

# **Linking Community-Based Monitoring to Water Policy in Canada**

**by  
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## Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

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## **Abstract**

This paper examines the relationships between Community-Based Water Monitoring (CBM) and government-led water initiatives. Drawing on a cross-Canada survey, the paper explores the reasons why communities undertake CBM, the monitoring protocols they follow, and the extent to which CBM program members feel their findings are incorporated into formal (i.e., government-led) decision-making processes. We find that despite following rigorous and recognized protocols, fewer than half of CBM organizations report that their data is being used to inform water policy at any level of government, and that respondents report higher rates of cooperation and data-sharing between CBM organizations themselves than between CBM organizations and their respective governments. This finding is significant, because governments at all levels continue to express support for CBM. We explore the barriers between CBM data collection and government policy, and suggest that structural barriers include lack of multi-year funding, inconsistent protocols, and poor communication. More broadly, we argue that the distinction between formal and informal programming is unclear, and addressing known CBM challenges will rely on a change in perception: CBM cannot simply be a less expensive alternative to government-driven data collection.

**Keywords:** Community based monitoring; citizen science; water quality monitoring; Canada; water governance

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## List of Acronyms

|          |  |
|----------|--|
| ACAP     | Atlantic Coastal Action Plan                     |
| CABIN    | Canadian Aquatic Bio-monitoring Network          |
| CAMP     | Community Aquatic Monitoring Program             |
| CBEMN    | Community Based Environmental Monitoring Network |
| CBM      | Community Based Monitoring                       |
| CCME     | Canadian Council of Ministers of the Environment |
| CURA H2O | Community-University Research Alliance           |
| ECCC     | Environment and Climate Change Canada            |
| EPA      | Environmental Protection Agency                  |
| PCA      | Parks Canada                                     |
| PTRM     | Provincial, Territorial, Regional, and Municipal |

# Chapter 1. Introduction

The involvement of communities in identifying and tracking the quality and availability of freshwater resources is often referred to as Community-Based Water Monitoring (CBM) (Conrad and Daoust, 2008; Whitelaw et al., 2003). This approach usually entails volunteers, either non-experts or trained scientists, engaging in one or more stages of collecting, analysing, and using data to answer locally-relevant questions (Conrad and Hilchey., 2011; Whitelaw et al., 2003). As such, CBM is generally compatible with the concepts of citizen science (Silvertown, 2009), community science (Armitage et al, 2017), crowd-sourced data collection (Lowry and Fienen, 2013), and participatory monitoring (Danielsen et al., 2005). Above all, CBM is marked by an emphasis on community-driven priorities and motivations for generating environmental data (Conrad and Hilchey, 2011; Pollock and Whitelaw, 2005; Whitelaw et al., 2003).

In recent decades, CBM has expanded rapidly – particularly in North America and Europe (Conrad and Daoust, 2008; Silvertown, 2009). This growth is attributed to many factors including (1) the limited capacity and scope of monitoring conducted by scientists in government and academia; (2) the growing concerns of communities regarding the health of their local environment; and (3) the rise of affordable and simple technologies for crowdsourcing data and undertaking robust and accurate water monitoring (Buytaert et al., 2014; Conrad and Hilchey, 2011; Pollock and Whitelaw, 2005; Silvertown, 2009). Consequently, data collected through CBM are filling gaps in environmental monitoring, promoting collaborative water governance, and engaging communities in the conservation and stewardship of ecosystems (Buytaert et al., 2014; Ochoa-Tocachi et al., 2016). As this phenomenon continues to grow, there is an emerging need to understand and document the conditions that foster success in improving local environments through CBM data, as well as the ongoing barriers to community-based approaches in environmental monitoring (Conrad and Hilchey, 2011).

## 1.1. Water Monitoring and Governance in Canada

Water monitoring is a scientific process of measuring water quality and availability across time for the purpose of identifying long-term trends, and ideally, informing the governance of freshwater resources (Levett et al., 2007). However, in

practice, both water monitoring and water governance in Canada face ongoing challenges that hinder their integration. Government-led monitoring of freshwater in Canada is hindered by both the vast geographic scale of Canada's watersheds as well as inconsistent funding and capacity to expand water monitoring sites (Conrad and Daoust, 2008; Kebo and Bunch, 2013). This has resulted in spatial and temporal gaps in water data and a potentially incomplete understanding of the health of some of Canada's 25 major watersheds (Bakker and Cook, 2011; WWF, 2014; 2016). On the other hand, as noted by Bakker and Cook, "water governance in Canada is characterized by a high degree of fragmentation in a decentralized federal state" (2011, pg. 275). That is to say, government departments responsible for water-related issues are divided across jurisdictional (e.g. federal, provincial, regional, municipal) and sectoral (e.g. fisheries, health, agriculture, land use, transportation) silos (Bakker and Cook, 2011).

To address fragmented decision-making about water, the literature on water governance generally focuses on improved policy harmonization, intergovernmental coordination, and stakeholder collaboration (Armitage et al., 2015; Bakker and Cook, 2011; Cohen, 2015; Hill et al., 2013). However, a contrasting perspective is that *too much* integration in water governance creates unnecessary burdens on decision-makers and that the involvement of various government and non-government actors should be determined by the context of a water-related issue (de Loë and Patterson, 2017). Opting for a similarly pragmatic approach, Pahl-Wostl et al. (2013) suggest a framework for water governance that emphasizes the role of legitimacy (valid and transparent process), representativeness (involvement of all relevant stakeholders), leadership (effective facilitation and coordination), and comprehensiveness (integrated resource management). Finally, Armitage et al., (2015) highlight the importance of fostering social learning, integrating diverse forms of knowledge, and engaging networks of researchers, policy-makers, and civil society to legitimize science-policy linkages in water governance.

These theoretical approaches align with the CBM literature, which emphasizes participatory and inclusive governance as an integral part of effective water monitoring (Conrad and Daoust, 2008; Pollock and Whitelaw, 2005; Whitelaw et al., 2003). Indeed, CBM manifests as an opportunity for citizens to co-generate knowledge relating to freshwater resources and an opportunity for governments to expand water monitoring and increase the legitimacy of water policy decisions.

In Canada's water governance landscape, CBM is increasingly recognized and supported by both governments and non-governmental organizations (NGOs). This is evidenced by the increase of programs enabling citizen science through access to training, equipment, data management, and monitoring networks (CABIN 2012, NWT 2010; Pollock and White, 2005). Moreover, governments and NGOs have published water monitoring protocols to provide standardized methods for collecting, managing, and interpreting water quality and quantity data. Some provincial and territorial governments now directly support and coordinate CBM programs, including Alberta, Northwest Territories, and Ontario (AEP, 2017; DESC, 2017; NWT, 2010). Moreover, federal departments including Fisheries and Oceans Canada<sup>1</sup>, Health Canada<sup>2</sup>, Indigenous and Northern Affairs Canada<sup>3</sup>, and Environment and Climate Change Canada<sup>4</sup> have implemented CBM programs for various forms of water monitoring. Meanwhile, several NGOs across Canada have also created monitoring networks with robust, scientifically-defensible protocols such as CURA H2O (Community-University Research Alliance), led by the Community Based Environmental Monitoring Network.

Although this abundance of CBM programs highlights the increasing legitimacy and value CBM within Canada, it also may suggest that community-based water monitoring in Canada faces potential redundancies that could be resolved through a more consistent and unified approach to monitoring. Additionally, there is a need for more analysis of whether such programs are indeed informing the governance of water at various scales (Conrad and Hilchey, 2011).

## **1.2. Research Objectives**

This research was initiated in to address unanswered questions relating to the status of CBM in Canada. In particular, our research team's interests converged on addressing the paucity of information about what CBM initiatives exist across the country, what water quality and quantity parameters are being monitored, where CBM data is analyzed, and how existing programs are supported and coordinated. We sought

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<sup>1</sup> Community Aquatic Monitoring Program

<sup>2</sup> Community Based Drinking Water Monitoring Program

<sup>3</sup> Cumulative Impact Monitoring Program

<sup>4</sup> Canadian Aquatic Biomonitoring Network

to answer these questions by surveying CBM organizations and groups through a nation-wide survey. The results of our survey were published in February 2017 in a report entitled: “A Snapshot of Community-based Water Monitoring in Canada.”

