Geoffrey F. Bruce Fellowship in Canadian Freshwater Policy

Community Science for Water Monitoring

Building Capacity and Strengthening Public Participation in Water Governance

Policy Brief

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Introduction

National and international agreements have identified a need to augment citizen participation in decision-making on matters related to the environment. The UN Convention on Biological Diversity (Rio, 1992), the Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus, 1998), and the UN Sustainable Development Goals (UN, 2015) each exemplify the "participatory turn" in the governance of science, technology, and the environment (Jasanoff, 2003), enshrining the right for non-experts to be included in deliberations about complex socio-ecological problems and environmental challenges (Fischer, 2000).

Community science is a participatory approach to research that includes members of the public in scientific investigations. Such an approach is consistent with a shift away from a top-down style of environmental management, and towards approaches to governance that incorporate the "lay expertise" held by members of the public who are recognized as legitimate producers of knowledge (Irwin, 1995; Wynne, 1996; Hess, 2016). Community science can strengthen existing efforts to incorporate Indigenous knowledge into the science-policy interface, by helping increase the scientific community's acceptance of co-created research efforts that respect multiple ways of knowing (Leach & Fairhead, 2002; McGregor, 2014; Danielsen et al., 2018).

Community science for water monitoring

Community science, which was originally referred to as "citizen science" (Irwin, 1995; Bonney, 1996) is a term that many practitioners are now adopting to avoid the problematic and exclusionary connotations of the word "citizen." Amateur scientists have long played important roles in advancing environmental research; the Audubon's Society Christmas Bird Count (est. 1900); and the USGS and Canadian Wildlife Service's North American Breeding Bird Survey (est. 1966) are two long-running projects that use members of the public to conduct baseline monitoring.

There is also a rich history of using community science to assist in the governance of freshwater resources. Following the establishment of the US *Clean Water Act* (1972), which requires states to assess surface water quality (Jalbert & Kinchy, 2016), voluntary community-based water monitoring (CBWM) projects blossomed across the country, with over 1,800 community monitoring groups active in the United States by 2014 (Buytaert et al., 2014).

In Canada, CBWM is also widespread; a report in 2011 identified 273 such groups (Devlin, 2011; Teichert, 2016). The importance of water monitoring is recognized by Canadian federal legislation, including the *International Boundary Waters Treaty Act* (1909), the *Fisheries Act* (1985), the *Canadian Environmental Protection Act* (1999), the *Canadian Environmental Assessment Act* (2012) and the *Great Lakes Water Quality Agreement* (2012) (WWF-Canada, Living Lakes Canada, & The Gordon Foundation, 2018), while Ontario's Clean Water Act (2006) established regional multi-stakeholder committees for source water protection.

Many in the scientific community have embraced community science as a way to collect information that can help with studies of environmental patterns and processes across broad spatial and temporal scales (Devictor et al., 2010; Pocock et al., 2017), and some sociologists have expressed interest in the potential to "democratize" science by bringing excluded perspectives into the fold (Kinchy, 2017; Hess, 2016). Environmental managers and policy-makers are also increasingly looking to community science as a way to produce the kind of relevant and timely information that is required for adaptive management (Aceves-Bueno et al., 2015), while also continuing to fulfill core mandates related to species conservation, stewardship, monitoring, and public engagement in the face of declining budgets (Pollock & Whitelaw, 2005; Conrad & Daoust, 2008; Teichert, 2016; Carlson & Cohen, 2018). An analysis of the Freshwater Watch published in *BioScience* compared labour hours invested in training and engagement against total hours volunteers spent sampling and measuring, and estimated a return on investment of 14:1 for Canadian CBWM groups (Thornhill et al. 2016).

CBWM sits at the intersection of environmental policy, scientific inquiry, and public health concerns (Figure 1).

