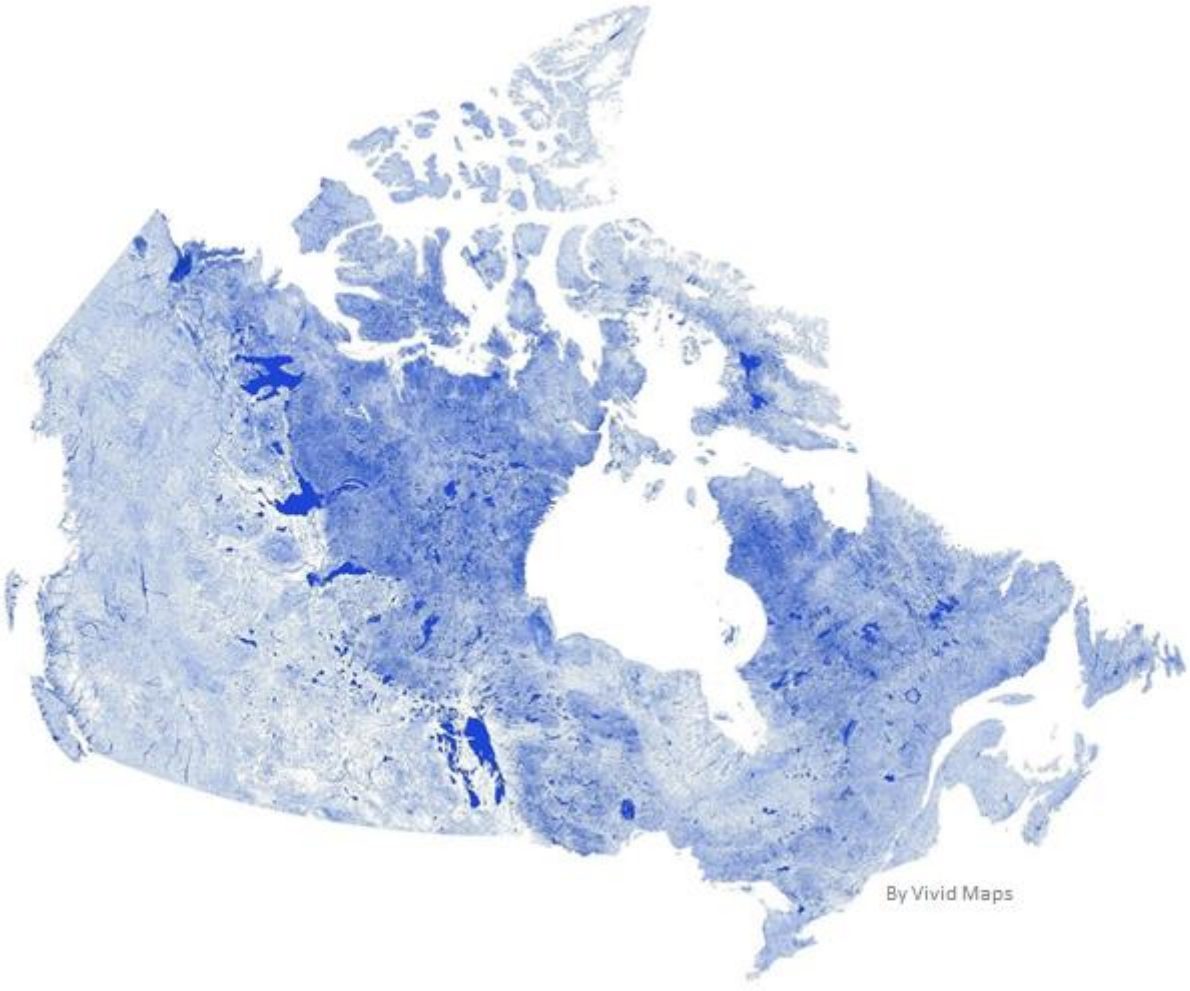
A SNAPSHOT OF COMMUNITY BASED WATER MONITORING IN CANADA



AUTHORS

Tyler Carlson
Graduate Student, Resource and Environmental Management, Simon Fraser University

Alice Cohen
Earth & Environmental Science and Environmental & Sustainability Studies, Acadia University

Kat Hartwig
Executive Director, Living Lakes Canada

CITATION

Carlson, T., Cohen, A., and Hartwig, K. (2017). *A Snapshot of Community Based Water Monitoring in Canada*.

ACKNOWLEDGEMENTS

Deborah Hartford
Executive Director, Adaptation to Climate Change Team, Simon Fraser University

Tzomi Burkhart
Student, Acadia University

Melissa Ristow
Student, Dalhousie University

TABLE OF CONTENTS

Executive Summary 4

Introduction 5

Research Objectives 7

Survey Findings 8

- Reasons for CBM 8
- Monitoring Locations 9
- Funding CBM 11
- Monitoring Parameters 12
- Traditional Ecological Knowledge 15
- Managing CBM Data 16
- From Data to Policy 17
- Working Collaboratively 19

Conclusion 20

Appendix 21

Works Cited 22

Endnotes 24

EXECUTIVE SUMMARY

Community-based monitoring (CBM) is providing invaluable support to the monitoring of Canada's freshwater resources. The diminished capacity of governments to monitor the health of watersheds and the absence of freshwater data in many regions across Canada has prompted communities to take a formative role in the water monitoring of their respective watersheds. Our research, consisting of a nation-wide survey of CBM organizations, indicates that CBM programs are filling information gaps on watershed health, informing decision-making at various levels of government, and fostering environmental stewardship in communities across Canada. Furthermore, the majority of CBM programs are following scientifically-rigorous protocols, having their data analysed by professional scientists, and addressing a diversity of community concerns relating to the health of freshwater resources. However, ongoing challenges for CBM include inadequate or unpredictable funding, inconsistent monitoring protocols, and difficulty in translating diverse and regionally-specific data to coherent recommendations for decision-makers. More consistent and extensive water quality and quantity data is needed in order to address human and water ecosystem health concerns. As government capacity to monitor freshwater has fluctuated in recent decades and gaps in our knowledge of Canada's watershed health remain, understanding the current state of CBM programs and their potential to inform decision-making is paramount.

INTRODUCTION

COMMUNITY-BASED WATER MONITORING IN CANADA

The health of Canada's freshwater is consistently ranked as a high priority for Canadians.[1,2,3] Water monitoring is a tool used by governments and communities alike to assess the health of watersheds and improve decision-making about freshwater resources.[4,5,6] This tool is particularly effective when monitoring data are consistent, accurate, and robust.[7,8] However, at present, there are insufficient data to assess the health of more than half of Canada's major watersheds.[9] This issue is further complicated by the decreasing capacity of governments to collect water data in recent decades.[10,11] In response to these challenges, and the growing concerns of citizens regarding watershed health, Canada is experiencing an upsurge of community-based monitoring (CBM).

