1 meter north and noting frequency. This should be replicated with the points to the west, south, and east. This method can help to track invasive species and their predominance if they start. This can be considered a cross section of the plants living in a 1 meter squared portion of the water body.

Data management

The cross section of the species should be done on paper copies at the moment when it is occurring, this could occur on a boat. These copies should be later scanned into a digital resource. Having scanned documents also allows other to replicate the research. The scanned documents can also be overlaid on top of one another to view how the changes to the growth patterns over time. The next edition of the GLEON Lake Observers App will most likely have a section for aquatic plant monitoring and noting invasive species. The cross sections can be a great visual to determine how the aquatic plants are growing over the year. It can show the changes over time and can later be compared to weather data and other collected research to determine what factors can influence the plant growth.

[65] Ibid.

Costs

The costs associated with monitoring aquatic plants are the costs of native plant guides. There is also the cost of printing maps to note instances of native and invasive plants.

Resources and other groups

Other groups are likely to monitor aquatic species and invasive species by creating their own guide to the water body they are looking at as well as creating cross sections to note species. Here are some helpful links to other cottager associations that monitor aquatic species and invasives and other helpful resources for identification.

1. https://micorps.net/wp-content/uploads/CLMP-AqPlant-FactSheet.pdf

   The link below is from the Michigan Clean Water Corps. They have a water quality citizen science monitoring program and the fact sheet below is for aquatic plant monitoring.

2. https://www.invasivespeciesinfo.gov/aquatics/main.shtml

   Below is a link from the United States Department of Agriculture National Agriculture Library. This link allows for people to identify common aquatic plants and invasive pests. It allows for anyone to search plants by common or Latin name and find their range in North America.

3. https://www.npss.sk.ca/home

This link demonstrates the native plants in Saskatchewan. It gives information and plant varieties in Saskatchewan. The link further breaks down into different types of plants commonly found in the region.

4. http://www.saskwildflower.ca/native-plant-photos.html

This resource helps to identify the different types of wildflowers that grow in the prairies. It uses photos to help users to identify the plant varieties in their yard.

What can you do?

It is important not just for aquatic species to be native species but also for terrestrial species that are planted near water bodies. By using and planting native species in gardens and for lawns it is more likely to attract wildlife that is native to the area.

Using native plants can help the biological productivity and diversity of the area by creating a biologically diverse space that caters to native species. This can help with the longevity of the ecosystems and hardiness to weeds and other foreign pests.

#8. Changing Shorelines

Key points

Changing shorelines can be due to natural geo-morphological processes[66]; these processes can be altered because of man-made choices and actions. It is important to keep track of the changing shorelines and the riparian zone. This is where much of the biological productivity of the water body is as well as where terrestrial plants and animals interact with the aquatic ecosystem[67].

What is it?

Changing shorelines can be a natural process but it can also be accelerated by man made choices that speed up the process of shoreline evolution[68]. Shorelines are an important area of the lake or waterway ecosystem. They are great places for aquatic life as well as terrestrial life; animals and fish use this area as part of their lifecycle or as a place to get necessary nutrients.

Healthy shorelines are important for both riparian health and aquatic health. Although, they are important natural features they are often overlooked or over

[66] Waikato Regional Council, "Shoreline Change Monitoring," *Waikato Regional Council*, accessed July 19, 2017, https://www.waikatoregion.govt.nz/environment/natural-resources/coast/monitoring-and-projects/cam-era-video-beach-monitoring/.
[67] Federation of Ontario Cottagers' Association, "Lake Planning Handbook for Community Groups," accessed July 12, 2017, http://www.foxboroughma.gov/pages/foxboroughma_conservation/l-04.pdf.
[68] Waikato Regional Council, "Shoreline Change Monitoring."

manicured areas[69]. It is important to note that the features that are most desirable for recreation are not the most important features for shoreline health.

Why we measure it?

Monitoring the shoreline is an important indication of what is going on in the water-body. The narrow strip where the water meets the land is a very productive area[70]. It is an important location for land animals to use the waterways as a resource[71]. It is an important spot where there is a breadth of aquatic plants are able to grow, and it is a place in which macrophytes live and grow and where invertebrates are able to gain necessary nutrients to live. The water in this area also tends to be shallow and warm, meaning that different varieties of aquatic life can live in this area that may differ from other areas of the water body. This area can be very indicative of the health of the rest of the aquatic ecosystem.
Measuring the changing shoreline can also be helpful to see if changes are accelerated by specific man-made events or climate change.