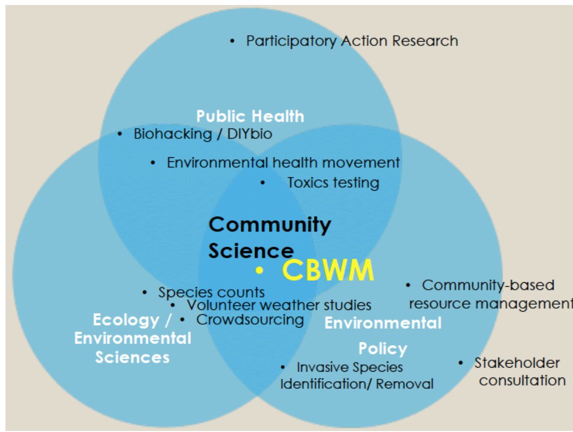

Figure 1. CBWM at the intersection of scientific inquiry, participatory governance, and public health concerns

The Policy Context

Although CBWM plays an important role in surface water monitoring in Ontario, and no policy barriers exist which hamper the abilities for CBWM to operate, there is a lack of a provincial or federal framework exists to guide and support the formulation and implementation of community science for use in decision-making about the environment. Furthermore, there is no central repository currently managed by government to track the progress and evolution of community science groups at either the federal or provincial scale. As a result, a situation may emerge wherein governments increasingly rely upon community scientists to engage in core monitoring, yet do not provide enough capacity to truly support such efforts.

In 2002, the Canadian Community Monitoring Network was established by the Ecological Monitoring and Assessment Network (EMAN) in order to provide a central repository for information about CBWM (Whitelaw et al., 2003), but this directory was taken offline around 2010 after a loss in funding (Teichert, 2016). More recent efforts to facilitate national coordination of CBWM have been undertaken by ENGOs. The Gordon Foundation has established three online interactive portals for data visualization, The Mackenzie Datastream, the Lake Winnipeg Datastream, and the Atlantic Datastream (The Gordon Foundation, 2020). The Government of Canada has also created the Indigenous Guardians Pilot Program Map, which lists Indigenous-led water monitoring and stewardship efforts (ECCC, 2020).

Despite the recent disbursement of government funding to CBWM (ie. Great Lakes Protection Initiative 2018; Indigenous Community-Based Climate Monitoring Program, 2020), consistent and sufficient long-term funding may still be a barrier that could impede the abilities of community science groups to provide these vital and cost-efficient services on an ongoing basis.

The European Union's "Science With and For Society" program of Horizon 2020 adopts a responsible research and innovation (RRI) approach which advocates for including members of the public in collaborative science projects, while its Open Science Policy Platform promotes co-design and co-development of a European Open Science Policy Agenda (Nascimento et al., 2018). In the United States, the U.S. Federal Citizen Science and Crowdsourcing Act (2017) grants federal agencies the authority to use community science to advance the mission of increasing public participation in research and innovation, citing a number of benefits including:

1) accelerating the pace of scientific research
2) increasing cost-effectiveness
3) fulfilling public participation mandates
4) addressing the needs of society
5) providing opportunities for hands-on learning

The United States operates a website, citizenscience.gov, which provides a catalog of existing projects that have been validated by federal employees, as well as a “toolkit” which provides new entrants with resources including tips, case studies, and models. Having a central hub operated by the federal government helps establish a framework for developing and implementing citizen science while also enhancing its credibility for environmental managers and policymakers. The European Union also maintains a similar web platform, eu-citizen.science, which exists as a clearinghouse for programs that are affiliated with the EU’s Horizon 2020 Program for Research and Innovation. Through the Citizen Science COST Action, the EU also invested in capacity to assess the extent to which community science can catalyze innovation and enhance scientific literacy in Europe, by establishing training schools, working groups, and network maps. The Atlas of Living Australia is a government-affiliated collaborative open data platform for biodiversity information that can be used by environment and land managers, industry, and the public. Their affiliated BioCollect mobile application has been designed for use by professional and community scientists alike, to facilitate the collection of ecological data.

Other potential benefits that community science can offer to policy-makers include improved public understanding of science and its role in informing policy, greater transparency about government decision-making, increased public buy-in, and robust policies informed by local knowledge (McIntosh & O'Neill, 2016). Community science also presents a number of challenges related to data quality, storing and sharing data, information silos, recruiting and retaining participants, effectively communicating results, and devolving responsibility onto volunteers.

In Ontario, community science and CBWM can help fulfill the mandate of the Province’s *Environmental Bill of Rights* (EBR, 1993) which establishes a legal right to public participation in environmental decision-making. Two lawsuits launched in August of 2020 allege that the Government has undermined the legal requirement for public participation as formulated by the EBR. On April 1, 2020, the Ontario government instituted Ontario Regulation 115/20, which exempts proposals from the public consultation process outlined in the EBR. Although the OR 115/20 was revoked on June 15, 2020, the omnibus Bill 197 instituted significant changes to the Environmental Assessment Act and the Planning Act, restricting public participation in decision-making. One lawyer from Ecojustice described the government's changes to environmental laws as part of an ongoing process to "gut public participation under the *Environmental Bill of Rights*" and to "erode Ontario's environmental laws and limit the public's role in environmental policy-making" (Ecojustice, 2020).