This paper builds on our initial report through a broader examination of the academic and grey literature on CBM, citizen science, participatory monitoring, and other relevant sub-disciplines, to contribute to the discourse on linking citizen-generated data to policy and decision-making. Using our analysis of CBM themes such as citizen motivations for CBM, data credibility, levels of citizen engagement, and institutional collaboration, we discuss new trends found in our research, such as increased use of standardized monitoring protocols among CBM groups. This paper aims to build on past literature relating to the data-policy interface of CBM and contribute new insights for programs seeking to incorporate CBM into decision-making (Conrad and Daoust, 2008; Conrad and Hilchey, 2011).

## **Chapter 2. Literature Review**

To further explore factors that foster or hinder the usability of CBM data, we review the academic and grey literature on CBM with an emphasis on four key considerations highlighted in previous scholarship (Alender; 2016; Burgess et al., 2017; Buytaert et al., 2014; Conrad and Hilchey, 2011; Danielsen et al., 2009; Frost and Scott, 2017; Kouril et al., 2016; Pollock and Whitelaw, 2005). First, we explore the reasons for which CBM programs initiate and the different data trajectories of CBM. Second, we review the credibility of CBM methodologies for collecting, storing, and/or analysing environmental data. Third, we discuss implications of the varying degrees of participation by local citizen scientists and external professional scientists throughout a CBM project life cycle. Fourth, we examine the potential benefits of CBM partnerships with governments, CBM networks, and other institutions in building capacity and fostering data-policy linkages in CBM programs. We utilise these four themes of CBM to shed light on outstanding questions in the CBM literature and to provide an analytical frame for our subsequent research questions.

### **2.1. Motivations for CBM**

Understanding the diverse and place-based motivations for engaging in CBM is essential to generating sustained interest and participation in CBM programs (Bonney et al., 2014; EPA, 2016; McNeil et al., 2006; Pollock and Whitelaw, 2005). Although the spectrum of community-specific reasons for collecting and using water data can be challenging to classify, at least three broad categories (or progressive stages) exist. First, motivations can stem from a desire to generate community awareness, increase scientific literacy, and contribute to scientific research (Cohn, 2008; Dickinson et al., 2012; EPA, 2016). Second, communities may undertake CBM to fill gaps in government-led monitoring, and to identify and track local concerns about ecosystem and human health (Whitelaw et al., 2003; Conrad and Hilchey, 2011; Garda et al., 2017). Third, CBM can be initiated to leverage scientific knowledge to inform and improve policy and decision-making at various scales of governance (Danielsen et al., 2009; McKinley et al., 2016; McNeil et al., 2006), and to promote better compliance with environmental laws (EPA, 2016). The degree to which these categories motivate individuals will vary, as participant motivations often change across time (Rotman et al., 2014), and can diverge

based on age, gender, level of education, and socioeconomic circumstances (Alender, 2016; Beza et al., 2017; Danielsen et al., 2005; Lewandowski et al., 2017; Raddick et al., 2013).

Another angle for examining motivations for CBM is to consider the potential uses of community-generated data. CBM data are variously used in academic publications (Ochoa-Tocachi et al., 2015; Scott and Frost, 2017), collected to supplement datasets collected by governments or NGOs (CABIN, 2012; McKenzie Datastream, 2017; McNeil et al., 2006), provided as evidence for prosecution in cases of violations of environmental laws (EPA; 2016), and disseminated to the public through reports, workshops, and conferences (Pollock and Whitelaw, 2005; Weston and Conrad, 2015). However, using citizen data to potentially inform and improve policy and decision-making is emphasized consistently across both academic and grey literature on CBM (Alender, 2016; Buytaert et al., 2014; Castleden, 2016; Conrad and Hilchey, 2011; Danielsen et al., 2010; EPA, 2016; Kanu et al., 2016; NWT, 2010; Pollock and Whitelaw, 2005). To this effect, Conrad and Daoust assert that “regardless of the specific mandate, [participants in CBM] tend to have the hope that their efforts will be used to assist in local decision making” (2008, pg. 359). Moreover, Alender (2016) studied volunteer water quality monitoring in the United States and found that the highest ranking motivators for CBM was enhancing the environment and using data to address environmental problems, which implicitly requires some level of action by decision-makers.

Thus far we have explored literature on motivations for CBM without explicit attention to place, but connecting data to decision-making also needs to be situated within socioeconomic and geographic realities. For instance, Danielsen et al., (2009) suggest that local communities in poorer countries are more likely motivated by the potential benefits that monitoring offers in terms of community ownership, empowerment and decision-making surrounding their local environment and natural resources. This is supported by Buytaert et al., (2014), who highlight several case studies of low-income rural farmers utilising CBM primarily to inform and improve governance of water resources vital to agrarian livelihoods. Additionally, Berkes et al. (2007) highlight cases of Inuit fishers and hunters in the Canadian Arctic using CBM and indigenous knowledge to support integrated management of marine ecosystems on which their subsistence depends. These cases highlight the motivation of conducting CBM with the intention of securing remote and vulnerable livelihoods dependent on the preservation of

ecosystems, which contrasts with more affluent regions where monitoring can arise out of a culture of volunteerism and outdoor recreation (Danielsen et al., 2005).

Considering the centrality of data-policy linkages within most CBM programs, it is important that monitoring programs are deliberately designed and implemented with the intention of generating actionable and credible information to decision-makers (Buckland-Nicks et al., 2016; Buytaert et al., 2014; McKinley et al., 2016). However, the credibility of CBM remains an ongoing challenge to achieving linkages between data and decision-making. Indeed, the issue of credibility has sometimes led government agencies and academic institutions to reject CBM findings that could otherwise potentially fill critical information gaps and guide environmental management decisions. Therefore, exploring past literature that has tested the validity of CBM and citizen science programs may shed light on approaches to avoid potential methodological issues that may arise in CBM and maximize the utility of citizen-generated data.

## **2.2. Credibility of CBM**

A long-standing barrier to CBM is the perception among scientists that citizen-generated data is not reliable (Conrad et al., 2011). In particular, skepticism is often directed toward issues of data accuracy and biases (Burgess et al., 2017; Kosmala et al., 2016). Scientists have expressed concern about the capacity of non-experts to mitigate data errors, calibrate equipment, and undertake robust data analyses, especially in more complex fields of scientific inquiry. Generally, the literature asserts that citizen science and CBM, while suitable when using basic methodologies in fields such as ecology, hydrology, and astronomy, is not appropriate in many other fields of science (Cohn 2008; McKinley et al., 2016; Snall et al., 2011). This corresponds with the fact that the most prolific areas of CBM tend to be ecological studies and environmental monitoring (Silvertown, 2009), which can also be made more accessible and engaging for citizen scientists and community monitors (Cohn, 2008).

However, a number of recent findings are increasingly supporting the validity and suitability of CBM. First, contrary to some academic perceptions of the invalidity of CBM methods, most biases in data interpretation are found equally among both professional scientists and citizen scientists (Kosmala et al. 2016). Second, advances in automatic sensing technology and statistical analysis have improved data accuracy and reduced

biases, respectively (Hochachka et al., 2012; Kosmala et al., 2016; Newman et al., 2012). Last, several case studies verify that when proper protocols are followed, citizen scientists can collect data with similar levels of accuracy as professional scientists (Au et al., 2000; Fore et al., 2001; Kosmala et al., 2016; Shelton, 2013; Storey et al., 2016). These findings suggest that a lack of awareness within the scientific community of the credibility of CBM may actually be a larger barrier than the technical competencies of citizen scientists (Burgess et al., 2017).

