**Trends and key elements in community-based monitoring: a
systematic review of the literature with an emphasis on
Arctic and Subarctic regions**

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Paper title: Trends and key elements in community-based monitoring: a systematic review of the literature with an emphasis on Arctic and Subarctic regions

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Abstract: Community-based monitoring (CBM) is receiving much attention from the research community, particularly in Arctic and Subarctic regions of Canada and other circumpolar regions. Currently, there is a lack of understanding of the trends and patterns in its use within the literature and a documented need to improve environmental CBM efforts in the Arctic and Subarctic regions. A systematic literature review was conducted of CBM publications in the peer-reviewed and grey literature in order to provide a synthesis of trends on the topic and clarify key elements that are needed to operate an environmental CBM program in Arctic and Subarctic regions. Both sets of literature show a significant growth in the publication of CBM studies over time with a high proportion of research taking place in North America and in the field of environmental sciences. More CBM studies are reported in connection to First Nations and Inuit groups as compared to other Indigenous groups. Thirteen key elements of environmental CBM programs commonly reported in the literature focused on Arctic and Subarctic regions were identified in the analysis. Specifically, traditional and local ecological knowledge (TLEK) was a unique component highlighted in Arctic and Subarctic sources and a specific feature observed in studies focusing on Indigenous groups. The identification of such key CBM elements serves as a resource to guide current and future environmental CBM initiatives in northern regions and elsewhere. Future research on this topic should contrast and compare literature findings with existing environmental CBM programs and provide more case studies to show the process and utility of environmental CBM initiatives in the Arctic and Subarctic, particularly with use of TLEK and the ways to facilitate it within a CBM program.

Key words: Community-based monitoring, Arctic, Subarctic, systematic literature review, Indigenous peoples.

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Trends and key elements in community-based monitoring: a systematic review of the literature with an emphasis on Arctic and Subarctic regions

Introduction

Community-based monitoring (CBM) practices are increasing globally, including in Canada (Pollack and Whitelaw 2005). The term and concept has gained prominence in various disciplines such as environmental sciences, public health, and international development (McKenzie et al. 2000; Barreto et al. 2006; Shukla 2013). In the environmental science literature, CBM is commonly defined as “a process where concerned citizens, government agencies, industry, academia, community groups, and local institutions collaborate to monitor, track and respond to issues of common community concern” (EMAN 2003: 4). In contrast to conventional scientific monitoring, CBM often entails “monitoring of natural resources undertaken by local stakeholders...in relation to aims and objectives that make sense to them” (Danielsen et al. 2014: 15).

CBM practices can take on many different forms that involve participants at various levels and at different stages of an initiative (Danielsen et al. 2005). This can range from community-directed monitoring initiatives that originate from residents' interests and needs to initiatives that simply involve community residents in some aspect of the data collection as field assistants/informants with little input (Dangles et al., 2010; Stokes et al., 1990).

Similarly, the potential benefits associated with CBM of local natural environments also vary. In the literature, CBM activities are promoted as a way to

empower communities and encourage decision-making to lead to better resource management (Danielsen et al. 2009); to reduce the cost of research while increasing flexibility to carry out research by community members during off-fieldwork seasons (Stokes et al. 1990; Dyck 2007); to create social capital by engaging citizens to work together on shared objectives and increase awareness of community issues (Bliss et al. 2011); to build trust and credibility among citizens, government representatives, organizations and other stakeholders (Fernandez-Gimenez et al. 2008); and to aid in skills development among local monitors and create employment opportunities for them to be employed by other monitoring programs in the future (Carvalho et al. 2009).

In Arctic and Subarctic regions of Canada and other circumpolar countries, environmental CBM activities have been strongly promoted in recent years. Emerging monitoring networks and initiatives such as the Sustainable Arctic Observing Network (SAON), Exchange for Local Observations and Knowledge of the Arctic (ELOKA), circumpolar monitoring program of the Conservation of Arctic Flora and Fauna (CAFF) working group of the Arctic Council, and the extensive literature on traditional ecological knowledge, show recognition of the value and benefit of involving communities in environmental monitoring and observation activities. Arctic residents hold a wealth of knowledge about their lands, water, and territories based on their direct interaction with the physical environment and knowledge passed down through generations (Huntington 2008). Their knowledge can contribute significant insight that may not be offered by scientific studies and hence, help build a more complete understanding of the natural environment (Kofinas et al. 2002; Mahoney et al. 2009; Johnson et al. 2013).