The recent changes to the Environmental Assessment Act suggest that the Ontario government is moving in the opposite direction when it comes to public participation in environmental decision-making. Building capacity for community science and formally incorporating it into the Province's vision for water governance is one way to strengthen the provincial commitment and legal requirement to recognize the public's right to participate in decisions related to the environment.

Investigating Participant Perspectives in Community Science

Developing recommendations for successful community science initiatives requires an in-depth understanding of volunteer motivations, attitudes, perspectives, and values. Following a meeting with the Global Lakes Ecological Observatory Network (GLEON) conference in Huntsville in November 2019; a study of Lake Partner Program (LPP) volunteer attitudes was initiated. The LPP is a community science lake monitoring program that attracts over 600 volunteers annually and has been operating since 2002 as a partnership between the Federation of Ontario Cottagers' Associations (FOCA) and the Dorset Environmental Science Centre (DESC). Volunteers conduct turbidity readings using Secchi discs and collect water samples that are sent to DESC, which analyzes them for concentrations of phosphorus and calcium.

This interview study followed a co-created research design model (Shirk et al., 2012), and research questions and methods were developed in partnership with the Director of FOCA, as well as three ecologists who use citizen science data. The study was designed to also generate information that would be of value to the LLP. Forty semi-structured telephone interviews were conducted with volunteer lake stewards during the summer of 2020. Volunteers were asked about their motivations, reflections on the program, and their opinions about whether participating in community science helps to build trust in science.

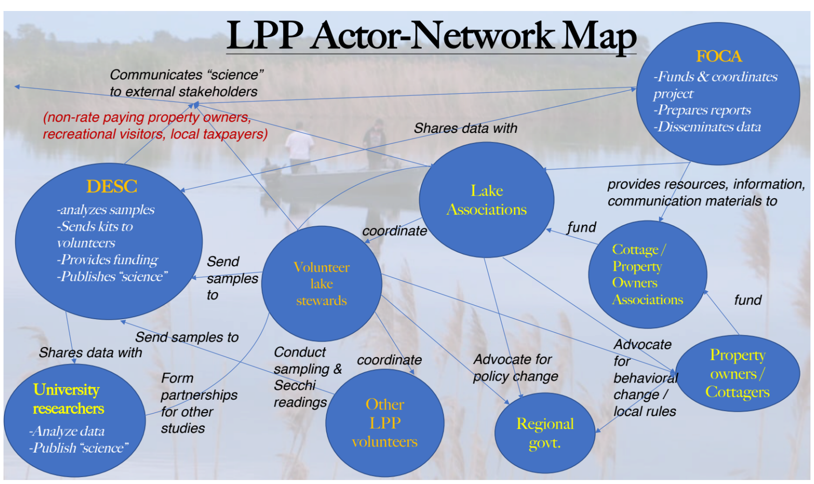

Figure 2. Actors involved in the Lake Partner Program, mapping three categories of stakeholders, internal (orange), connected (yellow), external (red)

Following the framework introduced by the Canadian Community Monitoring Network (Pollock & Whitelaw, 2005), a community mapping process was undertaken to identify the actors in the network and to facilitate governance analysis (Figure 2). The interview transcripts were coded and categorized into broader themes (Figure 3).

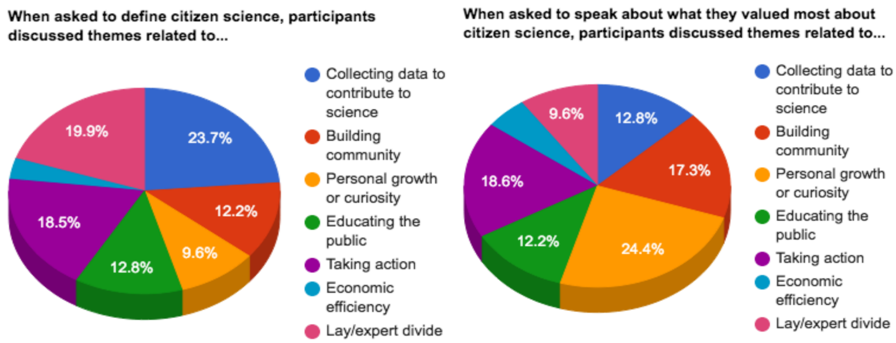

Figure 3. Frequency of codes generated in response to two interview questions

When defining citizen science, more codes were generated that related to 'data collection,' 'contributing to science,' and a 'lay/expert divide', whereas when asked to describe what they value most about citizen science, participants tended to discuss affective dimensions of participation, such as 'satisfying curiosity or contributing to personal growth,' as well as 'building community.'