How we measure it?

Measuring shorelines can be done by taking video or photographic evidence of the shoreline over time. This will help to indicate how the changes are occurring in the area. It can also help to determine the natural fluctuation of the water body throughout the year and as an effect of climate change. Having continuous

[69] Waikato Regional Council, "Shoreline Change."
[70] Ibid.
[71] Waikato Regional Council, "Shoreline Change Monitoring."

photographic content occurring can also monitor the use of the water body as well as what humans introduce to the water body.

Data management

The data collected for monitoring the shoreline should be kept on an online open access resource so that it can be compared to other pictures or video collected from the same water body. These video resources can then be compared to any historical data or pictures taken at the same location. Photos can be very helpful but they can also become quickly overwhelming if there is a large quantity of photos taken. It is important to understand the physical time limitations put into this part of citizen science. Therefore, photos should be taken at a decided amount of timed intervals that would create a number of photos that is usable without overwhelming the group.

Costs

The costs of collecting this data can range greatly. The human inputs of monitoring this data can also range depending on the type of camera used and the human input needed. The monitoring can occur by setting up a camera set up to a battery pack that can take timed photos or constant video that can then be directly uploaded to the internet or to a personal computer. Or the monitoring can occur by photos on cameras already obtained by a group whenever possible remembering to date stamp the resources.

Resources and other groups

Other groups are likely to monitor shorelines by taking photos or measuring from determined points that are significant to the monitoring group. Here are some helpful links to other cottager associations that monitor changing shorelines.

1. https://foca.on.ca/wp-content/uploads/2014/05/Watershed_booklet_FULL_2011_with_covers-1.pdf

   Below is a link from the Federation of Ontario Cottagers Association. It is a handbook about how to create healthy waterfronts. The handbook is specifically designed for Ontario cottages but there is some useful information that is transferable to the prairies.

2. https://www.waikatoregion.govt.nz/Environment/Natural-resources/coast/Monitoring-and-Projects/Cam-era-Video-Beach-Monitoring/ https://www.waikatoregion.govt.nz/environment/environmental-information/environmental-indicators/coasts/shoreline-change-report-card/#Shoreline%20change

   These links are to the Waikato Region in New Zealand. They have a citizen science monitoring program in place. Their program is specific to monitoring change on the ocean with tidal ranges but some of the information is convertible to the prairies.

#9. Macrophytes

Key points

Macrophytes are aquatic plants that grow near the shore and in the water body, they can be fully submerged, partially submerged or floating on top of the water body. These plants are important to in forming the fish habitat and are an overall indicator of lake health. Macrophytes are a type of aquatic plant, they are in a separate section to emphasize the importance of macrophytes in prairie lakes.

What are they?

Macrophytes are aquatic plants that grow near the water; these plants can be fully submerged, semi-submerged or floating on the top of the water. There are a numerous varieties of macrophytes and multiple types can be living and growing in one body of water at a time. Macrophytes are a source of energy and food for aquatic animals, while also releasing oxygen which, is also important for the aquatic animals to continue to live. The roots of these species also lower the turbidity of the water as they are able to hold sediment at the lake bottom. Overall macrophytes can help to determine the health of the aquatic ecosystem.

Why do we measure them?

Macrophytes can be an overall indicator of lake health as they are a vital source of food and habitat fro fish and invertebrates[72]. They also can decrease the turbidity of the lake, as the roots are able to keep the lake bottom in place[73]. They are also create and release oxygen into the lake through the process of photosynthesis.

How do we measure them?

Monitoring macrophytes can be difficult; the first step in monitoring would be to determining the variety of macrophytes present in the water body. This could be done by taking clippings from the different varieties of macrophytes and identify the species. The amount of area that the macrophytes cover in the water body should be noted on a map. There can be multiple maps that identify where the macrophytes are that are fully submerged, one for semi submerged and one that is floating. This helps to narrow down the species so that the citizen scientist observer does not become overwhelmed with the quantity of macrophytes. These maps can be broken down further and attempt to identify the types of macrophytes going in each general area.

[72] UK Environemntal change network, "Aquatic Macrophytes — Environmental Change Network," Protocol, *UK Environemtnal Change Network*, (1999), http://www.ecn.ac.uk/measurements/freshwater/fma.
[73] Ibid.