Despite research supporting the theoretical potential of CBM to be conducted robustly, at least three practical challenges remain. First, CBM is data intensive, and when monitoring programs have inadequate funding and resources, data quality issues are often more prevalent (Alender, 2016; Conrad & Daoust, 2008). In general, more funding needs to be allocated to improving data management and analysis tools in CBM programs to continue advancing standards of CBM data quality (Bonney et al., 2014). Second, it may be difficult to match monitoring protocols with different cultural contexts and locally-specific motivations for monitoring. Pollock and Whitelaw note the experience of CBM coordinators in remote aboriginal communities in Canada with oral cultures, where “the ‘double translation’ of protocols into traditional languages and translation of results into English remains a distinct challenge” (2005, pg. 223). Third, the emphasis on data quality and robust analysis is sometimes at variance with the participatory and place-based nature of CBM (Danielsen et al., 2005). While professional scientists may recommend that CBM data be stored and analysed by trained professionals in laboratories, several case studies show that when data is stored and analysed within local communities, CBM can have a more significant impact in local decision-making scenarios (Danielsen et al., 2005).

Moreover, evidence suggests that concerns of keeping research place-based are sometimes more important to communities, even if data quality is somewhat decreased as a result (Danielsen et al., 2005). More broadly, these cases allude to the different tensions between locally-based and externally-driven approaches to monitoring, in which local communities and external experts participate variously throughout the research process. The next section explores different approaches to citizen participation in CBM and citizen science projects, which is a salient consideration when evaluating the potential benefits and challenges associated with the degree of community ownership of CBM projects.

## 2.3. Degrees of Citizen Participation

Monitoring projects have varying levels of involvement of professional scientists and local communities. For instance, in monitoring programs established by governments, citizens usually participate only as data collectors whereas professionals determine monitoring objectives, methodology, and data uses. In contrast, monitoring programs initiated at the community-level often entail community members taking a leading or collaborative role in data collection, analysis, and usage (Conrad & Hilchey, 2011; Danielsen et al., 2009). The degree and quality of community participation in CBM have far-reaching implications on a program's outcomes and potential policy impact (Danielsen et al., 2010; Shirk et al., 2012).

Several frameworks exist for assessing the level of engagement of citizens in community-based monitoring programs. Whitelaw et al. (2003) describe four approaches to CBM including *government-led, interpretive, advocacy, and multiparty*. This typology acknowledges that multiple approaches to monitoring can coincide, since CBM sometimes involves both interpretive (educational) and advocacy components. Other approaches posit a spectrum of engagement with lesser and greater levels of citizen participation. For instance, Danielson et al. (2009) propose a spectrum of five monitoring schemes based on the varying roles of citizen scientists and professional scientists in data collection and data use. These include *externally-driven, collaborative, and autonomous local monitoring* approaches. Similarly, Conrad and Hilchey (2011) conceptualize three governance structures for monitoring programs, which frame the role of citizens as being *consultative, collaborative, or transformative*.

Common among all these frameworks is a characterization of benefits and challenges for programs across the participatory spectrum, from externally-driven to locally-based approaches. First of all, local and collaborative forms of monitoring are substantially more affordable than external and government-led monitoring (Brammer et al., 2016; McNeil et al., 2006), but the former can face challenges relating to data management, long-term funding, and governance (Conrad & Daoust, 2008; Conrad & Hilchey, 2011). Moreover, Danielsen et al. (2010) find that in locally-based monitoring significantly speeds up the rate at which resource management decisions are made. In particular, the authors note that participatory monitoring can “lead to rapid decisions to solve the key threats affecting natural resources, can empower local communities to

better manage their resources, and can refine sustainable-use strategies to improve local livelihoods” (Danielsen et al., 2010, pg. 1). However, the authors also note that government-led monitoring may be better suited for contributing to national and international scales of decision-making (Danielsen et al., 2005; 2010).

Acknowledging trade-offs between these different approaches, Danielsen et al. (2009) suggest criteria for selecting which degree of local participation is most effective given local circumstances and monitoring objectives. For instance, CBM programs aiming for high data quality generally require greater involvement by professional scientists, whereas programs focused on empowering local communities in decision-making necessitate higher degrees of community participation in data collection, analysis, and use (Danielsen et al., 2005; 2009). Therefore, CBM programs must be carefully designed to reflect the appropriate level of local participation for a particular community and environmental issue (McKinley et al. 2016). In some cases, programs are able to achieve both locally-driven monitoring as well as the benefits of funding and capacity support from governments through collaborative arrangements with governments and other parties (McNeil et al., 2006; Whitelaw et al., 2003). This is detailed further in literature focusing on partnerships in CBM.

## **2.4. Collaboration and Partnerships**

While communities may be asking questions that are quite distinct from those of professional scientists, the potential for collaboration is optimized when these questions overlap (Buytaert et al 2014, Céleri et al., 2009). Building synergies through monitoring partnerships and networks can substantially increase the feasibility and technical capacity of a CBM project while reducing potential overlap in monitoring initiatives (Bonney et al., 2014; Latimore and Steen, 2014; McNeil et al., 2006; Pollock and Whitelaw, 2005). To this effect, Pollock and Whitelaw note that potential partnerships can be formed with a wide range of actors including “municipal, provincial and federal government agencies, environmental organizations, industry representatives, community groups, academic institutions (from elementary to post-secondary), conservation areas, field naturalists, parks, and biosphere reserves, to name a few” (2005, pg. 221). Determining which among these actors are most suitable for partnerships often depends on the context in which CBM is being implemented and problems communities aim to address.

For CBM programs aiming to inform policy and decision-making, partnering with government actors and non-governmental organizations (NGOs) involved in water monitoring and management is usually a necessary step (Conrad and Daoust, 2008; EPA, 2016; McNeil et al., 2006; Whitelaw et al., 2003). In cases of collaboration between communities and governments, Conrad and Daoust (2008) suggest that an effective starting point for communities “identifying the kinds of information environmental managers require to make good decisions” (2008, pg. 359). Another aspect of identifying appropriate decision-makers is assessing the levels of government that have relevant jurisdictional authority to address a particular ecosystem and water resource management issue. In the case of Canada, the mandated authority could be municipal/regional (e.g. stormwater runoff, water extraction, municipal sewage), provincial/territorial (e.g. mining, forestry, agriculture), or federal (e.g. commercial fishing, interprovincial energy projects). In some cases, multiple levels of government are implicated in order to holistically address a water-related issue (e.g. fish habitat).

Of course, partnerships with relevant governmental actors do not guarantee that local environmental conditions will improve, or even that CBM data will be used effectively (Conrad and Daoust, 2008). However, the legitimacy of citizen-generated data is often bolstered through such partnerships, as it enables communities to collect data that is compatible with government frameworks for water monitoring (McNeil et al., 2006).

Nevertheless, an ongoing challenge in cases of monitoring partnerships between communities and government is the lack of communication of how CBM data is used (Alender, 2016; Conrad and Daoust, 2008). McNeil et al., (2006) report statistics from a federal government-run CBM program (Atlantic Coastal Action Program) in which metrics are provided for the benefits and uses of citizen data. However, instances of government departments publicly reporting such data outcomes appear less common in the past decade. This is partly because governments supporting CBM are sometimes unable to verify how and if monitoring data is used, it is also due to a recent and past decreases in government funding capacity to support CBM (Au et al., 2000; Savan et al., 2003; Conrad and Daoust, 2008). The uncertainty of whether data is being used in decision-making remains a significant challenge for CBM (Conrad and Hilchey, 2011). Ultimately, overcoming such challenges are necessary to increase the utility of CBM for all parties involved.

Despite the rich literature outlined above, key questions remain central to understanding the barriers to CBM uptake. Specifically: (1) Are CBM programs across Canada addressing the reasons for which they were originally initiated? (2) What protocols are being followed by CBM groups and which parameters are being monitored? (3) To what extent do CBM program members feel their findings are incorporated into government-led decision-making processes? These questions are important because they take current understandings of the challenges and benefits from literature reviews and specific case studies to broader-scale understandings of trends over time. As is further detailed in the Discussion section, the results of a cross-country survey provided unique insights into these questions and can help scholars and practitioners better understand the relationships between CBM programs and the broader water governance landscape.

## **Chapter 3. Methods**

In Canada, as elsewhere, CBM is an increasingly popular and important part of the water governance landscape. With over 200 CBM organizations across the country, Canada provides a rich case study in which to ask some of the broader scale questions that remain unanswered in the literature (see above).