Volunteers were also asked to describe any other community science or volunteer monitoring efforts that they are involved in. A word cloud displays frequencies of mentions of additional data collection undertaken by LPP participants (Figure 4). In addition to participating in the LPP, many volunteers were also involved in invasive species monitoring, benthic macroinvertebrate sampling, shoreline assessment and restoration, and monitoring indicator species such as birds and herpetofauna. Whether this is due to a "ripple effect," where becoming involved in one project inspires volunteers to join or start others, or is evidence of "participation inequality" where a small percentage of committed volunteers tend to contribute the most information to community science (Haklay, 2018) is a question that warrants further investigation.

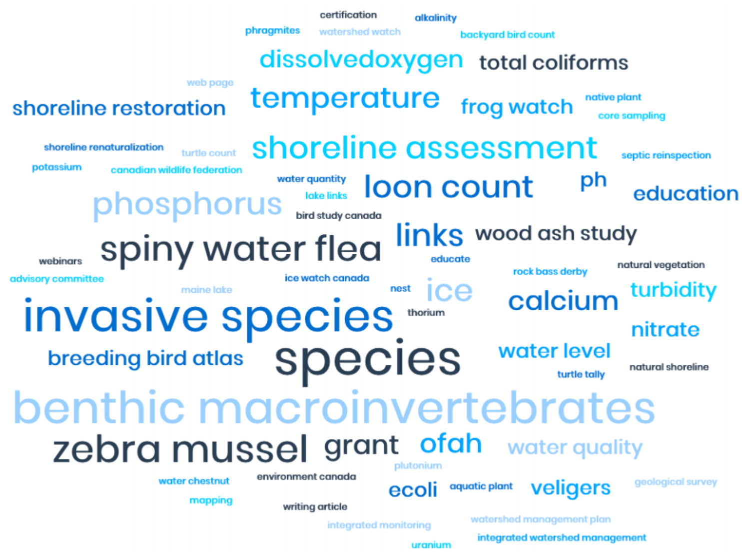

Figure 4. Word cloud displaying the frequency of additional monitoring efforts mentioned by volunteers

These figures represent the results of analysis done on a subset of the interview data. Further analysis is currently underway to investigate the central research question related to whether participants feel that participating in community science builds trust in science.

Although the LPP is a model of CBWM that can be classified as "government-led" (Whitelaw et al., 2003), "contributory" (Shirk et al., 2012), or "classic citizen science" (Haklay, 2013), with a focus on generating reliable data that can be used by professional scientists, volunteers often described data collection as part of a larger process that involves informing decision-making at local scales, taking direct action to conserve their lakes, and mobilizing for regional policy changes that can help protect water quality. For instance, some volunteers used their data to inform efforts to enact local bylaws related to natural shorelines and mandatory septic inspections. For many, participating in the program meant going beyond the training materials provided to them, serving as a catalyst for further education about science, science communication, and environmental governance.

Identifying and Overcoming Challenges

Building cyberinfrastructure platforms for community science comes with a number of benefits, especially since the data's value is often closely linked to its scale. However, several challenges exist, and an effort to create a framework or central hub for community science in Canada should keep the following issues in mind.

Data Quality: Data quality is often cited as a limitation of community science. Although comparative studies suggest that trained volunteers can collect data on par with professionals (assuming the right protocols are in place), some believe that community science methods are too prone to error to generate useful data. Data quality issues can stem from uneven skill levels of volunteers, inadequate training, or even the potential for volunteers to intentionally submit inaccurate information based on a personal agenda or conflicts of interest (for instance, over- or underreporting the presence of a species at risk). At the same time, community science offers the potential to generate large numbers of data points, which may compensate for erroneous observations. While automated technological methods exist for verifying data (automated flagging of unlikely results, GPS timestamps, drop-down menus for data entry, augmented reality displays on smartphones), program coordinators can also significantly improve data quality by offering clear instructions and providing training opportunities for volunteers.