As a result, CBM will play an increasingly substantive role in the monitoring of Canada's freshwater resources.[12,13] CBM programs, which involve communities in the collection of environmental data, are expanding the geographic and temporal ranges of water quality sampling,[14,15] engaging communities in environmental education and stewardship,[16,17] and providing opportunities for communities to co-generate scientific knowledge alongside governments.[18,19] In practice, a CBM program can range from a scientist organising water monitoring activities to educate high school students about aquatic ecosystem health, to more complex networks of CBM groups operating across regions and sharing data hubs and expertise to inform government decision-making.[20,21] In both cases, evidence suggests that many CBM groups are following data collection protocols with similar levels of accuracy and rigor as professional scientists.[22,23,24,25]

Consequently, CBM is also increasingly recognized by governments in Canada and abroad through policies and programs that enable communities to access government databases, funding opportunities, and monitoring networks. In the United States, the *Crowdsourcing and Citizen Science Act of 2015* was passed into federal law "to help solve problems or scientific questions by encouraging and increasing the use of crowdsourcing and citizen science methods within the Federal Government."[26] The US Environmental Protection Agency is one of many federal departments actively supporting community-based monitoring projects across the United States.[27] Meanwhile, in Canada, the Federal government and non-governmental organizations (NGOs) have established water monitoring protocols, such as Environment and Climate Change Canada's program known as CABIN – Canadian Aquatic Biomonitoring Network. These protocols guide and train volunteers in standardized methods of collecting, storing, and interpreting data on freshwater ecosystem health. In addition to providing scientific data, CBM also encourages cross-sectoral collaboration between different levels of government and NGO monitoring networks.[28]

Although support for CBM is growing, several challenges remain. First, CBM data is largely underutilised by governments in Canada,[29] and more research is needed regarding the conditions that foster or hinder linkages between citizen data and government decision-making.[30] Second, the fragmentation and utilisation of data also pose challenges. Water monitoring parameters are often chosen to address place-based water issues and so the task of translating diverse data from multiple different regions into cohesive policy recommendations

remains a significant challenge. Third, the inconsistency of funding and the isolation of some CBM programs creates the added challenge of establishing continuity in monitoring. To address such challenges, CBM will require greater collaborative solutions from all actors involved.

Case studies across Canada have suggested that CBM programs offer potential to fill information gaps for data required to assess freshwater ecosystem health, improve decision-making at local and national scales of water governance, and foster environmental stewardship and social capital among communities in Canada.[31,32] The impacts of climate change on watersheds requires, now more than ever, consistent and extensive water quality and quantity data to support informed decision-making related to community and ecosystem health. Government capacity to monitor water quality has fluctuated in recent decades,[33] and therefore, understanding the current state of CBM programs and their potential to support decision-making is paramount.

RESEARCH OBJECTIVES

Despite the rising prevalence of CBM in Canada, little is known about the state of CBM across the country. Unanswered questions include: how many programs exist, where are they located, and what is being monitored? Moreover, how are data managed, where is it housed, how is it accessed, how is data collection funded, and what is the relationship between CBM data collected and policy development? We set out to address some of these questions, and to create a 'snapshot' of the current state of CBM in Canada – by surveying hundreds of organizations across the country.[i]

[i] 270 survey invitations were sent; we received 123 responses

SURVEY FINDINGS

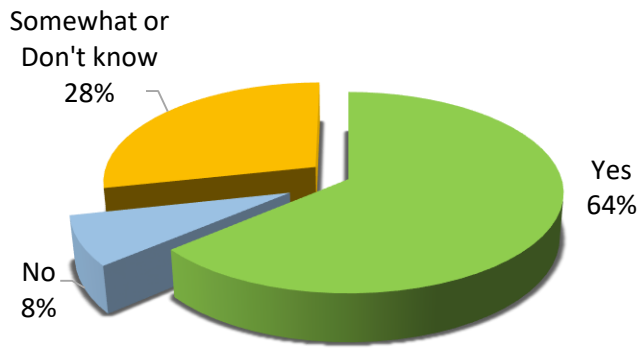
REASONS FOR CBM

***Figure 1*. Word Cloud of CBM Motivations**

Wordcloud by Tzomi Burkhart

The motivations for starting a CBM program are diverse. Some communities and groups are monitoring water to address a perceived lack of data, whereas others are motivated by concerns such as cumulative effects, eutrophication, and flooding. Still others undertake water monitoring as a form of community engagement and education, or to address public health concerns.

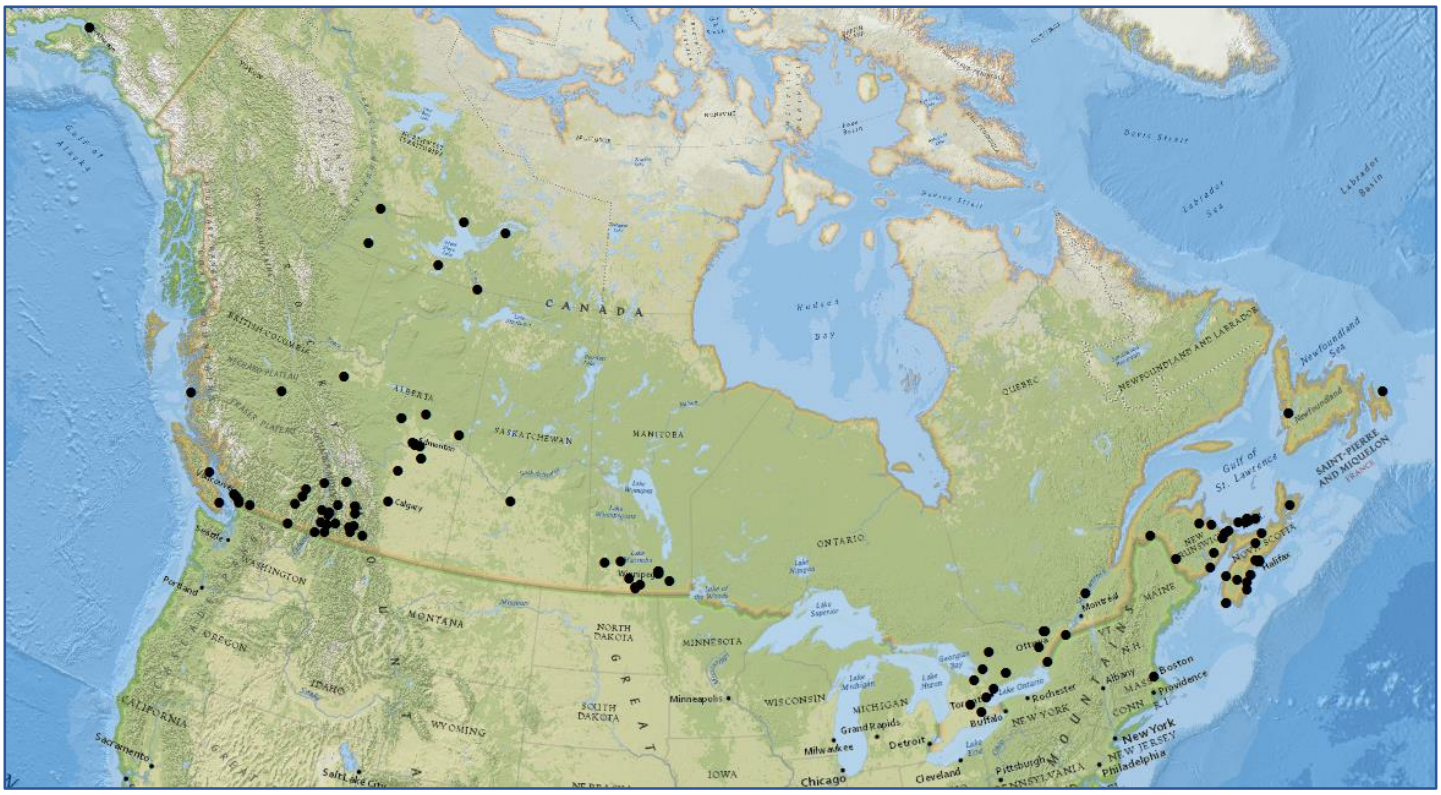
***Figure 2*. Are the reasons for starting a CBM program being addressed?**



To further understand this spectrum of CBM motivations, we asked whether or not an organization's CBM program was addressing its initial goals. Our results indicated that the majority (64%) of the 123 groups who responded to the survey, believed that their reasons for starting a CBM program were being addressed. Many others (28%) stated that their initial concerns were partially addressed, usually resulting from the groups not having enough information to evaluate the success of their program or that it was too early to know.