### **3.1. Cross-sectional Survey**

To answer these questions, we created a cross-sectional online survey in order to examine (1) the degree to which communities are addressing their environmental concerns through CBM, (2) the monitoring protocols they follow and parameters they monitor, and (3) the extent to which CBM program members feel their findings are incorporated into government decision-making surrounding water resources. The scope of community-based monitoring for the survey includes organizations and groups that involve volunteers and non-professionals in the collection of water quality and quantity data within Canada. This was inclusive of water monitoring that assesses physical (e.g. temperature), chemical (e.g. pH) and biological (e.g. benthic invertebrates) parameters across freshwater bodies, including lakes, streams, rivers, wetlands, glaciers, and groundwater.

The survey was distributed by email in both French and English between July 2016 and September 2016. Participants were informed that the purpose of the study was to build a better understanding of what CBM initiatives exist across the country, what is being monitored and analyzed, and how existing programs are supported and coordinated.

### **3.2. Participant Recruitment**

Recruitment was carried out through virtual sampling using purposive and snowball approaches. A purposive sample is constructed from a population for a specific purpose and a snowball sample entails enlisting the help of prospective participants to recruit other suitable participants (Atkinson and Flint, 2001; Palys, 2008). The former method was employed to identify individuals in management or coordination roles within

organizations conducting CBM, whereas the latter method was used to recruit participants through existing CBM networks and to reach individuals that may not appear in internet search engine results. Using a combined sampling approach helped to maximize the quality and quantity of the sample size. This was necessary due to the lack of a national inventory of CBM initiatives at the time of the survey design (May 2016 – June 2016).

### **3.3. Limitations**

Given the nature of CBM as an inclusive form of scientific research involving the general public, the level of expertise of respondents was variable, ranging from volunteers without formal scientific training to professional scientists. Moreover, participants also varied in their level of involvement in their respective program. Some respondents played a central role in coordination and oversight of a CBM program whereas others were only involved through contributing data. These discrepancies in expertise and experience may affect the accuracy of responses to survey questions that require a more reliable understanding of water science and the history of their CBM program, respectively.

## Chapter 4. Results

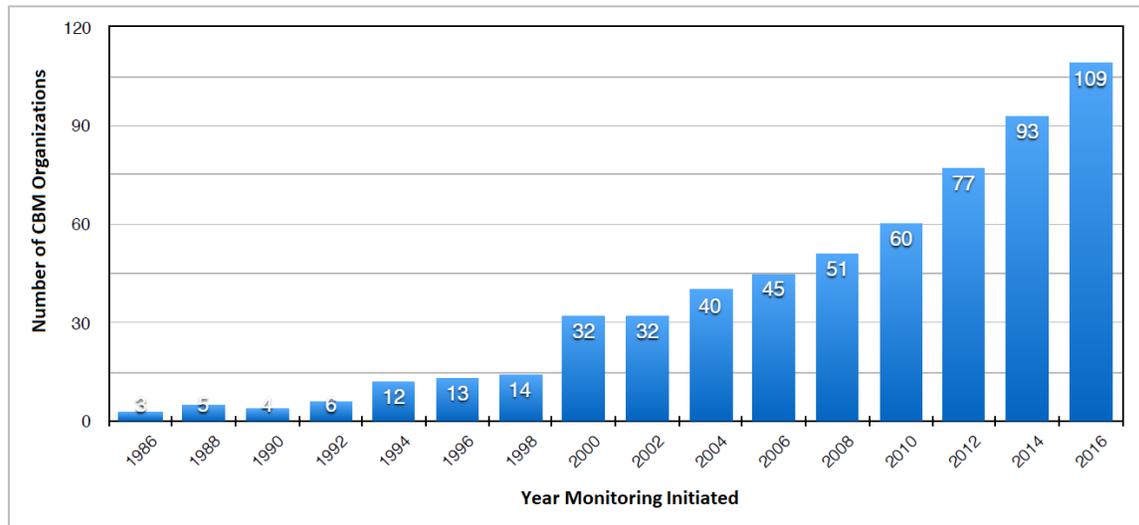
The survey was distributed by email to 270 individuals, of which 121 (45%) responded. Most respondents were located in British Columbia (n=33), Nova Scotia (n=25), Ontario (n=13), and Alberta (n=13), and the majority of respondents (n=85) were located outside of metropolitan areas (StatsCan, 2016). CBM activities varied widely in geographic scope, ranging from CBM networks monitoring over 240 water bodies to local groups monitoring a single river or stream.



**Figure 1. Map of CBM organizations by postal code (Credit: Melissa Ristow)**

Initial survey questions prompted participants to report when their organization started monitoring and when gaps in monitoring have occurred. The average length of continual monitoring by the CBM programs sampled was 8.9 years, with shortest being less than a year and the longest continuing for 47 years. Only 9 of 121 programs explicitly reported multi-year gaps in their monitoring activities. However, other respondents reported that their monitoring sites have sometimes changed or expanded over time, and that the intensity of monitoring varies year by year. Lastly, we found here that the number of CBM programs have nearly quadrupled between 2000 and 2016,

which supports previous literature that CBM is rapidly expanding in Canada (Conrad and Daooust, 2008; Conrad and Hilchey, 2011).



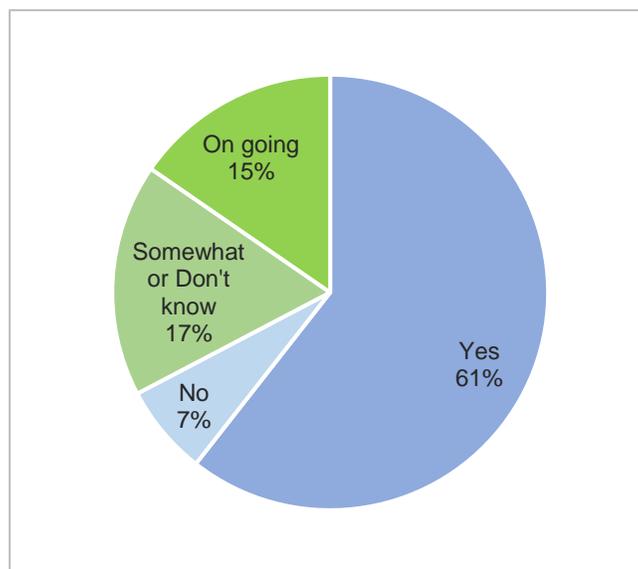
**Figure 2. Growth of CBM programs from 1986-2016.**

## 4.1. Effectiveness of CBM programs

To identify trends in effective CBM programs, we first employed an open-ended question to discern the initial reasons for which respondents implemented a CBM program, and whether or not these reasons have been, or are being, addressed. Here we define “effectiveness” as the respondents’ perception of their CBM program to produce or contribute to a desired outcome (e.g. improved community stewardship of a local stream, or stricter regulations on industrial wastewater treatment). We coded key words in responses by frequency and conducted a thematic analysis to distinguish subtleties in expression. Of 107 respondents to this question, the majority (n=67) provided multiple reasons for which their CBM program started. Responses generally fit within five categories: (1) addressing local concerns about ecosystems (n=63), (2) fostering education, engagement, and stewardship (n=32), (3) filling gaps in existing data, monitoring, and local knowledge (n=26), (4) informing decision-making and local ecosystem management (n=24), and (5) conducting scientific research and establishing baseline data to assess long-term trends and impacts (n=18).

Evidently, the above categories are not mutually exclusive. It is possible that some respondents may have not listed certain categories as an initial reason for monitoring, but these may have become a justification for continuing the program at later stages once CBM data start to reveal ecological trends. For instance, categories (2), (3), (4) or (5) can variously act as necessary strategies to achieve category (1). Many of individuals from Category (1) reported that their concerns derived specifically from impacts of mining (n=8), farming (n=7), urban development (n=7), flooding (n=4), logging (n=3), boating and recreation (n=2), municipal water extraction (n=2) hydraulic fracturing (n=1) and hydropower development (n=1). This may suggest that CBM programs have to be carefully designed to address the appropriate questions that corresponds with a particular water quality or quantity issue.

Participants were then asked whether their CBM program is addressing their initial reasons for monitoring. 107 responses were coded as “yes”, “somewhat”, “no”, and “on going/to be determined” – to account for temporary and continual evaluations of monitoring efficacy. 59% (63/107) of participants reported that their reasons for monitoring are being addressed, whereas 18% (19/107) indicated that their reasons are partially or somewhat addressed, 7% (7/107) stated “No”, and the remaining 15% (16/107) reported that their evaluation of CBM outcomes is “ongoing” or “to be determined.”