Data management

Once samples are collected and identified they should be dried and pressed so that if there is a question about identifying macrophytes in another region of the water body identification can become easier. The maps should be compared to each other over seasons to see the growth and movement of the macrophytes in the water body. This data can be compared to other collected data sources to see how other factors influence the macrophytes growth. Something that would be very interesting to compare is the growth of other aquatic plants in comparisons to macrophytes growth.

Costs

The costs of performing this type of monitoring are relatively low. Aquatic plant handbooks or macrophytes guides may need to be purchased to aid in the identification process. The maps of the lake, identification and sampling procedure can be time-consuming but have no real costs associated with them.

Resources other groups

This link demonstrates the best practice to be used when collecting and identifying macrophytes.

1. http://www.ecn.ac.uk/measurements/freshwater/fma

   This link is from the United Kingdom Environmental Change Network. On this website, they host a downloadable file that goes over sampling procedure of macrophytes.

2. https://www.epa.gov/national-aquatic-resource-surveys/indicators-macrophytes

The link below is from the United States Environmental Protection Agency. The website gives background information on what macrophytes are and their role in the aquatic ecosystem.

3. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2179-975X2010000200011

This link is to an academic journal that can help to explore the different processes that macrophytes go through in a water body and how the presence of macrophytes can impact the surrounding water quality and other water quality parameters

#10. Weather

Key points

The weather has an impact on everything around us. It can be especially important to monitor the weather that occurs around a body of water that is being monitored. The weather can tell users if there is going to be changes in the water body.

What is it?

Weather is the state of the atmosphere directly around us. The weather includes cloud cover, temperature, precipitation, and humidity. The weather influences our daily lives as it can impact our ability to do see or do things.

Why we measure it?

Monitoring the weather is an important indicator that can impact the water body. If there are storms occurring it is more likely that the water turbidity will be increased. The amount of snowfall in the winter is a very important indicator of the overall soil moisture and determines the amount of melt that will enter various water bodies. Having these records over long periods of time can help to determine weather patterns and trends in the weather.

The snowfall and ice coverage on a water body can impact a variety of factors even once the snow and ice has melted. Monitoring over the winter can also be important. Since winter in the prairies can be incredibly harsh and long there is a lot of data that can be collected over this period of time. Aside from the above listed weather trends that should be measured the ice thickness and ice duration over the water body can be monitored. Measuring the ice can let citizen scientists know what volume of water can be approximately expected during snowmelt. The thickness of the ice can also help to determine if the changes experienced in the year are a result of warmer or colder winters or be a result of a different factor.

How we measure it?

The weather can be measured by making observational notes. These notes can be objectively taken by any citizen scientists. The amount of cloud cover can be noted along with temperature taken using an outdoor thermometer, and precipitation quantity by using a simple rain gauge. A wind speed gauge can also be used to determine the wind speed.

Data management

Data collected should be stored in hard copy as well as a digital copy so that results can easily be shared with others and matched to data collected in previous years. The data can also be stored using the GLEON Lake Observer App. Data collected based on the current weather can also be important to other groups. As noted above not all locations in Canada are monitored for water quality but the weather in these regions are also not tracked. Thus, this data can be important to other groups and researchers who are monitoring weather data.

Costs

The supplies needed to accurately monitor the weather are an outdoor thermometer, a wind gauge, and a precipitation gauge. A rain gauge can be made at home or purchased at any building store for fewer than 20 dollars. A wind speed gauge can cost between $150 to $3000. And an outdoor thermometer can cost under 10 dollars but a more sophisticated version could be purchased that could also identify relative humidity. During the winter snow depth can be measured with a ruler.

Resources and other groups

This link demonstrates the best practice to be used when collected observational weather data. This link is shared elsewhere in the document as it is a comprehensive document that notes a variety of topics that can be monitored by citizen scientists.

http://www.tu.org/sites/default/files/offline/science/WaterQualityV2.pdf

#11. Total Dissolved Solids (TDS)

Key points

Total dissolved solids are the parts in the water that are not pure water molecules. The levels of total dissolved solids can be higher in the prairie region that other places around the world because of the distinct geography of the region, and often higher concentration of salts and other solutes.

What is it?