MONITORING LOCATIONS

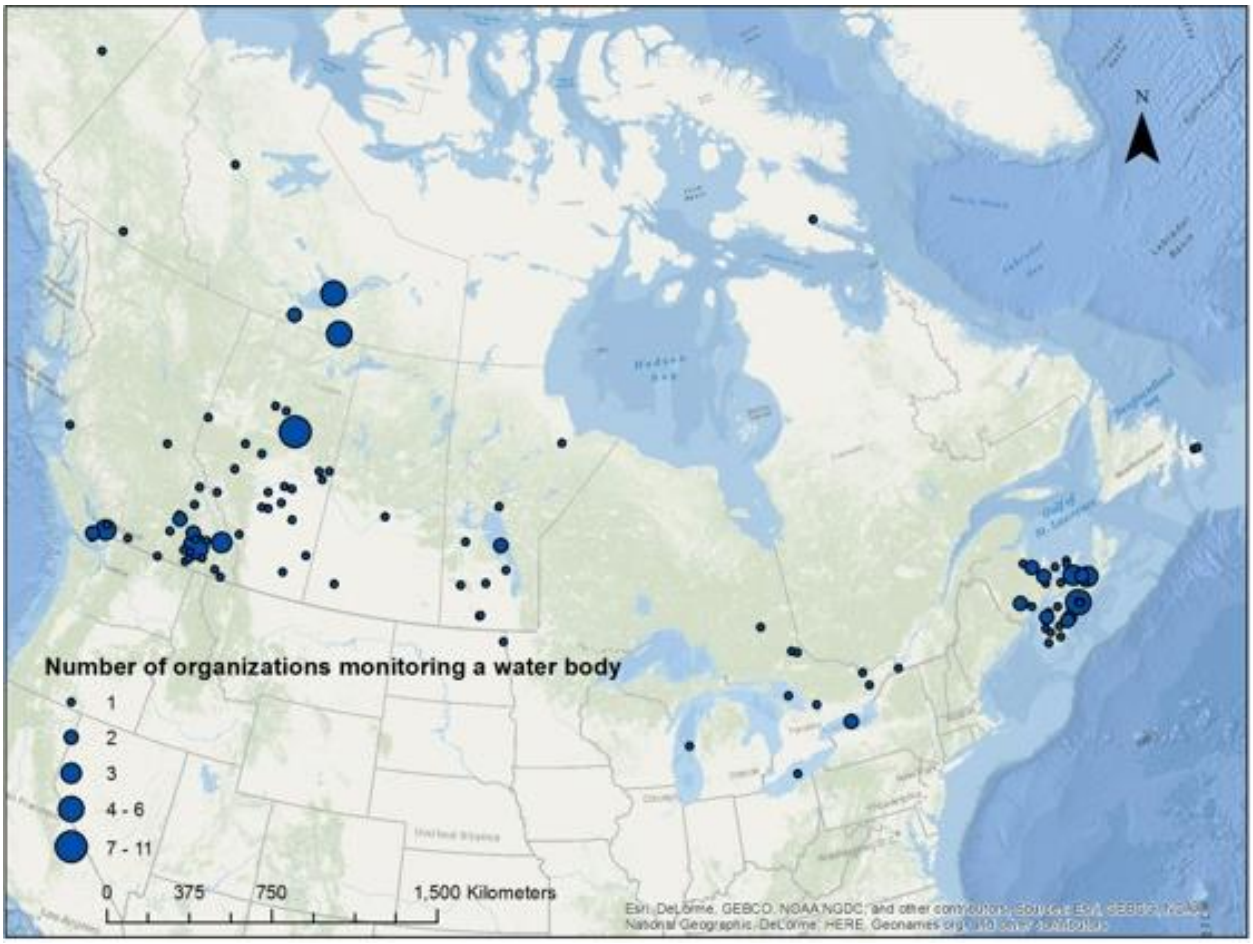
***Figure 3*. Map of CBM survey respondents by postal code**



Map by Melissa Ristow

Literature suggests CBM is growing and occurring across the country.[34,35,36] However, there is limited knowledge of *where* these activities are occurring.[37] Figure 3 shows where the surveyed organizations' offices are located, while Figure 4 shows which water bodies are being monitored.

***Figure 4*. Map of CBM survey respondents by monitoring area**

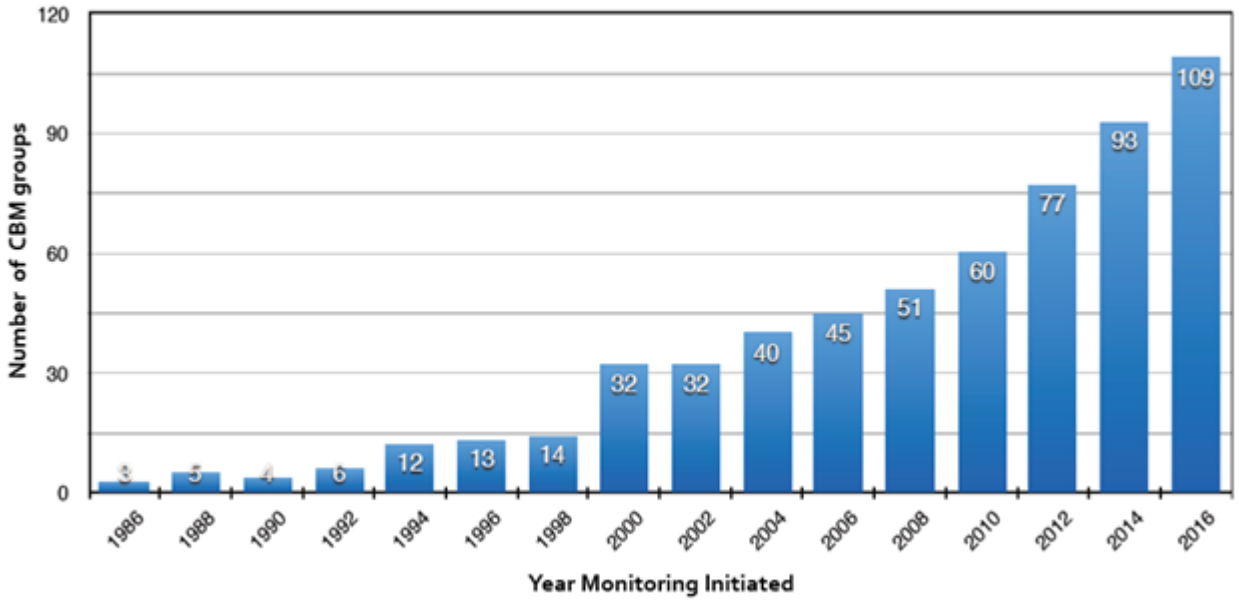


Map by Melissa Ristow

FUNDING CBM

The number of community-based monitoring projects in Canada has substantially increased in the past decade.[38] We found that between 2000 and 2016 the number of projects more than tripled. Community concerns about the health of local rivers, streams, and lakes and a desire to be more involved in water stewardship accounted for a large portion of this increase.[39,40,41] A recurring issue with CBM, however, is maintaining continuity of monitoring across time to establish long-term datasets, which is often constrained by inconsistent or inadequate funding for CBM groups.