**Figure 3. Are the reasons for starting a CBM program being addressed?**

## 4.2. Correlation between effective and collaborative CBM

Based on previous literature emphasizing partnerships as a key factor in effective CBM (McNeil et al., 2006; Latimore and Steen, 2014; Ochoa-Tocachi et al., 2015; Kouril et al., 2016), we investigated potential correlations between CBM programs with partnerships and the likelihood of achieving program goals. Notably, 74% (35/47) of respondents that collaborate with both government(s) and CBM networks reported that their program is addressing its original purpose. In contrast, programs collaborating only with government(s) or only with CBM networks answered “Yes” 50% (13/26) and 44% (8/18), respectively. Only 29% (4/14) of programs without any partnership or collaboration reported that they were addressing their initial reasons for monitoring.

This finding may support the notion that partnerships with governments and CBM networks often strengthen the capacity and effectiveness of local initiatives. For instance, in many cases, respondents reported that municipalities, regional districts, and provincial governments loaned monitoring equipment, provided data storage, and supported program planning and coordination – all of which can potentially increase the efficacy of monitoring. Interestingly, no significant correlation was found between the number of governments (i.e. municipal, regional, provincial, federal, and Indigenous) a CBM group collaborated with and the perceived success of the program.

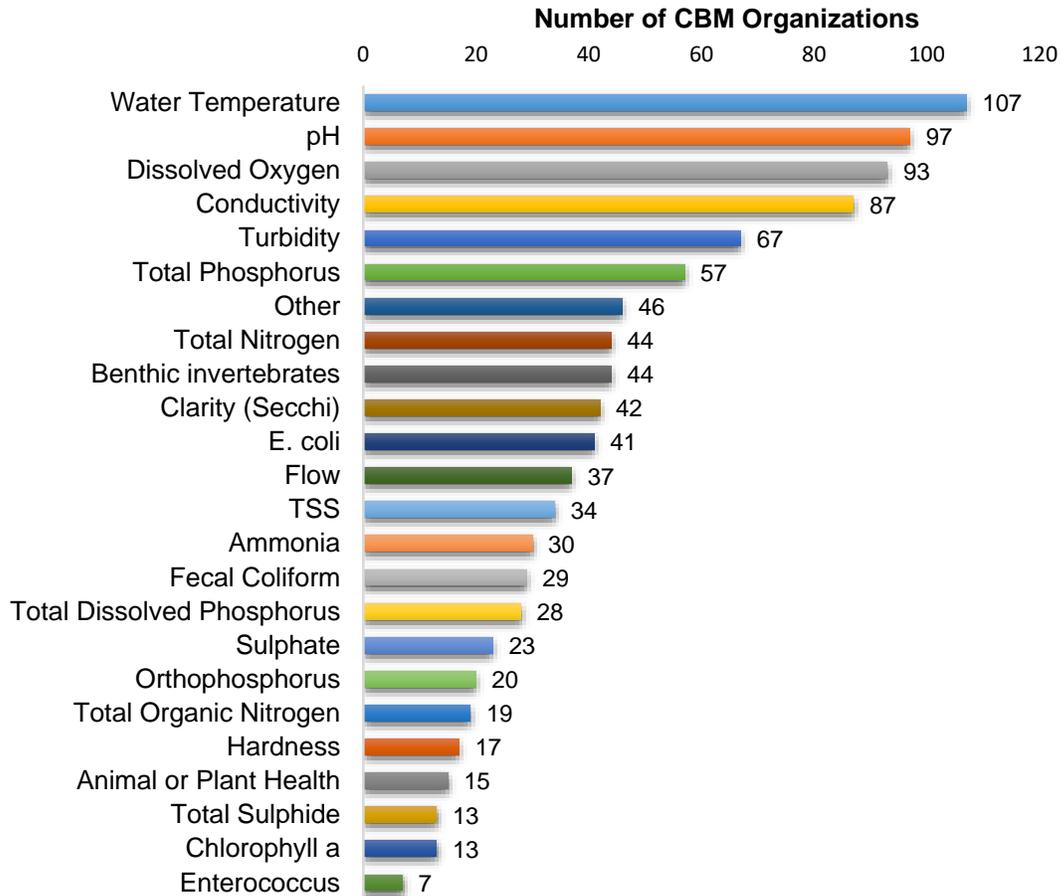
## 4.3. Prevalence of standardized monitoring protocols

We asked respondents to state whether or not they follow a standardized monitoring protocol.<sup>5</sup> We provided an option to respond “Unsure” to account for respondents who may not be acquainted with the protocols their organization follows. The majority of respondents (78%) followed a monitoring protocol, while 12% were unsure and 10% did not. These results contrast with those of Conrad and Daoust (2008), who surveyed CBM groups based in the province of Nova Scotia and found that 73% of respondents did not use a standardized protocol to collect data. Moreover, within our sample size from the same province (n=20) that these authors studied, we found that 75% of respondents follow standardized monitoring protocols. At the very least, this

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<sup>5</sup> Here, we define ‘monitoring protocol’ as any prescribed methodology for collecting, analyzing, and/or interpreting water quality or quantity data. Examples include municipal or provincial monitoring protocols that include testing parameters for particular substances.

indicates that CBM has likely become more standardized in the past decade in this particular province, but may also suggest monitoring protocols have become more prevalent for CBM programs across Canada.

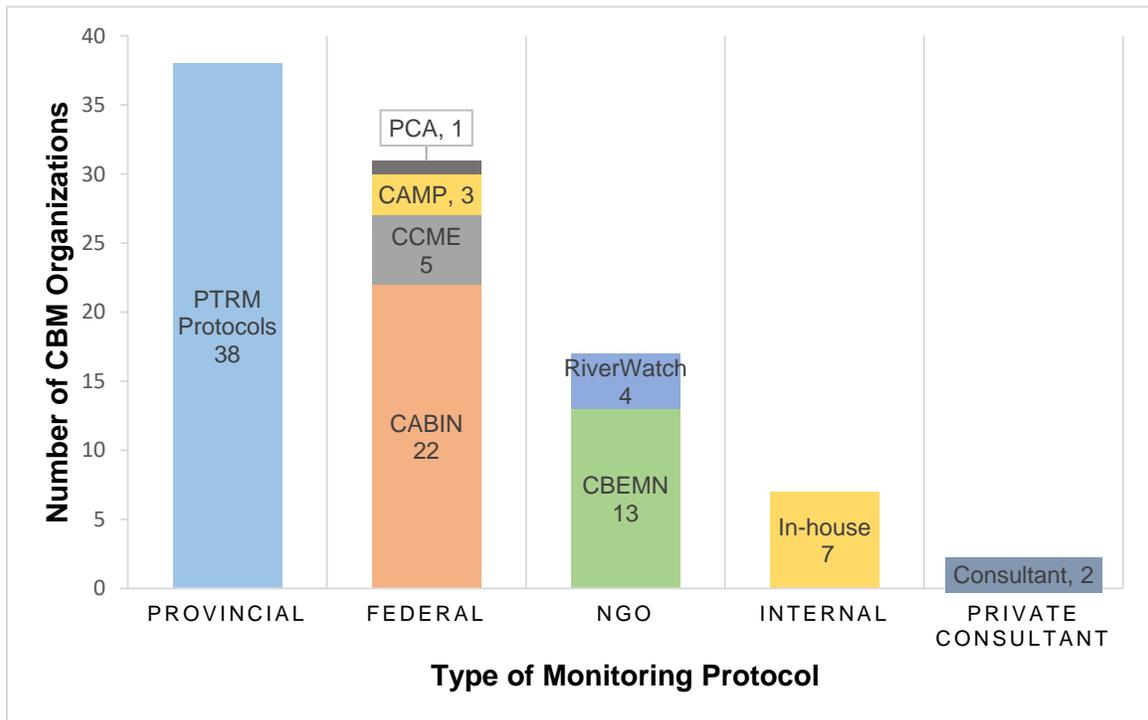


**Figure 4. Parameters Monitored By CBM Organizations**

Monitoring protocols are often designed for specific water quality parameters. We asked participants what parameters they monitoring in order to understand how it may inform of a protocols. The most common parameters were Temperature (n=107), pH (n=97), Dissolved Oxygen (n=93), Conductivity (n=87), Turbidity (n=67). Total Phosphorus (n=57), Total Nitrogen (n=47). We then provided participants with five options to convey how these parameters were selected. The results are as follows: “monitoring protocol standards” (34%), “federal, provincial, or territorial standards” (36%), “community priorities” (38%), and “capacity of monitoring equipment and/or resources” (56%). The remaining option available to participants was an open-ended

answer, in which some participants (26%) clarified that monitoring parameters were selected based on the advice of professional scientists or due to the specific nature of the program (e.g. accessibility for high school students, or relevance to monitoring climate change impacts).