A more pernicious data quality issue relates to the inherent biases of opportunistic sampling, such as spatial or temporal bias. Volunteers may be more likely to sample accessible or interesting areas (Millar et al., 2019), or to sample on week-ends or outside of normal work hours. Spatial bias is not just a data quality issue, it can also detract from the principles of environmental justice. Although community science has a long history of directly attending to issues like environmental racism, opportunistic sampling methods can also result in a participation inequality (Haklay, 2018). "Bottom-up" monitoring is most likely to occur in more affluent areas where individuals have more resources, leisure time, and social capital to initiate monitoring. While the accuracy of volunteer sampling can be improved with sufficient training, and spatial bias can be mitigated by targeted sampling or addressed using statistical methods, in many instances community science should generally be treated as a tool to complement professional monitoring, rather than supplement it.

Information silos: Community science benefits from network effects, where the value of a network increases as more nodes are added to it. This is especially true for CBWM, since the value of the data produced by one organization increases as other groups join their network. For instance, a water monitoring group in Pembroke may benefit from the data collected by a water monitoring group near North Bay. However, the decentralized nature of CBWM can result in information silos or "data islands," where environmental data can be produced using different standards, may be housed in unconnected databases, and recorded in non-interoperable formats. Data sharing between CBWM groups not only requires that groups submit their data to the same location, but that they follow compatible data collection methods and protocols. However, streamlining methods and protocols for data collection, data entry, and data storage may result in reorienting programs away from local contexts, knowledge, and needs. With CBWM and community science, scaling up to a regional or national standard can be a challenging task that involves negotiating the variegated institutional and organizational governance practices of a diverse range of community groups and other actors.

Identifying appropriate technologies: The increased sophistication and proliferation of technologies are often celebrated as catalysts for community science. This is particularly the case for geospatial mobile devices and mapping applications, with technologists and scientists alike envisioning a future where anyone carrying a smartphone can be plugged into an always-on network of citizen sensors who gather information about their local environments. Mobile apps are currently used to track a range of parameters including water levels, algal blooms, water clarity, water colour, indicator species, and plastics; when paired with external sensors these apps can also be used to monitor additional parameters including water quality, pH, temperature, and contaminants of emerging concern. Novel technologies can indeed help community science in a number of ways, including recruiting volunteers, communicating results, providing training, mitigating data quality issues, and automating certain parts of the data collection process. At the same time, when building capacity and establish a framework for community science, it is important to closely scrutinize new technological approaches before adopting them. The most cutting-edge technologies are not always best suited to the local context, and more "low tech" monitoring tools may be more reliable, cost-effective, and easier for volunteers to master. It is important to be aware of the range of mobile apps, platforms, sensors and sensor networks that exist which support CBWM, while also avoiding the lure of what technology critic Evgeny Morozov (2013) describes as "technological solutionism," a mindset which assumes that all problems are best resolved with technological solutions.

Clarifying responsibilities

Without an expressed and ongoing commitment to support CBWM, a "defunding treadmill" can emerge, where budgets for environmental monitoring budgets may be cut based on an assumptions that volunteers can pick up the slack, without building the capacity for the volunteers to do so. This can in turn contribute to the perception that CBWM is haphazard or inefficient, which might then provide further justification for additional budget cuts. There is also the risk that a confusion might arise over the delegation of responsibilities, especially if volunteers perceive that the government is "offloading" its monitoring responsibilities onto citizens, who then feel disempowered and skeptical that the government will take remedial action if needed (Savan et al. 2003). This has been identified as a strain on the capacity for governments initiating and managing citizen science water monitoring efforts in Ontario (Teichert, 2016). One Ontario-based study found that Conservation Authority staff resources were directed towards securing funding via grants and partnerships, which directed their resources away from administering CBWM efforts.

In the absence of an established framework and support structure to directly connect CBWM to decision-makers, there is a risk that community science can exacerbate a trend in environmental governance towards what Wendy Brown (2015) has described as "responsibilization," wherein state, private sector, and civil society actors invoke a rhetoric around personal responsibility and where voluntary, free market mechanisms come to replace state responsibilities. Volunteers are most committed to monitoring when they feel they are involved in a mutually beneficial partnership with government, rather than undertaking their efforts in independently and in isolation.