Figure 5. CBM Projects Per Year

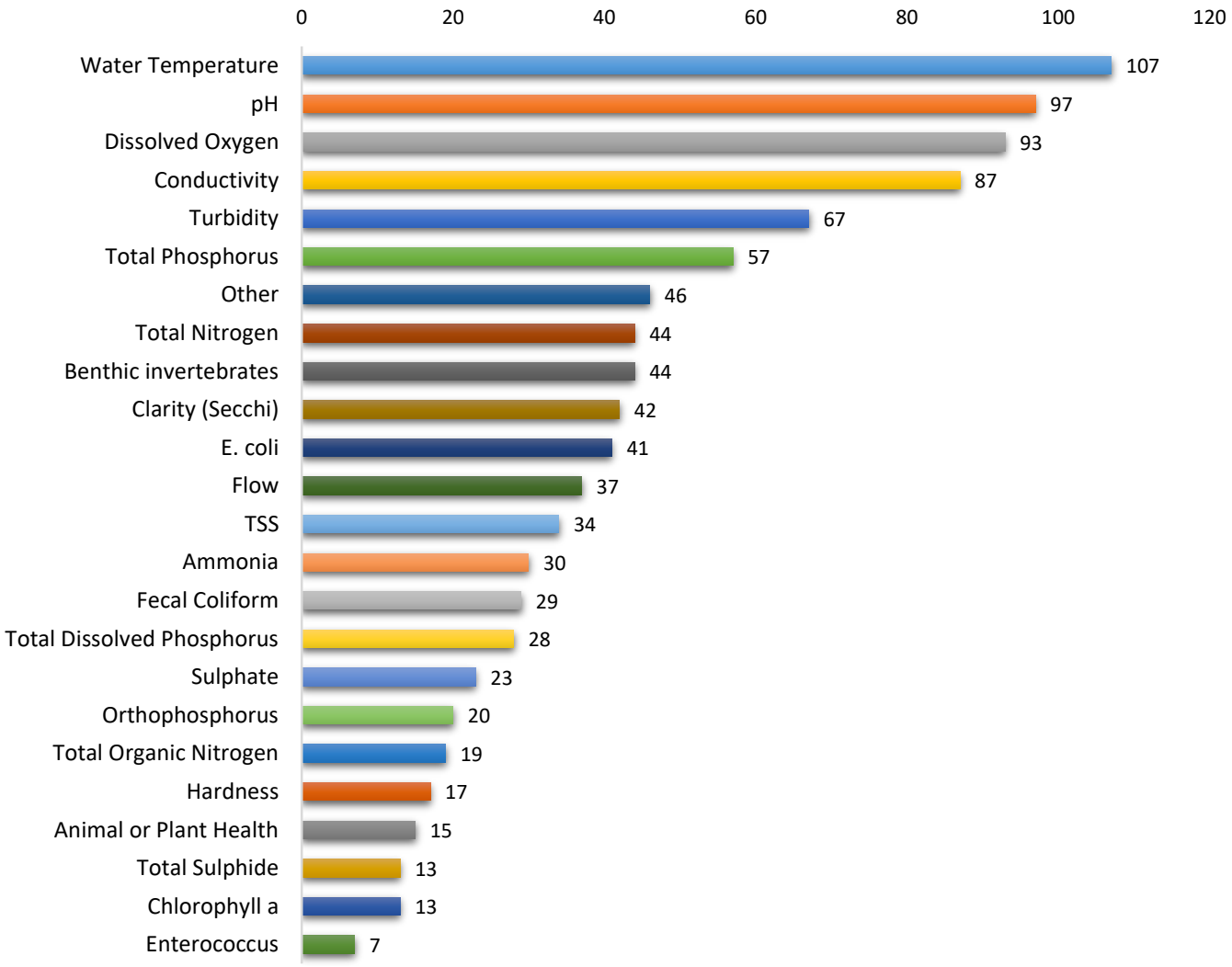


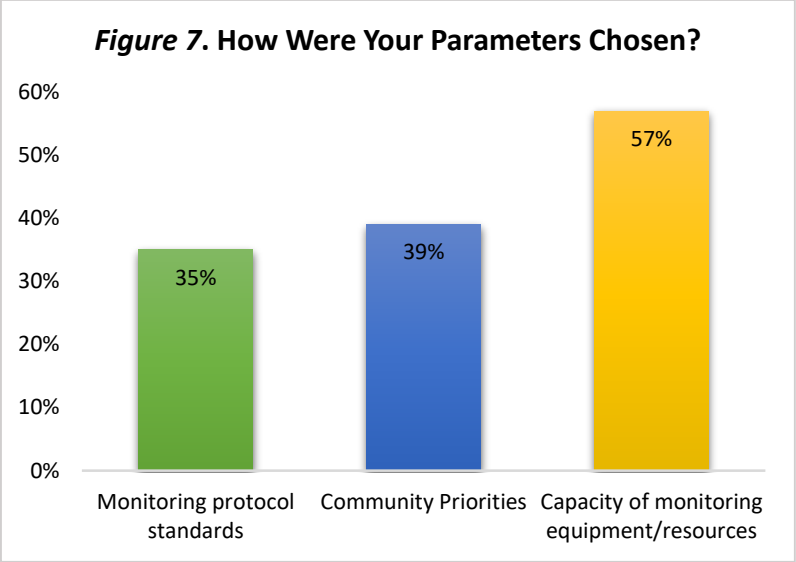
Indeed, many survey respondents indicated that due to insufficient funding, monitoring has been conducted sporadically, sometimes with multi-year gaps between monitoring. When asked about funding, 35% reported they operate with multi-year funding whereas 33% indicated they operate with only annual funding (the remaining 32% did not complete this section of the survey). Inconsistent monitoring partially explains why at the time this survey was conducted (2016) only 109 out of 123 CBM projects were active. This highlights an ongoing challenge in CBM, because ensuring continuity in monitoring is critical to establishing baseline data, which is used as a reference point to which future water quality of a river or lake can be compared.

MONITORING PARAMETERS

At present, the water quality parameters being collected through CBM are often based on regionally-specific water issues, and are shaped by the capacity of the community groups and the monitoring equipment used. Although standardized protocols exist for certain parameters, such as benthic invertebrates through Environment and Climate Change Canada's CABIN program, there is still a challenge of translating data across geographic regions into a coherent understanding of freshwater ecosystem health. As a result, using incompatible water data remains a current limitation to rendering CBM data more actionable in decision-making contexts.

***Figure 6*. Parameters Monitored By CBM Groups**





When water monitoring protocols are followed by CBM groups, the parameters are standardized resulting in more consistent collection and management of data. The survey asked: "How were your parameters chosen?" to investigate the broader context that is informing choices to monitor specific water parameters. Respondents were able to check one or more of three boxes: (1) a standardized monitoring protocol, (2) priorities of the community living adjacent to the water resource being monitored, and (3) capacity of monitoring equipment and other resources. While respondents often attributed parameter choices to all of the above categories, the most influential factor was the capacity of the equipment available to a CBM group.

Our survey also asked CBM groups if they follow a water monitoring protocol, as directed by a government agency, NGO network, Indigenous community, or others organizations. A majority (78%) of respondents are following a water monitoring protocol. We included the category "Unsure" to account for respondents who may be more involved in data collection and less involved in analysis and interpretation, and therefore, may not be acquainted with the protocols their organization follows.