Despite the growing attention and the reported benefits of community-based approaches to environmental monitoring, or ‘environmental CBM’ as we refer to it here,

it is not known if this increased attention is reflected in the literature. Although some studies have reviewed existing CBM activities or provided an overview of monitoring approaches, little attention has been paid to the global trends in the number, location, discipline and representation of particular cultural groups in the peer-reviewed and grey literature on this topic (Johnson et al. 2015; Conrad and Hilchey 2011; Danielsen et al. 2009; Newman et al. 2011). To date, little examination of the patterns in the literature on this specific topic has been done through a systematic review. In addition to this, there is a documented need to improve CBM efforts in the Arctic and Subarctic regions (Gearheard 2010; Johnson et al. 2013). This need could be met, in part, by clarifying the types of CBM approaches that are used, those that are most common, including the critical components of each approach.

Thus, the study aimed to answer two questions: 1) what are the trends in the peer-reviewed and grey literature on the topic of CBM, and 2) what are the key elements of environmental CBM approaches used in the Arctic and Sub-Arctic regions as represented in the literature.

Methodological Approach

A systematic review of both the peer-reviewed and grey literature on the topic of CBM was conducted, following the methods of Jesson et al. (2011), Okoli and Schabram (2010) and Furgal et al. (2010).

The peer-reviewed literature was searched using the following online publication databases: Scholars Portal, ProQuest, EBSCOhost, GALE, Medline, and Web Science. These databases cover a variety of academic disciplines giving the opportunity to capture literature on the topic from these different perspectives. For example, Scholars Portal,

ProQuest, EBSCOhost, GALE, and Web of Science provide access to multidisciplinary research, whereas Medline contains journal citations and abstracts on biomedical and public health literature around the world. In order to be inclusive and ensure capture of literature related to the Arctic and Aboriginal communities, databases such as, Arctic Science and Technology Information System were searched. This database provides publications and research publications specifically about northern Canada and other areas of the circumpolar North. Agency and government department databases such as United Nations and Environment Canada were searched and helped inform how governments and international organizations approach and report on the concept of CBM. Additional grey literature sources (non-peer-reviewed journal articles, reports, conference proceedings and theses) were also identified in the online databases used for the peer-reviewed literature (i.e. ProQuest). Once collected, sources were identified as peer-reviewed or grey literature by verifying with the Academic Search Complete database (which identifies peer review status of articles and journals) and reviewing other periodical websites and database information.

Based on preliminary literature findings and trial runs of key words, combinations and permutations of seven terms were used in the search (where an asterisk denoted variations of the word): “community based monitor*”, “local* based monitor*”, “citizen based monitor*”, “citizen monitor*”, “collaborative monitor*”, “volunteer monitor*”, and “particip* monitor*”. Combinations of synonyms of CBM were also tested (e.g. “citizen driven monitor*”, “locally driven data collecting”) however no further relevant literature was found.

Searches for these terms in the title, abstract, and keywords of sources in all databases (if applicable) were performed. In the case where the search returned a large

number of matching sources or 'hits' (> 200), the first 200 sources were reviewed individually for relevance and inclusion in the study. As the databases returned results based on relevancy criteria in association with the keywords entered, after inclusion of the first 200 sources, every 50th source was reviewed for relevance. If deemed relevant, the 51st, 52nd, etc. source was reviewed until a source not relevant to the goals of the search was found at which time another 50 sources was skipped to check for relevancy again (as in Furgal et al. 2010). This process was repeated to check all identified matched sources until the 600th source (or the end of the returned list of matched sources). This process was used in the search for both peer-reviewed and grey literature to be inclusive to considering all sources identified in databases using the keyword combinations presented here. Duplicate sources were then eliminated and remaining sources were manually reviewed to ensure that CBM and associated terms were the main topic of the publication. Some grey literature references did not include an abstract, therefore a review of the full text was used to assess relevancy.