Other aspects of monitoring protocols we considered are their respective scope and coordinating entity. The most commonly followed protocols came from the Canadian Aquatic Bio-monitoring Network (CABIN) (n=22) and Community Based Environmental Monitoring Network (CBEMN) (n=13), which are coordinated by a federal government department and a non-governmental organization, respectively. In contrast, many of the remaining respondents reported following various provincial, territorial, regional and municipal (PTRM) protocols<sup>6</sup> (n=38). The latter were amalgamated in this analysis because these were too numerous to evaluate and a comparison would be skewed by provinces with the highest response rates (British Columbia and Nova Scotia). When separated by sector, CBM groups were following protocols coordinated by: government (n=69), NGOs (n=18), internal protocols (n=7), and private consultants (n=2).

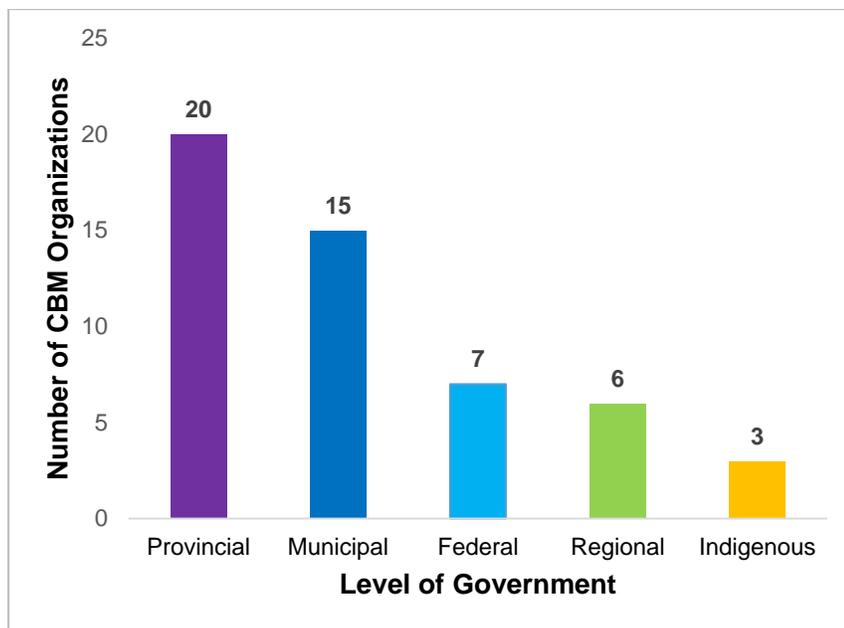


**Figure 5. Water Monitoring Protocols Used by CBM Organizations**

<sup>6</sup> No Indigenous monitoring protocols were mentioned by participants. However, 30% of respondents (n=121) reported they incorporate traditional ecological knowledge (TEK) into their monitoring.

#### 4.4. Perceptions of CBM data uptake in policy and decision-making

We asked respondents to indicate if their data is informing policy at any level of government. All but one participant responded to this question (n=120) and we measured responses as a percentage of total sample size. When asked if their data informs policy, respondents (n=115) stated “Yes” (46%), “No” (30%), or “I don’t know” (24%). Those who responded “Yes” reported that the level of government primarily using the data was provincial (n=20), municipal (n=15), federal (n=7), regional (n=6), and Indigenous (n=3).

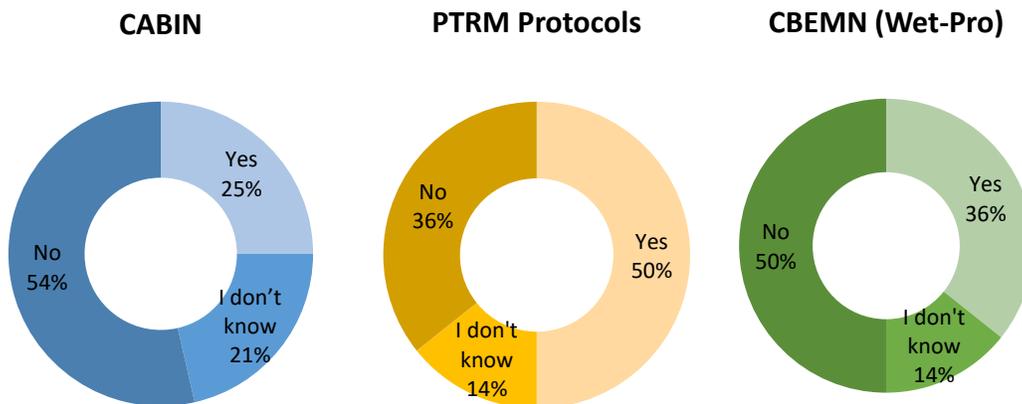


**Figure 6. Levels of government using CBM data as perceived by respondents.**

The finding that nearly one-third of respondents reported that their data are not informing policy is plausible considering that several respondents did not report this as an objective of their program. To explore this hypothesis further, we cross-tabulated the reasons for initiating CBM as discussed in section 3.1 and the frequency at which participants responded that their program informs government policy. We found that initial reasons for monitoring were not a significant indicator of how CBM programs responded to the above question. For instance, programs with primary objectives of

“informing ecosystem management and decision-making” (55%) were not substantially more likely to inform policy than programs with primary objectives of “education” (47%) and “engagement” (36%).

Next, we compared responses across the most common monitoring protocols followed by CBM organizations (as discussed in section 3.2) to determine potential distinctions across the different coordinating entities for monitoring protocols. We found that 50% of respondents following provincial, territorial, regional, or municipal protocols perceived they were informing policy, whereas the same was true for only 36% and 25% of respondents following CBEMN and CABIN protocols, respectively. Although the amalgamation of PTRM protocols reduces the granularity of the data analysis, it is still notable that the rate at which respondents perceive data-policy linkages within a federal government protocol (CABIN) is half (25%) (n=22) of that of respondents following protocols from lower orders of government (PTRM) (50%) (n=38).



**Figure 7. A Comparison of Participant Responses to "Does your data inform government policy?" Based on CBM Monitoring Protocols**

The final analysis conducted in relation to data-policy linkages within CBM is the potential effect of the longevity of programs. We grouped the age of CBM programs into four categories: <2 years (n=19), 2-5 years (n=36), 5-15 years (n=31), >15 years (n=31) – these temporal ranges were selected to ensure comparisons relied on relatively even sample sizes. We found a trend in which the oldest programs (>15 years) were the most

likely to be informing policy (58%), longer and shorter-term programs (5-15 years and 2-5 years) ranged in the middle (45% and 44%, respectively), and the most recent programs (<2 years) reported the lowest rate of informing policy (26%) and the highest rate of responding “I don’t know” (37%). Not surprisingly, this finding indicates that program longevity is an important factor in measuring potential impacts on decision-making, possibly due to time lags between program initiation, sufficient data collection and analysis, and translation of findings into relevant policy and management actions (Danielsen et al., 2010; Kouril et al., 2016).

In sum, the survey found the following: (1) partnerships tend to increase the efficacy of monitoring, (2) two-thirds of respondents perceived that their program’s data was being used by one or more levels of government, (3) programs using government-driven protocols were more likely to report their data being used by government – especially by lower orders of government, and (4) a correlation exists between program longevity and perceived data usage in policy. These findings build on and enrich existing CBM research (Conrad and Daoust, 2008; Conrad and Hilchey, 2011; Jollymore et al., 2017; McNeil et al., 2006; Pollock and Whitelaw, 2005) and may offer some concrete suggestions to groups hoping for policy uptake.