Monitoring protocols exist across multiple sectors and jurisdictions in Canada. Several provincial and territorial governments have established guidelines for the collection and management of data with varying levels of support for CBM programs, including Alberta,[42] British Columbia,[43] Manitoba,[44] Northwest Territories,[45] Nova Scotia,[46] Ontario,[47,48] Quebec[49] and Yukon[50]. Moreover, federal departments including Parks Canada, Fisheries and Oceans Canada,[51] and Environment and Climate Canada[52] have implemented water monitoring protocols. Meanwhile, several NGOs across Canada have also created monitoring networks with robust, scientifically-defensible protocols such as Community Based Environmental Monitoring Network (CBEMN).[53]

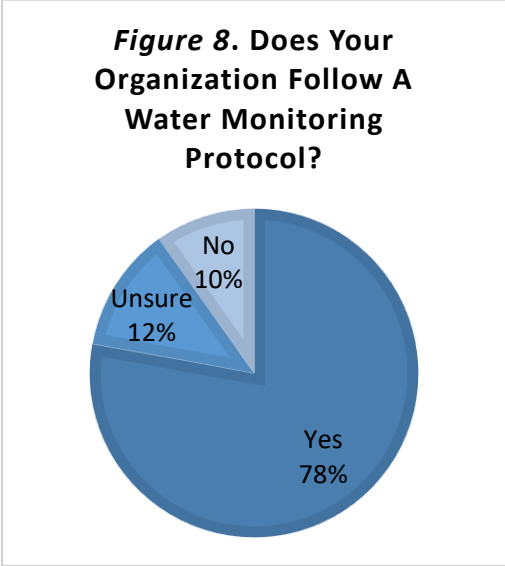
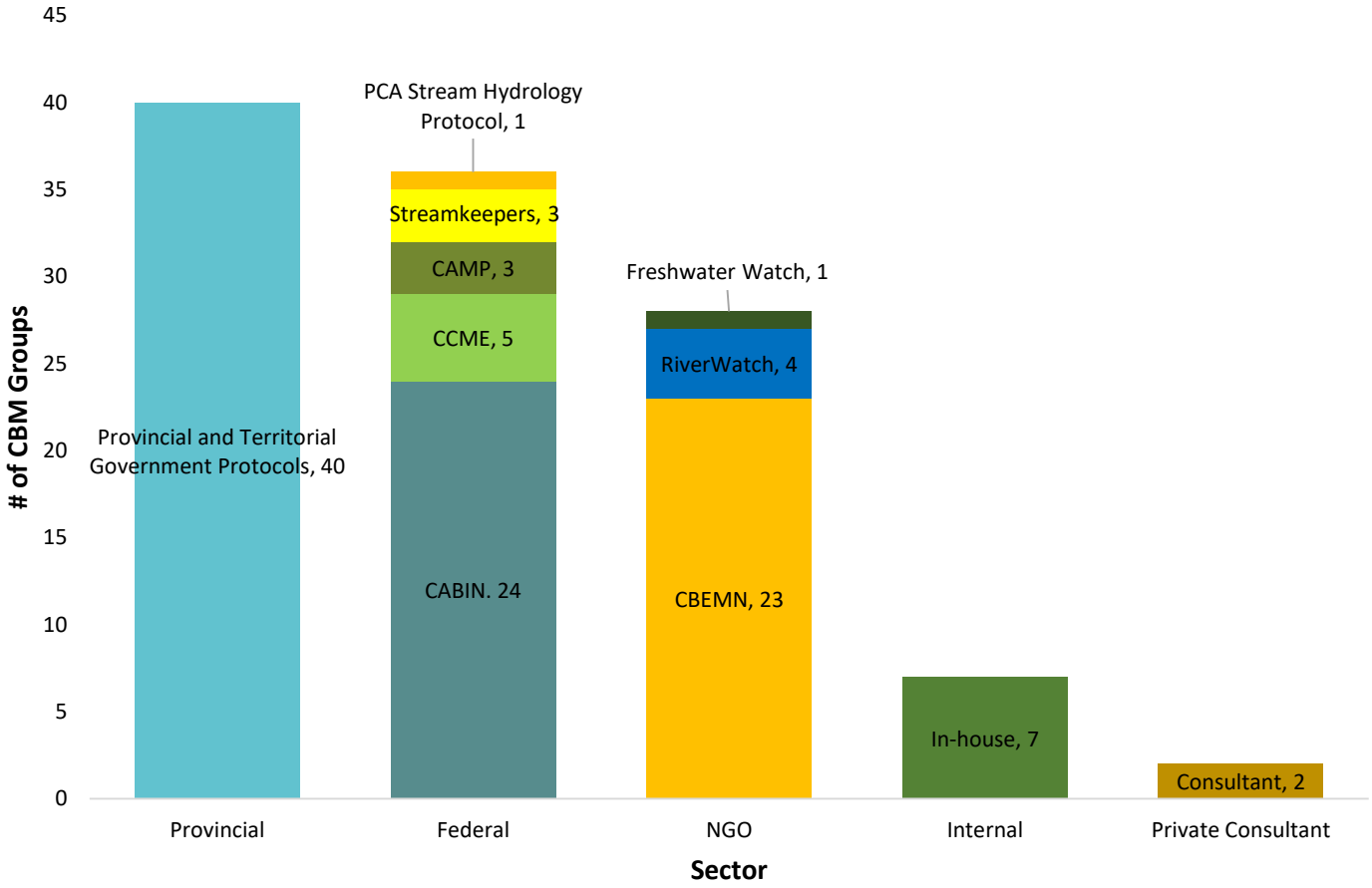


***Figure 9*. Water Monitoring Protocols Used By CBM Groups**



*See Appendix 1 for further details on water monitoring protocol acronyms

Although this abundance of CBM protocols highlights the increasing legitimacy and value CBM within Canada, it also may suggest that community-based water monitoring programs in Canada face potential redundancies that could be resolved through a more consistent and unified approach to monitoring.

In the survey results, the different types of provincial and territorial government protocols were too numerous to be visually represented in Figure 9. Many of the protocols in this category were regionally-specific, such that a comparison would be skewed by the provinces with the highest response rate (British Columbia and Nova Scotia). Five protocols were listed among CBM groups following federal government monitoring programs, some of which only operate in certain regions, such as the DFO's Community Aquatic Monitoring Program (CAMP) in Atlantic Canada. The prevalence of overlapping protocols within certain jurisdictions supports the notion that cross-departmental efforts to consolidate monitoring protocols and databases may facilitate the standardization of CBM. However, efforts to standardize CBM in Canada must also recognize and respect the use of local and indigenous knowledge of freshwater resources.

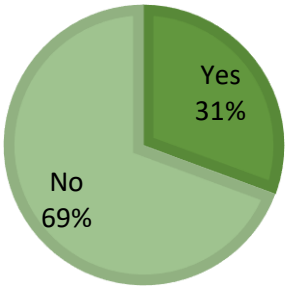
TRADITIONAL ECOLOGICAL KNOWLEDGE

Traditional ecological knowledge (TEK) can be defined as "a cumulative body of knowledge and beliefs, evolving by adaptive processes and handed down through generations by cultural transmission."[54] A more thorough list of aspects encompassed by TEK is provided by Turner et al.,[55] which includes:

> *Knowledge of ecological principles, such as succession and interrelatedness of all components of the environment; use of ecological indicators; adaptive strategies for monitoring, enhancing, and sustainably harvesting resources; effective systems of knowledge acquisition and transfer; respectful and interactive attitudes and philosophies; close identification with ancestral lands; and beliefs that recognize the power and spirituality of nature.*

Indigenous observations of ecosystem health are distinct from the scientific measurements used in water monitoring protocols. Therefore, in the context of CBM, it is a considerable challenge – and in many cases, undesirable – to translate water data derived from both TEK and Western science into a set of coherent findings and policy recommendations[56]. However, using both knowledge systems collaboratively and appropriately offers a more holistic and comprehensive examination of freshwater health. This collaboration is what Mi'kmaq elder Albert Marshall referred to as "two-eyed seeing."[57]

***Figure 10*. Is Traditional Ecological Knowledge A Part Of Your Monitoring Program?**



The Final Report of the Truth and Reconciliation Commission of Canada outlines a principle of "supporting Aboriginal peoples' cultural revitalization and integrating Indigenous knowledge systems, oral histories, laws, protocols, and connections to the land into the reconciliation process are essential."[58] In this context, exploring the role of traditional knowledge in ecological monitoring may help to clarify a pathway for CBM to be respectful and inclusive of different knowledge systems within Canada.