Once collected, sources were identified as peer-reviewed or grey literature. In this study, peer-reviewed literature refers to academic articles published in a peer-reviewed journal. These articles are externally reviewed and evaluated by researchers in the field before acceptance for publication. In this study grey literature included government reports, conference proceedings, conference abstracts, book chapters, theses, and magazine articles that did not undergo a formal academic peer-review process before publication.

Full text PDFs were then downloaded when available. Open internet searches and the Trent University Library RACER system (Rapid Access to Collections by Electronic Requesting) were used to access PDFs not accessible to

the authors through online databases. All sources were then stored in Endnote X5 for sorting and coding.

Descriptive Analysis

Using the title and abstract, each reference in the peer-reviewed and grey literature was individually reviewed and the year of publication, geographical region of focus, discipline of publication, and cultural group of focus in the reported study were identified (Zikmund and Babin 2007). Full text of grey literature sources were assessed when no abstract was present and when the abstract did not identify the above listed characteristics of the study.

Discipline categories were informed by the categorization of journals provided by the online databases used in this review. For example, the Malaria Journal was categorized under the discipline of health and medicine by GALE, this subject heading was used in the review. For non-journal sources, the content of the source was assessed and then applied to an appropriate discipline category as defined in the databases above. Geographical regions were classified into continents (Africa, Asia, Australia, Europe, North America, and South America). Within this classification, Arctic and Subarctic groupings were specifically identified. In this study, Arctic and Subarctic regions were identified as outlined by the Arctic Monitoring and Assessment Program (AMAP) Reports (e.g. AMAP 1998).

When categorizing the Indigenous groups focused on in a publication, the reference had to explicitly specify a cultural group (e.g. Inuit, Dene First Nation, etc.) or generally refer to the target population of the study as Indigenous,

Aboriginal, Native or another recognizable synonym for First Peoples. In this study, “Indigenous” peoples and often used synonyms refer to peoples having historical continuity with pre-colonial and/or pre-settler societies, strong links to territories and surrounding natural resources, distinct languages, cultures, and beliefs (UNPFII nd).

Once publications were categorized, a frequency count of the number and percent of total papers was tabulated to examine patterns over time and space in the described categories within the peer-reviewed and grey literature.

Thematic Analysis

A thematic content analysis of sources was used to identify key elements of CBM approaches in the literature. This type of analysis involved identifying, analyzing and reporting patterns (common themes) within the data (Braun and Clarke 2006). Inclusion criteria were established to only use relevant sources from the literature database generated for this aspect of the review. Sources deemed relevant were those in which the focus of monitoring activity was on the environment in natural, urban, and rural areas. Also retained were those in which a CBM framework and/or elements of a CBM framework were identified.

A two-stage coding process was then applied to peer-reviewed and grey sources (Saldana, 2009). First, descriptive coding was done to identify common general approaches and key elements of CBM initiatives. This was followed by pattern coding to group codes into sets of themes (Saldana 2009).

A classification scheme of general CBM approaches was adapted from Danielsen et al. (2009) to provide the conceptual structure for categorizing monitoring approaches

presented in the literature. Each source was carefully examined for strong evidence to suggest it could be classified into one of the four general CBM approach categories (Table 2). For example, in the study presented by Townsend et al., 2005, the authors clearly described the extensive involvement of local Indigenous community members in a turtle monitoring program in Ecuador which included: initiating partnerships in developing monitoring methods, participating in data collection and analysis, and presenting final results to the community. From this description it was determined that the source met the characteristics of approach 2 (collaborative monitoring with local data analysis and interpretation; Table 2). In one particular case, a source self-identified their monitoring program with Danielsen's classification scheme and this statement was used to classify that paper (De Angelo et al. 2011). When sources did not provide a clear description of the CBM approach used or lacked evidence to suggest it belonged to one of the CBM categories, it was excluded from this stage of the analysis.