## Chapter 5. Discussion

Our survey results address important questions raised elsewhere in the literature. Specifically, we build on Conrad and Hilchey's conclusions from their CBM review, where they state that "there remains a need to enhance our understanding of community based-monitoring" (2011, 284). In particular, they make the following recommendations for future research:

(1) a need to "compare and contrast the success (and the situations that induce success) of CBM programs which present sound evidence of citizen scientists influencing positive environmental changes in the local ecosystems they monitor" and (2) "more case studies showing use of CBM data by decision-makers or the barriers to linkages and how these might be overcome" (284).

In the subsequent sections, we respond to this call for further research (4.1) and raise a new one: the potential tensions between the importance of locally-defined monitoring protocols and the push toward standardization (4.2)

### 5.1. Connecting Monitoring Objectives with Actionable Data Uses

Although we agree on Conrad and Hilchey's first point about the need to draw connections between CBM and ecological outcomes, it is often infeasible to definitively identify causal relationships between CBM, citizen science, and environmental changes. For instance, CBM in the context of ecological restoration may discern a positive long-term impact on water quality resulting from improved aquatic and riparian habitat, but in cases where CBM data is amalgamated to inform a broader water management process, it is usually unrealistic to provide sound evidence of a positive environmental change.

We do, however, address the second point of Conrad and Hilchey (2011) about the relationship(s) between CBM and the use of CBM data by decision-makers. Indeed, the paucity of information about the relationship(s) between these two factors was one of the driving forces for the survey. To that end, we explicitly asked survey participants if they felt their results were being used by decision-makers in municipal, regional, provincial, national, or Indigenous governments. The results of that survey question

indicate that almost half of the CBM programs believe their programs were informing government policy, while nearly one third were unsure.

These findings raise further questions. First, how might one know if a government is using CBM data? If the CBM data are being shared with one or more governments, are those governments reporting back to CBM groups with respect to the use of that data? Moreover, in what way(s) are the data being used? One could imagine any number of “use” scenarios, including, for example:

- The incorporation of baseline data into government databases;
- Ongoing monitoring for contaminants of concern and watching for concentrations or amounts above a prescribed threshold;
- Assessment of downstream effects;
- ‘Before and after’ monitoring with respect to particular developments on a given waterway;
- Examining potential links between monitoring data and public or ecological health;
- Measuring community involvement and public outreach (i.e., the number of volunteer monitors, turnout at community events, etc).

This list brings up a second question, namely, on what timescale are the data being used? This question links to the point in Section 3.3 about the correlation between program longevity and increased likelihood of perceived data usage. Indeed, it seems obvious that the longer-running the program, the more opportunities exist for data usage. For example, if the data are being used for ongoing monitoring of contaminants of concern, with a ‘flag’ raised if concentrations or amounts exceed allowable levels, are the data being ‘used’ if said amounts or concentrations are never reached? This is the problem of the null hypothesis as outlined in the case of conservation biology by Legg and Nagy (2006), where they suggest that a change within acceptable limits is still indeed a change. Similarly, if the purpose of a given CBM program is to generate baseline data, that baseline data can be used for any number of things, over a highly variable timeframe.

Together, these two questions raise a critical point about the relationship between monitoring and government. Since, as others (e.g. Conrad and Daoust 2008; Kebo and Bunch, 2013) have pointed out, many CBM initiatives have developed to fill the void left by the withdrawal of government from ongoing monitoring activities, it stands

to reason that governments would have an interest in incorporating the results of this lower-cost alternative into their existing (or recently cut) programs. But CBM cannot simply be about replacing government programs with a less expensive alternative, and the unique advantages of CBM can – and indeed should – be drawn out to work in concert with government programs and not in their stead. These distinct advantages and their ability to work synergistically with (rather than replace) those programs for which governments are responsible present a fruitful avenue for future research.

## **5.2. Diverse Monitoring Protocols**

A second set of CBM issues arising from the survey addresses the diversity of monitoring protocols used across the country. Monitoring protocols exist across multiple sectors and jurisdictions in Canada. In general, water monitoring is fragmented across numerous actors, including local to national governments with mandates relating to health, environment, fisheries, wastewater, stormwater, and land use planning (Bakker and Cook, 2011). This is compounded by local, Indigenous, industry, and NGO water monitoring protocols that were identified by respondents to our survey. This diversity of protocols is not necessarily a challenge in and of itself. Indeed, since one of the benefits of CBM is the perceived ability to address locally-relevant concerns, and since Canada is large enough to have a wide array of local water-related issues (see Results section), it makes sense that each locale works with the protocol that is best suited to their program's purpose and their particular issues of concern.

At the same time, however, such diversity of protocols can stymie the collection of regional, provincial, or even national meta-data, complicating the compilation of the types of longitudinal data required to assess the impacts of climate change, or particular developments, or to measure downstream impacts on waterways hundreds or thousands of kilometres long. Moreover, our finding that 56% of respondents identified “capacity of monitoring equipment / resources” as the driving force behind their monitoring parameters of choice is problematic. While equipment capacity is indeed a practical consideration in developing CBM programs, we suggest that the underlying monitoring questions should be driving protocol and instrument choice – not the other way around.

For this reason, we suggest that the solution to the ‘problem’ of diverse protocols lies perhaps in our earlier discussion point about the overall purpose of a given CBM program beyond filling a government void: that form could follow function. That is, once a desired dataset is identified on the basis of a particular question (or set of questions), the monitoring protocols and appropriate scale of decision-making follow from there.

## **Chapter 6. Conclusions**

There are a diversity of motivations to undertake CBM in Canada. Community concerns about aquatic ecosystems have been an impetus for the expansion of CBM, along with local objectives of raising awareness, filling data gaps, contributing to scientific research, and informing policy. The latter objective is arguably the most complex to implement or evaluate. Nevertheless, the initial stage of problem identification is essential to the critical path for a CBM program, as scientific questions and monitoring objectives should correspond with a trajectory for citizen-generated data.

### **6.1. Fostering collaborative and adaptive CBM**

At its core, CBM provides an opportunity for governments to rapidly increase the spatial coverage and temporal frequency of water monitoring, and an opportunity for communities to leverage scientifically-robust data to inform decision-making about their local environment. However, realizing these mutual benefits requires a more formal recognition of the value of CBM. In other words, citizen scientists, who are often seldom compensated for the data they collect, cannot be expected to undertake singlehandedly the work of government scientists. Considering that CBM is often indirectly supporting the mandates of multiple levels of government responsible for water-related issues, governments should play a role in alleviating the financial, technical and logistical burdens associated with CBM.

When CBM organizations form partnerships with governments and broader CBM, it ideally creates a multidirectional flow of data, expertise, and resources to collectively improve water stewardship. However, the time scale of establishing effective and collaborative CBM with observable results is usually at odds with the durations of government-funded programs, which very rarely exceed a decade (McNeil et al., 2006), and electoral cycles. On this latter point, changes of government can lead to fiscal austerity for CBM – as witnessed by now-defunct CBM programs in Canada and elsewhere (Mackechnie et al., 2011; Whitelaw et al., 2003). Subsequently, these fluctuations in government capacity highlight the need for CBM programs to develop more adaptive funding models and collaborate with other stakeholders such as NGOs,

local industry, and community organizations to build their capacity beyond government partnerships.

## **6.2. Standardizing CBM at appropriate scales of governance**

Although skepticism regarding the robustness and accuracy of CBM remains, standardized monitoring protocols are increasingly followed by CBM groups in Canada. This is a positive finding from the perspective of literature advocating for broader standardization of CBM in order to increase its scientific credibility (Au et al., 2000; Fore et al., 2001; Kosmala et al., 2016; Silvertown, 2009). However, there is a need for future research to analyse the broader implications of standardization, as it may hinder the incorporation local and indigenous knowledge systems (Berkes et al., 2007), and the benefits derived from locally-driven monitoring (Danielsen et al., 2005).