To highlight the importance of TEK, we examined how often TEK is explicitly included as part of CBM monitoring activities. Among the respondents whose organizations incorporate TEK into monitoring, many indicated the significance of involving elders in the process by relying on their historical and observational knowledge, while some also discussed the importance of carrying out monitoring in a way that respects wildlife and upholds traditional laws.

MANAGING CBM DATA

Data collected through CBM can follow many different trajectories. In order to understand what happens to CBM data, it is necessary to examine the various structures and functions of CBM. For instance, communities participating in government-led monitoring initiatives such as CABIN have their data analysed, stored and reported on, primarily by federal government scientists. Conversely, CBM programs that are more autonomous and community-driven may have their data externally analysed (for example, at a nearby university or consulting firm), internally analysed or not analysed at all. The two former outcomes are often associated with monitoring networks seeking to use data to understand local watershed health or to inform government decision-making, whereas the latter outcome is usually the case for CBM activities that are conducted solely for educational or recreational purposes.[59,60]

***Figure 11a*. Does your data get analysed?**

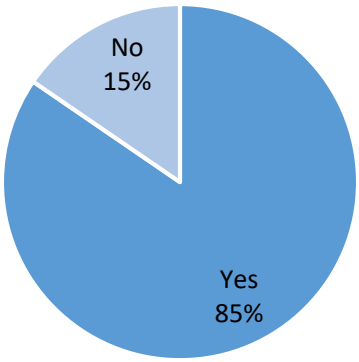
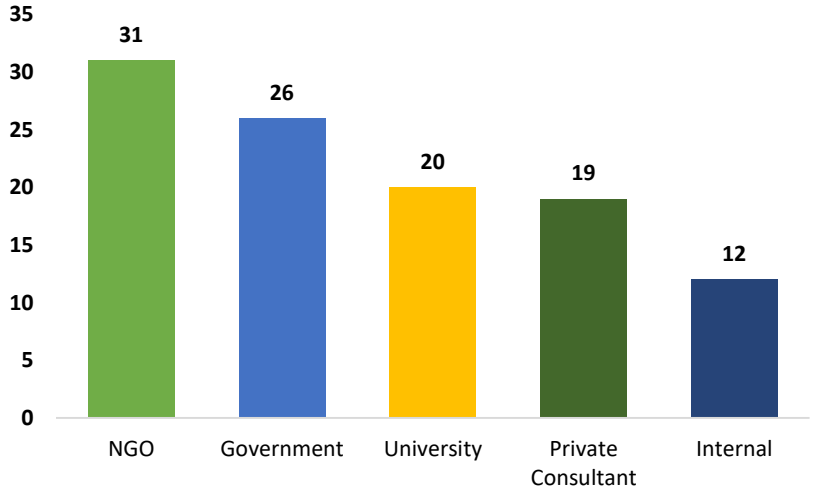


***Figure 11b*. If yes, who analyses the data?**



The survey asked participants to report if their water quality and quantity data are analysed, and if so, by whom. The results indicate that 85% of the CBM groups have their data analysed. However, these data are being analysed by a variety of organizations across the private, public, and non-profit sectors. A potential implication here is that during the analysis stage of CBM, information may become disconnected from other regional water data because it may not be shared or made publicly accessible within certain organizations. Data analysis is especially relevant as it is often a prerequisite before CBM can be translated into any form of actionable knowledge that can inform policy.

FROM DATA TO POLICY

A key motivation for conducting CBM is the potential to inform government decision-making that affects freshwater health. An example of such decision-making could be enforcing stricter regulations on industries whose upstream activities may be affecting downstream fish habitat, or developing a strategy to reduce storm water run-off that leads to flooding in rivers and streams. The ability of CBM to influence policy is also closely tied to the relative jurisdictional authority of the government receiving CBM data. For example, water quality management is a joint federal-provincial responsibility under the *Canada Water Act* (1985), whereas other activities directly affecting water quality may fall under the jurisdictions of all five governments. Ultimately, mitigating the threats to freshwater health will require cooperation across multiple scales of governance.

***Figure 12*. Does your data inform government policy?**

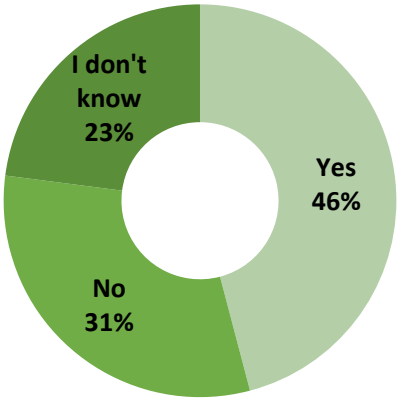
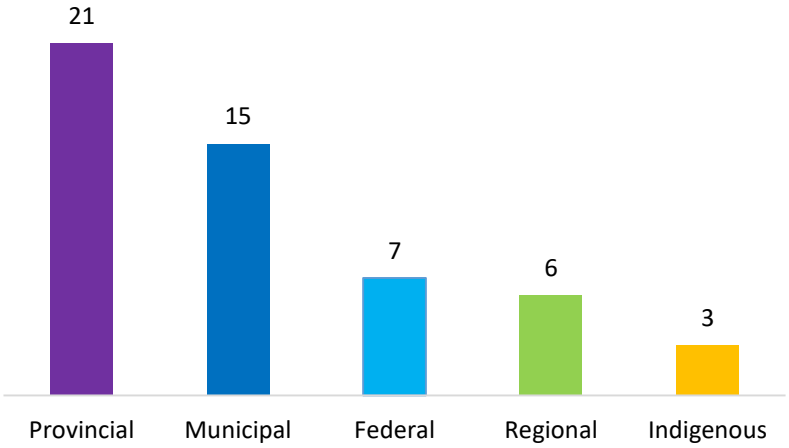


***Figure 13*. Which level of government uses the data?**



The survey first asked respondents to state if their data is informing government policy at any level. Respondents answered 46% “Yes”, 31% “No, and 23% “I don’t know.” The latter of the three is perhaps the most significant, as it demonstrates that nearly one in four respondents are unaware of the policy impact of their data. While Figure 12 and 13 only represent the perceptions of respondents, it is worth noting that government agencies may act on CBM data but fail to communicate when policies change. Another complication is that CBM datasets are often amalgamated with government datasets, making it difficult to distinguish the impact of a particular group’s data.