Projects that are haphazardly designed and implemented may fail to engage volunteers or secure the long-term interest of volunteers, which is why it is important to build central repositories and information hubs which outline best practices and disseminate tips, strategies, and resources. With proper administration, oversight, clearly defined objectives, sufficient funding, and effective volunteer engagement strategies, community science projects can flourish and help government achieves fulfil their mandates related to the protection, stewardship, and management of the country's freshwater resources.

Recommendations

To leverage the full potential that community science can offer, this report makes the following recommendations:

1. The Government of Canada should formally incorporate community science into its federal environmental policy, and establish community science as a key component of the Canada Water Agency.

2. The Government of Canada should establish an online community science "hub," which will serve as a central directory of community science projects and repository for information about community science, including best practices for initiating new programs.
3. The Government of Canada and the Government of Ontario should allocate funds for building capacity for community science, including funding to support staffing and administrative costs for long-running CBWM programs such as the LPP, while also supporting community workshops, and building information-sharing resources. While community science is cost-effective compared to traditional government monitoring strategies, a baseline of ongoing support is required to ensure project success.
4. CBWM should be based on principles of community science, treating volunteers as active participants in the research process, rather than as sources of data. CBWM should also be based on principles of environmental justice, which seeks an equitable distribution of environmental benefits and burdens.
5. The Government of Ontario should build capacity for community science projects that are specifically focused on communities whose demographics are traditionally neglected by local field naturalist communities. In addition to supporting long-standing CBWM programs, some funding should be allocated to initiate new programs that target non-property owners and urban residents in under-served communities, who also have a right to participate in environmental monitoring and governance.

References

Aceves-Bueno, E., Adeleye, A. S., Bradley, D., Tyler Brandt, W., Callery, P., Feraud, M., Garner, K. L., Gentry, R., Huang, Y., McCullough, I., Pearlman, I., Sutherland, S. A., Wilkinson, W., Yang, Y., Zink, T., Anderson, S. E., & Tague, C. (2015). Citizen Science as an Approach for Overcoming Insufficient Monitoring and Inadequate Stakeholder Buy-in in Adaptive Management: Criteria and Evidence. *Ecosystems*, *18*(3), 493–506.

Bonney, R. (1996). Citizen science: A lab tradition. *Living Bird*, *15*, 7-15.

Brown, W. (2015). *Undoing the demos: Neoliberalism's stealth revolution.* Princeton University Press.

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T.C., Bastiaensen, J., Bièvre, B.D., Bhusal, J., Clark, J., Dewulf, A., Foggin, M., Hannah, D.M., Hergarten, C., Isaeva, A., Karpouzoglou, T., Pandeya, B., Paudel, D., Sharma, K., Steenhuis, T.... M. Zhumanova (2014). Citizen science in hydrologyand water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Sciences* 2(26), 1-21.

Carlson, T., & Cohen, A. (2018). Linking community-based monitoring to water policy: Perceptions of citizen scientists. *Journal of Environmental Management*, *219*, 168–177.

Conrad, C. T., & Daoust, T. (2008). Community-based monitoring frameworks: Increasing the effectiveness of environmental stewardship. *Environmental Management*, *41*(3), 358–366.

Danielsen, F., Burgess, N.D., Coronado, I., Enghoff, M., Holt, S., Jensen, P.M., Poulsen, M.K., & Rueda, R.M. (2018). The value of indigenous and local knowledge as citizen science. In S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, & A. Bonn (Eds). *Citizen science: Innovation in open science, society, and policy.* (pp. 110-123). UCL Press.

Devictor, V., Whittaker, R. J., & Beltrame, C. (2010). Beyond scarcity: Citizen science programmes as useful tools for conservation biogeography. *Diversity and Distributions*, *16*(3), 354–362.

Devlin, J.F. (2011). Community engagement for adaptive management in environment al assessment: Follow-up, final report. N.T. Yap Environmental Systems Analysts Limited. http://publications.gc.ca/collections/collection_2011/ec/En106-99-2011-eng.pdf

Ecojustice. (2020, April 7). *Ecojustice reacts: Ford suspends public participation in proposed Ontario government environmental decisions.* https://ecojustice.ca/pressrelease/ford-suspends-public-participation/

Environment and Climate Change Canada (ECCC). (2020, October 1). *Indigenous Guardians Pilot Program Map.* https://www.canada.ca/en/environment-climate-change/services/environmental-funding/indigenous-guardians-pilot-program/map.html#year_3

Fischer, F. (2000). *Citizens, experts, and the environment: The politics of local knowledge.* Duke University Press.