Key elements of CBM programs were then reviewed in the sources and descriptive codes were developed to identify common categories or groups of key elements or components associated with CBM programs (Saldana 2009). In this study, an 'element' refers to a component of the structure or process of CBM or specific procedures/tools used in CBM activities. 'Key elements' were identified by identifying those elements found in at least three or more different sources or reports from CBM programs or activities and identified as being important to a CBM program in the literature source. The strength of the statement identifying the value of the element was assessed by the author's use of language in the text. Words such as "essential", "must have", "need" "fundamental", "required," were taken to identify a key component of a

CBM being described. The same process described here was then used to code grey literature sources meeting the inclusion criteria for this stage of analysis.

Findings

Literature Trends of CBM Publications

During the initial capture phase, 3573 citations were identified. After removal of duplicates and non-relevant references a total of 244 peer-reviewed articles and 177 grey literature sources were retained for descriptive analysis (Table 1). The list of all references retained for this study is available in the supplementary information provided with this manuscript¹. The peer-reviewed and grey literature identified and retained for this study spanned the years 1981 to 2014.

Year of Publication

An increase in the use of the CBM term and associated keywords is seen since the first identified paper in this analysis was recorded in 1981 (Fig. 1). The peer-reviewed literature shows more continuous growth, beginning in 1988 and reaching its peak in 2012 with 28 publications. In the grey literature, this growth reached its peak in 2006 and then declined steadily after this time.

Geographic Distribution

¹ Supplementary data for this article are available on the journal website (<http://er.nrc.ca>)
<https://mc06.manuscriptcentral.com/er-pubs>

Figure 2 presents the proportion of references and their geographical region of focus. In the peer-reviewed literature, 34.4% of references focused on North America, making it the highest proportion of all articles retained in the analysis compared to other continents. Similarly, the grey literature shows a pattern in which 69.4% of publications were classified as focusing on North America. Furthermore, North America represents the largest proportion of publications focusing on Arctic and Subarctic regions with 8.1% in the peer-reviewed literature and 18% in the grey literature (Fig. 2).

Discipline

A very strong representation of CBM publications was observed in the field of Environment Sciences/Studies in both the peer-reviewed (82.7%) and grey literature (83%). Other disciplines (i.e. International Development, Planning and Evaluation, Health and Medicine, Economics and Business, Education, and Political Science) reported in both sets of literature have significantly smaller proportional representations as compared to the field of Environmental Sciences/Studies. The proportions of these disciplines are below 14% in peer-review and grey literature.

Indigenous Groups

In general, the proportion of publications identifying themselves as Indigenous populations represented 16.3% of the peer-reviewed literature and 20.9% of the grey literature retained in this study (Fig. 3). Within the peer-reviewed literature focusing on an Indigenous group, a varied distribution of group representation exists with multiple

Indigenous groups (3.2%), South American Indigenous groups (2.8%) and Canadian Indigenous groups, specifically First Nation and Métis peoples (2.8%) and Inuit (3.6%). By comparison, the grey literature displays a higher representation of literature focused on Inuit groups (12.9%), followed by First Nations and Métis people (3.3%) and multiple Indigenous groups (2.8%) (Fig. 4).

Key Elements of CBM Approaches

A total of 84 sources (61 peer-reviewed and 23 grey literature sources) were retained for thematic analysis from the literature database. Four general approaches of CBM were identified in this study (adapted from Danielsen et al. 2009) and include: 1) autonomous local monitoring, 2) collaborative monitoring with local analysis and interpretation, 3) collaborative monitoring with external data analysis and interpretation, and 4) externally driven monitoring with data collectors (Table 2). For each CBM approach, key elements were identified, and those representing sources that focused on Arctic and Subarctic regions were also reported (Table 3). Table 4 explains each element, and their reported importance, as described in the literature.

Approach 1: Autonomous Local Monitoring

No formal autonomous local monitoring schemes were reported in the gathered literature (0%) (Table 2). Since no representation was found in the literature reviewed for this study, it was not possible to identify key components of this approach.