Total dissolved solids are natural and man made substances that are dissolved in water. Total dissolved solids is related to the electrical conductivity of the water body. TDS can be raised in freshwater systems when there are elevated level of nutrients such as magnesium, sulphate, potassium, sodium, and chlorides.

Why do we measure it?

Measuring the total dissolved solids is important in the prairie region. As noted in the introduction the prairie geography is unique, the landscape is both nutrient rich, and has elevated salinity in some areas. Thus, it is important to collect information that can determine a baseline of the total dissolved solids in the water body and how this level can change because of different natural and manmade events.

How do we measure it?

There are a number of different techniques used by scientists and citizen science groups to monitor for total dissolved solids in the water body. Some of these

include collecting samples baking them in an oven and weighing the residue left after the water has evaporated. Whereas, other measurements can be taken using a piece of electronic equipment known as a TDS meter, because of the room for error in collecting samples with certain filters, baking and accurately weighing the residue I recommend that a handheld meter be used. These TDS meters test for the electrical conductivity of the water and make estimates from there on what the TDS level of the water would be with a high level of accuracy[74].

Data management

The results of the TDS meter should be stored both in hard copy and digitally. It is important that the piece of equipment be properly cleaned after each use so that there is no left over unwanted particles on the sensors that take the measurements.

Costs

Some total dissolved solids testers can be very cheap, fewer than 20 dollars reaching upwards of 500 dollars. For the research that is being done at a citizen science level, there should be no problem using a relatively cheap meter, as their results are fairly accurate.

[74] Ron Samborn, "Water Testing 101: TDS | Water Quality Products," January 8, 2008, www.wqpmag.com/water-testing-101-tds.

Resources other groups

Most other groups do not seem to monitor for total dissolved solids as it is not an issue in all parts of the world. Below I have included links to other resources you may find useful.

1. https://www.wqpmag.com/water-testing-101-tds

   This link explains how total dissolved solids are tested. It goes into details about how TDS meters work and how they calculate the amount of TDS from the conductivity of the water body.

2. http://www.water-research.net/index.php/water-treatment/tools/total-dissolved-solids

   This link noted what total dissolved solids are and how they can impact drinking water quality. It also gives different examples of how total dissolved solids can be tested for and how to interpret and understand test results.

#12. Beyond this project

This document and the links contained in this research is just a starting point. I included as much as I could in the time period but there is always more research that can be done and other factors that can be monitored. Do not feel constrained to monitor everything and what is outlined in this document, create a monitoring program that is the best fit for your community. Below I have listed some ideas and helpful links for more monitoring if you are interested in expanding your knowledge.

Conductivity

http://www.fivecreeks.org/monitor/cond.shtml

This link is from a community water quality citizen science monitoring program. It helps the readers to understand what the conductivity of water is and the role that plays while explaining how to make calculations associated with conductivity.

pH

http://www.tu.org/sites/default/files/offline/science/WaterQualityV2.pdf

This guide is noted in other sections of this paper. It is a comprehensive guide to different things that could be measured by citizen scientists. The link goes on to give helpful information about what pH is and how it impacts water quality.

Phytoplankton

https://www.epa.gov/sites/production/files/2017-05/documents/phytoplankton-monitoring-network-habs-r9.pdf

This link is to a informational guide created by the National Oceanic and Atmospherics Administration. The guide is created as a biotoxin monitoring guide that can help to understand the effects of harmful cyanobacteria blooms.

Groundwater Monitoring

http://www.bfenvironmental.com/pawaters.php

The link below is from the B.F. Environmental consulting group located in the United States that helps citizen scientists to monitor the ground water in their area.

This resource can be especially helpful for those who are on lakes that are spring fed.

Plant Monitoring

https://www.naturewatch.ca/plantwatch/

This link is to the plant watch section of Nature Watch. An organization that is committed to enable citizen scientists to monitor the plants in their area.

Macroinvertabrates

http://www.water-research.net/Waterlibrary/Lake/Bugs.pdf

The resource below is for citizen science monitoring of macroinvertabrates. It explains the importance of macroinvertabrates and what their impact is on the aquatic ecosystem and how they can be monitored.

Boating Impacts on Lakes

http://dnr.wi.gov/topic/ShorelandZoning/documents/201301041052.pdf

This link is focused on the impacts that boating, more specifically power boating can have on the aquatic ecosystem. It goes through different topics that can be monitored for and what motorized boating can do and how it can impact these water quality parameters.

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