***Figure 14*. Does your data inform government policy?**

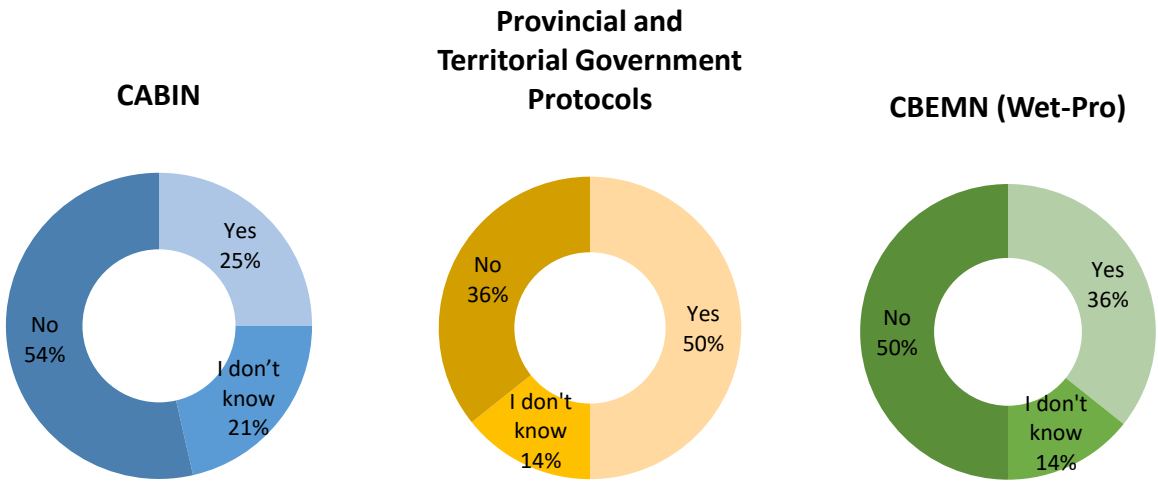


Figure 14 shows a comparison of the top three most common monitoring protocols selected by CBM groups. Cumulatively, these three protocols cover 70% of survey respondents. Among the three, provincial and territorial protocols account for a large portion of respondents who indicated "Yes" that their data is being used to inform policy, whereas CABIN and CBEMN have markedly lower rates.

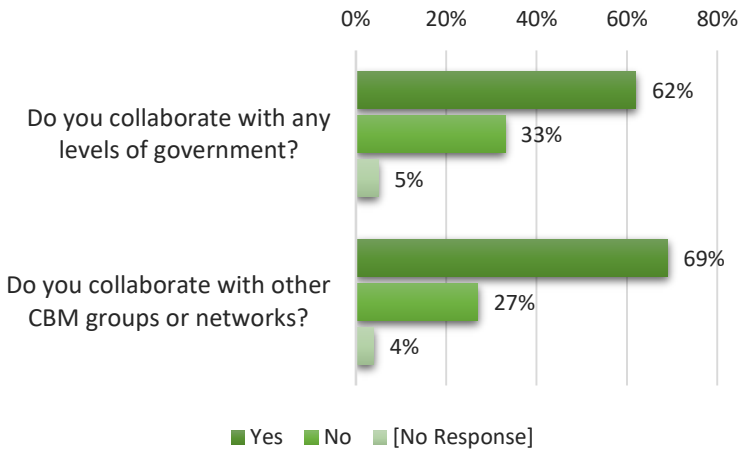
WORKING COLLABORATIVELY

Although cases of regional CBM networks and government-community partnerships exist, many CBM activities remain disconnected from collaborative networks. The consequences of this disconnect may include limited access to funding, training, and equipment. Moreover, communities monitoring in isolation may not have options for data storage, analysis, or reporting. All of the above are essential for maximizing the impact of CBM.

The benefits of community-government collaborations in water monitoring have been documented. In addition to benefits such as: improved access to monitoring resources and expertise, opportunities to utilise local and indigenous knowledge to inform decision-making, and increased level of community participation and scientific literacy regarding the health of their watersheds. Furthermore, there are also financial benefits. Environment and Climate Change Canada initiated the Atlantic Coastal Action Program (ACAP) in 1991 with the intention of taking a collaborative, community-based approach to monitoring local watersheds and coastal areas. A study on the profitability of this CBM collaboration indicated that if ECCC had implemented ACAP using only government resources and personnel, it would require 12 times as much funding to operate.[61]

We asked CBM groups if their program collaborates with governments or other CBM networks. Figure 15 indicates that the majority of CBM groups surveyed collaborate with governments and other CBM networks. This finding highlights the lesson that CBM collaborations, although abundant, can potentially expand and include isolated CBM organizations. Such support would help to strengthen and unify CBM activities across Canada.

Figure 15. CBM Collaborations



CONCLUSION

Community-based monitoring is playing a formative role in monitoring the health of Canada's watersheds. This is particularly relevant when federal and provincial governments' capacity to monitor rivers, lakes, streams and wetlands can be uncertain due to shifting priorities and funding constraints.[62] CBM presents an opportunity for water monitoring to expand to new regions, educate and engage citizens, and ensure that water policymaking reflects the best available science.

Some of the key strengths of CBM are its cost-effectiveness compared to government programming, and its diverse and place-based focus. Our survey found that communities are motivated to undertake CBM for reasons ranging from concerns about eutrophication and flooding, to a desire to engage citizens in watershed stewardship and education. The diversity of CBM is also noticeable in the data collection parameters and monitoring protocols being followed. For some CBM groups, this entails using either Western science or Traditional Ecological Knowledge or both in their monitoring of aquatic ecosystem health. On the other hand, ongoing challenges for CBM include inadequate or unpredictable funding, inconsistent monitoring protocols, and the difficulty of translating diverse and regionally-specific data into actionable knowledge to inform policy. Lastly, data collected through CBM are following many different trajectories, some of which result in data not being analysed nor communicated, thereby limiting its potential to contribute to our collective knowledge of Canada's freshwater health.

In alignment with recommendations throughout the literature, this report emphasizes the need for organizations and networks involved in CBM to build on the momentum thus far by (1) following scientifically-rigorous and consistent protocols, (2) respecting culturally diverse sources of knowledge such as TEK, (3) ensuring data and data analysis is accessible to communities, (4) continuing to produce actionable outcomes with data that can influence decision-making, and (5) seeking adequate funding and support for monitoring to continue in the long-term.[63,64] Fulfilling these recommendations requires resources – human, financial, and time – and therefore necessitates coordinated action at all scales, from the community level to municipal, Indigenous, provincial, territorial, and federal government. Through our collective efforts, community-based monitoring may continue to advance our understanding of Canada's watersheds.

APPENDIX

List of Acronyms and Water Monitoring Protocols

ACAP
Atlantic Coastal Action Program

CABIN
Canadian Aquatic Biomonitoring Network

CAMP
Community Aquatic Monitoring Program

CBEMN
Community-Based Environmental Monitoring Network

CBM
Community-Based Monitoring

CCME
Canadian Council of Ministers of the Environment

DFO
Fisheries and Oceans Canada

NGO
Non-Governmental Organization

PCA
Parks Canada

WORKS CITED

Au, J., Bagchi, P., Chen, B., Martinez, R., Dudley, S., and Sorger, G. (2000). Methodology for public monitoring of total coliforms, Escherichia coli and toxicity in water ways by Canadian high school students. J. Environ. Manag.58,213–230. doi:10.1006/jema.2000.0323

Berkes, F. 1999. *Sacred ecology: Traditional ecological knowledge and resource management*, Philadelphia and London: Taylor & Francis.

Berkes, F., Berkes, M. K., & Fast, H. (2007). Collaborative integrated management in Canada's north: The role of local and traditional knowledge and community-based monitoring. Coastal management, 35(1), 143-162.

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T. C., Bastiaensen, J., & Foggin, M. (2014). Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*, *2*, 26.

Canada Water Act (R.S.C., 1985, c. C-11)

Civic Impulse. (2017). S. 2113 — 114th Congress: Crowdsourcing and Citizen Science Act of 2015. Retrieved from https://www.govtrack.us/congress/bills/114/s2113

Cohn, J. P. (2008). Citizen science: Can volunteers do real research?. *BioScience*, *58*(3), 192-197.