To this effect, our findings suggest that monitoring protocols from local or sub-national scales of government are more likely to link data to decision-making, based on perceptions of CBM participants. This outcome can be partly attributed to the place-based nature of CBM and the diverse issues impacting water quality and quantity across Canada. It is also possibly due to the jurisdictional authority of lower orders of government is more appropriate for addressing many community concerns related to water quality and quantity. Connections must therefore be drawn between the nature of a water issue, the appropriate management scale to address the issue, and the desired level of community ownership of a CBM project.

More broadly, we posit that understanding local motivations, employing robust methods, fostering citizen participation, and establishing collaborative partnerships remain key elements in CBM, and will ensure communities can continue playing formative role in the monitoring of freshwater resources.

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# Appendix A. Community-based Water Monitoring Survey

This survey is about Community Based Water Monitoring (CBWM) in Canada. It was created to develop a better understanding of what CBWM initiatives exist across the country, what is being monitored and analyzed, and how existing programs are supported and coordinated. In short, we aim to paint a picture of the state of CBWM in Canada.

We encourage you to fill out this survey by July 31st, 2016. The findings of this research will be shared with you via email in September 2016.

## Consent Form

You are being asked to complete a short online survey. The survey will take approximately 10-15 minutes, and you may withdraw at any time without penalty. Understanding which programs are monitoring where is key to understanding CBWM in Canada, so you will be asked to name the CBWM program with which you are affiliated. As a result, your answers will not be anonymous to the researchers, but will be presented in aggregate (i.e., generalized) form once the study is complete. Only the researchers will have access to the survey response data. It will be stored in a password-protected file folder on a password-protected computer for ten years. Your data is non-retractable after you click 'submit' at the end of the survey.

You will not be compensated for your participation. Minimal risks of economic or reputational harm are associated with this study, whereas the potential benefits include new partnerships, funding mechanisms, and data storage alternatives for CBWN groups. In any case, you are free to withdraw your participation at any time without consequence. By participating, you do not waive any rights to legal recourse in the event of research-related harm. The survey was created using FluidSurveys software. For more information about FluidSurveys' privacy protections, please see <http://fluidsurveys.com/about/privacy>.

Should you have any questions or concerns about this study, please contact the researchers directly at [...]@sfu.ca or 778-[...], or [...]@acadiu.ca or 902-[...].

Alternatively, you may contact the Director of the SFU Office of Research Ethics, Dr. Jeff Toward at [...]@sfu.ca or 778- [...], or the Chair of the Acadia University Research Ethics Board, Dr. Stephen Maitzen at [...]@acadiau.ca or 902- [...].By clicking 'Next', I consent to participating in the survey.

## Background

### 1. What is the name of your community or organization?

### 2. What is the name of your monitoring program?

### 3. Where does your organization conduct water-quality monitoring?

- |                    |                       |                           |
|--------------------|-----------------------|---------------------------|
| Province/Territory | <input type="radio"/> | Alberta                   |
|                    | <input type="radio"/> | British Columbia          |
|                    | <input type="radio"/> | Manitoba                  |
|                    | <input type="radio"/> | New Brunswick             |
|                    | <input type="radio"/> | Newfoundland and Labrador |
|                    | <input type="radio"/> | Northwest Territories     |
|                    | <input type="radio"/> | Nova Scotia               |
|                    | <input type="radio"/> | Nunavut                   |
|                    | <input type="radio"/> | Ontario                   |
|                    | <input type="radio"/> | Prince Edward Island      |
|                    | <input type="radio"/> | Québec                    |
|                    | <input type="radio"/> | Saskatchewan              |
|                    | <input type="radio"/> | Yukon                     |

or Indigenous Traditional  
Territory (if applicable)

Watercourse(s) (i.e.  
river, lake, stream, etc.)

**4. Please indicate your community's or organization's office address**

This will be used to create a map of all CBM groups across Canada

Street/Number

City, Town or Village

Postal Code

**5. In what years has your community or organization conducted monitoring?**

- |            |                       |      |
|------------|-----------------------|------|
| Start Year | <input type="radio"/> | 2000 |
|            | <input type="radio"/> | 2001 |
|            | <input type="radio"/> | 2002 |
|            | <input type="radio"/> | 2003 |
|            | <input type="radio"/> | 2004 |
|            | <input type="radio"/> | 2005 |
|            | <input type="radio"/> | 2006 |
|            | <input type="radio"/> | 2007 |
|            | <input type="radio"/> | 2008 |
|            | <input type="radio"/> | 2009 |
|            | <input type="radio"/> | 2010 |
|            | <input type="radio"/> | 2011 |
|            | <input type="radio"/> | 2012 |
|            | <input type="radio"/> | 2013 |
|            | <input type="radio"/> | 2014 |
|            | <input type="radio"/> | 2015 |

- End Year
- 2016
  - 2000 or earlier
  - 2001
  - 2002
  - 2003
  - 2004
  - 2005
  - 2006
  - 2007
  - 2008
  - 2009
  - 2010
  - 2011
  - 2012
  - 2013
  - 2014
  - 2015
  - 2016
  - To Present

If monitoring is not continuous, please list the years your organization has been active in monitoring (e.g. 2000-2005, 2010, 2014)

## Data Collection and Management

**6. Is traditional ecological knowledge part of your monitoring program?**

- Yes
- No

**If yes, how is it included?**

**7. Which parameters do you monitor?**

- Water Temperature
- pH
- Conductivity
- Dissolved Oxygen
- Clarity (Secchi)
- Turbidity
- TSS
- Hardness
- Total Sulphide
- Sulphate
- Total Nitrogen
- Total Organic Nitrogen
- Ammonia
- Total Phosphorus
- Total Dissolved Phosphorus
- Orthophosphorus
- Fecal Coliform
- E. coli
- Enterococcus
- Chlorophyll a
- Flow
- Benthic invertebrates
- Animal or plant health
- Other, please specify... \_\_\_\_\_

**8. Does your community or organization follow any water quality monitoring protocol(s)?**

- No

- I don't know
- Yes, please specify... \_\_\_\_\_

**9. How were your monitoring parameters chosen?**

- Monitoring protocol standards
- Provincial, territorial, or federal standards
- Community priorities
- Capacity of monitoring equipment and/or resources
- Other, please specify... \_\_\_\_\_

**10. Where is the data stored?**

Please select all applicable databases and provide the name of each one

- University database \_\_\_\_\_
- Government database \_\_\_\_\_
- NGO database \_\_\_\_\_
- Indigenous community database \_\_\_\_\_
- Other, please specify... \_\_\_\_\_

**11. Does your community or organization's data get analyzed?**

- Yes

- No

**If yes, who analyses the data?**

- Private consultant
- NGO
- University
- Government
- First Nations, Métis, or Inuit community
- Other, please specify... \_\_\_\_\_

**12. Is your community or organisation's data being used to inform government policy?**

- Yes
- No
- I don't know

**If yes, which level of government uses the data?**

- Municipal
- Regional
- Provincial

- Federal
- Indigenous community or government

**13. Who do you contact if your data indicates a public health concern and requires an emergency response?**

### **Governance and Partnerships**

We would like to understand how CBM programs are supported across Canada

**14. Is your program part of an overarching provincial, territorial, or national program?**

- Yes - if so, please list them \_\_\_\_\_
- No

**15. If known, please fill in the following:**

| Primary funding sources | Name of funding source                                   | Duration of funding  |
|-------------------------|--|--|
| 1.                      | <input style="width: 166px; height: 26px;" type="text"/> | <input type="radio"/> One year<br><input type="radio"/> Multi-year |
| 2.                      | <input style="width: 166px; height: 26px;" type="text"/> | <input type="radio"/> One year<br><input type="radio"/> Multi-year |

3.

One year

Multi-year

**16. Other than funding partnerships, does your program collaborate with any levels of government? (municipal, regional, provincial, federal, Indigenous)**

Yes

No

**If yes, please list them here:**

**17. Does your program collaborate with other CBM groups or networks?**

Yes

No

**If yes, please list them here:**

**18. What were the reasons for deciding to implement a CBM program?**

Please answer in point form

**19. Have these reasons been, or are they being, addressed?**

Please answer in point form

**20. Please include any additional comments you may have:**