The Gordon Foundation. (2020). *Datastream.* https://gordonfoundation.ca/initiatives/datastream/

Haklay, M. (2013). Citizen Science and Volunteered Geographic Information: overview and typology of participation. In Sui, D.Z., Elwood, S. and M.F. Goodchild (eds.), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*. Berlin: Springer. pp 105-122

Haklay, M. (2018). Participatory citizen science. In S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, & A. Bonn (Eds). *Citizen science: Innovation in open science, society, and policy.* (pp. 52-62). UCL Press.

Hess, D.J. (2016). *Undone science: Social movements, mobilized publics, and industrial transitions.* MIT Press.

Irwin, A. (1995). *Citizen science: A study of people, expertise, and sustainable development.* Routledge.

Jalbert, K., & Kinchy, A. (2016). Sense and influence: Environmental Monitoring Tools andthe Power of Citizen Science. *Journal of Environmental Policy & Planning, 18* (3), 379–397.

Jasanoff, S. (2003). Technologies of humility: governing citizen participation in science. *Minerva,* 41(3), 223–244).

Kinchy, A. (2017). Citizen Science and Democracy: Participatory Water Monitoring in the Marcellus Shale Fracking Boom. *Science as Culture*, *26*(1), 88–110. https://doi.org/10.1080/09505431.2016.1223113

Leach, M., & Fairhead, J. (2002). Manners of contestation: "citizen science" and "indigenous knowledge" in West Africa and the Caribbean. *International Social Science Journal*, *54*(173), 299–311.

MacIntosh, J., & O'Neill, K. (2016, April 8). *Citizen science: Data collection or analysis projects done by volunteers to aid researchTitle of page*. The Policy Community: The New Policy Instruments and Approaches Collection. https://policomm-commpoli.gccollab.ca/npi/en/articles/citizen-science.html

McGregor, D. (2014). Traditional Knowledge and Water Governance: The ethic of responsibility. *AlterNative: An International Journal of Indigenous Peoples*, *10*(5), 493–507.

Millar, E. E., Hazell, E. C., & Melles, S. J. (2018). The 'cottage effect' in citizen science? Spatial bias in aquatic monitoring programs. *International Journal of Geographical Information Science*, 1–21.

Nascimento, S., Rubio Iglesias, J.M., Owen, R., Schade, S., & Shanley, L. (2018). Citizen science for policy formulation and implementation. In S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, & A. Bonn (Eds). *Citizen science: Innovation in open science, society, and policy*. (pp. 219-240). UCL Press.

Pocock, M. J. O., Tweddle, J. C., Savage, J., Robinson, L. D., & Roy, E. (2017). The diversity and evolution of ecological and environmental citizen science. *PLoS ONE*, *12*(4), e0172579.

Pollock, R. M., & Whitelaw, G. S. (2005). Community-based monitoring in support of local sustainability. *Local Environment*, *10*(3), 211–228.

Shirk, J. J. L., Ballard, H. H. L., Wilderman, C. C., Phillips, T., Wiggins, A., Jordan, R., McCallie, E., Minarchek, M., Lewenstein, B., Krasny, M. E., & Bonney, R. (2012). Public participation in scientific research: A framework for intentional design. *Ecology and Society*, *17*(2), 29.

Teichert, S. (2016). *The influence of capacity and attitudes in the use ofwater quality citizen science and volunteer benthicmonitoring in the freshwater management activitiesof Ontario's Conservation Authorities* (3690) [Doctoral dissertation, University of Western Ontario]. Electronic Thesis and Dissertation Repository. https://ir.lib.uwo.ca/etd/3690

Thornhill, I., Loiselle, S., Lind, K., & Ophof, D. (2016). The Citizen Science Opportunity for Researchers and Agencies. *BioScience*. *66*(9), 721.

Whitelaw, G. S., Vaughan, H., Craig, B. & Atkinson, D. (2003). Establishing the Canadian Community Monitoring Network. *Environmental Monitoring and Assessment 88*(1-3), 409-418.

WWF-Canada, Living Lakes Canada, & The Gordon Foundation. (2018). *Context for a national discussion: Elevating community-based water monitoring in Canada.* Roundtable Discussion Paper. https://gordonfoundation.ca/resource/elevating-community-based-water-monitoring-in-canada-a-national-discussion/

Wynne, B. (1996). May the sheep safely graze? A reflexive view of the expert-lay knowledge divide. In *Risk environment and modernity* (pp. 44–83).