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

Conrad, C. C., & Hilchey, K. G. (2011). A review of citizen science and community-based environmental monitoring: issues and opportunities. Environmental monitoring and assessment, 176(1-4), 273-291.

Danielsen, F., Burgess, N. D., Balmford, A., Donald, P. F., Funder, M., Jones, J. P., & Child, B. (2009). Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology*, *23*(1), 31-42.

Dickinson, J. L., Shirk, J., Bonter, D., Bonney, R., Crain, R. L., Martin, J., ... & Purcell, K. (2012). The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*, *10*(6), 291-297.

Fore, L. S., Paulsen, K., & O'Laughlin, K. (2001). Assessing the performance of volunteers in monitoring streams. *Freshwater Biology*, *46*(1), 109-123.

Hatcher, A., Bartlett, C., Marshall, A., & Marshall, M. (2009). Two-eyed seeing in the classroom environment: Concepts, approaches, and challenges. *Canadian Journal of Science, Mathematics and Technology Education*, *9*(3), 141-153.

Kosmala, M., Wiggins, A., Swanson, A., & Simmons, B. (2016). Assessing data quality in citizen science. *Frontiers in Ecology and the Environment*, *14*(10), 551-560.

Kouril, D., Furgal, C., & Whillans, T. (2015). Trends and key elements in community-based monitoring: a systematic review of the literature with an emphasis on Arctic and Subarctic regions. *Environmental Reviews*, *24*(2), 151-163.

McNeil, C. T., Rousseau, F. R., & Hildebrand, L. P. (2006). Community-Based Environmental Management in Atlantic Canada: The Impacts and Spheres of Influence of the Atlantic Coastal Action Program. *Environmental Monitoring and Assessment, 113*, 367-383.

Murphy-Mills, E. (2015). Community-based water monitoring: A case study of the Oak Ridges Moraine, Ontario, Canada.

Our Living Waters. (2016) *Realizing the Potential of Community Based Monitoring in Assessing the Health of Our Waters.*

Royal Bank of Canada. (2013). *RBC Canadian Water Attitudes Survey*; Royal Bank of Canada: Toronto, Canada. Available online:

Royal Bank of Canada. (2015). *RBC Canadian Water Attitudes Survey*; Royal Bank of Canada: Toronto, Canada. Available online: http://www.rbc.com/community-sustainability/_assets-custom/pdf/CWAS-2015-report.pdf

Royal Bank of Canada. (2016). *RBC Canadian Water Attitudes Survey*; Royal Bank of Canada: Toronto, Canada. Available online: http://www.rbc.com/community-sustainability/_assets-custom/pdf/CWAS-2016-report.pdf

Sharpe, A., & Conrad, C. (2006). Community based ecological monitoring in Nova Scotia: challenges and opportunities. *Environmental monitoring and assessment*,*113*(1-3), 395-409.

Shelton, A. (2013). The Accuracy of Water Quality Monitoring Data: a Comparison Between Citizen Scientists and Professionals. Master's thesis, Saint Mary's University, Halifax, Nova Scotia.

Shiklomanov, A. I., Lammers, R. B., & Vörösmarty, C. J. (2002). Widespread decline in hydrological monitoring threatens pan-Arctic research. *Eos, Transactions American Geophysical Union*, *83*(2), 13-17.

Silvertown, J. (2009). A new dawn for citizen science. Trends Ecol. Evol. 24, 467–471. doi:10.1016/j.tree.2009.03.017

Truth and Reconciliation Canada. (2015). Honouring the truth, reconciling for the future: Summary of the final report of the Truth and Reconciliation Commission of Canada. Winnipeg: Truth and Reconciliation Commission of Canada.

Turner, N. J., Ignace, M. B., & Ignace, R. (2000). Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. *Ecological applications*, *10*(5), 1275-1287.

Weston, S., & Conrad, C. (2015). Community-based water monitoring in Nova Scotia: Solutions for sustainable watershed management. *Environment and Natural Resources Research*, *5*(2), 1.

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

World Wildlife Fund. (2016). Watersheds Report. Available Online. http://watershedreports.wwf.ca/#intro

ENDNOTES

[1] RBC, 2016
[2] RBC, 2015
[3] RBC, 2013
[4] Conrad and Hilchey, 2011
[5] Weston et al., 2015
[6] Buckland-Nicks et al., 2016
[7] Cohn, 2008
[8] Buytaert et al., 2014
[9] WWF, 2016
[10] Conrad and Daoust, 2008
[11] Shiklomanov et al., 2002
[12] Conrad and Hilchey, 2011
[13] Murphy-Mills, 2015
[14] Cohn, 2008
[15] Silverton, 2009
[16] Cohn, 2008
[17] Dickenson et al., 2012
[18] Berkes et al., 2007
[19] Buytaert et al., 2014
[20] Cohn, 2008
[21] Conrad and Hilchey 2011
[22] Au et al., 2000
[23] Fore et al., 2001
[24] Shelton, 2013
[25] Kosmala et al., 2016
[26] Civic Impulse, 2017, pg. 1
[27] https://www.epa.gov/sites/production/files/2016-12/documents/nacept_cs_report_final_508_0.pdf
[28] Conrad and Daoust, 2008
[29] Sharpe and Conrad, 2006
[30] Conrad and Hilchey, 2011
[31] Conrad and Hilchey, 2011
[32] Our Living Waters, 2016
[33] Conrad and Daoust, 2008
[34] Whitelaw et al. 2003
[35] Conrad and Hilchey, 2011
[36] Weston and Conrad, 2015
[37] Whitelaw et al., 2003
[38] Conrad and Hilchey 2011
[39] Whitelaw et al., 2003
[40] Conrad and Hilchey, 2011
[41] Murphy-Mills, 2015
[42] http://aep.alberta.ca/water/programs-and-services/surface-water-quality-program/documents/AquaticEcosystemsFieldSampling-Mar2006.pdf
[43] http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/science-data/man_bc_hydrometric_stand_v10.pdf
[44] http://www.gov.mb.ca/waterstewardship/water_quality/quality/pdf/mb_water_quality_standard_final.pdf
[45] http://www.nwtwaterstewardship.ca/sites/default/files/128-CBM%20Water%20Quality%20Results-Press.pdf
[46] https://novascotia.ca/nse/surface.water/docs/NSPModelReport.pdf
[47] http://www.nvca.on.ca/provincial-monitoring-network
[48] http://desc.ca/sites/default/files/OBBN%20Protocol%20Manual_Compressed.pdf
[49] http://www.mddelcc.gouv.qc.ca/eau/rsvl/protocole-echantill-qualite.pdf
[50] http://www.yukonplacersecretariat.ca/pdf/water_quality_objectives_monitoring_protocol.pdf

[51] http://www.dfo-mpo.gc.ca/Library/329182.pdf
[52] http://www.ec.gc.ca/Publications/C183563B-CF3E-42E3-9A9E-F7CC856219E1/CABINFieldManual_EN_2012.pdf
[53] http://wet-pro.ca/
[54] Berkes, 1999, pg. 8
[55] Turner et al., 2000, pg. 1275
[56] Berkes, 2007
[57] Hatcher et al., 2009
[58] Truth and Reconciliation Canada, 2015, pg. 4
[59] Whitelaw et al., 2003
[60] Danielson et al., 2009
[61] McNeil et al., 2006
[62] Sharpe and Conrad, 2006
[63] Conrad and Hilchey, 2011
[64] Our Living Waters, 2016