Approach 2: Collaborative Monitoring with Local Analysis and Interpretation

The proportion of publications classified as collaborative monitoring with local analysis and interpretation represented 20.2% of the literature (Table 2). Collaborative monitoring with local analysis and interpretation encourages project co-construction, transfer of ownership and knowledge sharing with community members. As such, a common objective of such monitoring schemes is to enhance local ownership and local capacities to collect, understand, and deliver monitoring data. This is evident in cases described by Metzger and Lendvay (2006), and Tremblay et al. (2008). For example, the Nunavik Integrated Community-based Monitoring (ICBM) program follows an “investigation in the North, for the North and by the North” approach in which local community researchers are trained in data collection and analysis so that they can progressively take charge of the project in their own communities, however external support was needed to assist with proposal writing, fundraising, training, and analysis of locally collected data (Tremblay et al. 2008).

Key elements of this CBM approach are identified in Table 2. Feedback and communication, partnerships, qualitative methods, standardized and simple methods, as well as training were dominant themes under this approach as reported in the literature. Unique components highlighted in one Arctic source were traditional and local ecological knowledge, and local champion/coordinator (Tremblay et al. 2008).

Approach 3: Collaborative Monitoring with External Analysis and Interpretation

Collaborative monitoring with external analysis and interpretation represents the second greatest number of sources represented in the literature in this study (33.3%)

(Table 2). A good example of this approach is described by Larter (2009). Following a regional workshop with Dehcho First Nations in Northwest Territories, the need was identified for a CBM program to determine baseline information on moose populations in the region. In discussions with local community members, project scientists and technicians, decisions were reached on the location of monitoring surveys, method techniques, and the amount of compensation provided to local monitors (Larter 2009). Dehcho harvesters were recruited to provide biological samples. These samples were then shipped for analysis to Environment Canada Laboratory in Ontario, Canada. Although local communities had input into the decision-making process and were responsible for collecting data, the overall design and final analysis remained in the power of external experts.

Key components of this approach are identified in Table 2. Agenda setting and preparation, feedback and communication, partnerships, qualitative methods, standardized and simple methods, and training were dominant themes under this approach as reported in the literature.

Approach 4: Externally Driven Monitoring with Data Collectors

Compared to the other CBM approaches discussed in this study, a high representation of externally driving monitoring schemes was identified in the literature (48.8%) (Table 2). This approach often involves hundreds or even thousands of volunteers collecting data on a large scale (Jiquet et al. 2012; Baker 1999; Bonney et al. 2009; Ely 1997). This is evident in the case of the Birdhouse Network, in which approximately 5,000 participants have monitored 75,000 bird nests in 49 states in

America and seven Canadian provinces over the duration of ten years (Bonney et al. 2009). Furthermore, these types of projects are typically initiated and coordinated by government agencies and researchers, in order to fulfill their own monitoring objectives (Bonney et al. 2009; Brereton et al. 2011). However, there are some initiatives that are driven by pre-existing community interest (Barrington 2005).

Key elements of this approach are identified in Table 2. Similar to the other approaches, training was a dominant CBM component reported in the literature, followed by simple and standardized methods, partnerships, and feedback and communication.

Key Elements of CBM Approaches Reported in Sources: Emphasis on Arctic and Subarctic Regions

Key elements that pertain to Arctic and Subarctic regions were identified under two approaches: collaborative monitoring with local data analysis and interpretation, as well as collaborative monitoring with external data analysis and interpretation (Table 3). Two sources were identified under collaborative monitoring with local data analysis and interpretation (2.3%), while eight sources were reported as collaborative monitoring with external data analysis and interpretation (9.5%). Many of these case studies focused on monitoring wildlife populations and wildlife health (Veitch et al. 2004; Veitch and Kutz, 2006; Larter 2009; Brook et al. 2009; Snortland 2012). While other studies concentrated on sea ice monitoring activities (Tremblay et al. 2008), land use monitoring in the context of climate change (Ford et al. 2013) and observations of various ecological changes associated with weather, sea ice, plants and wildlife (Gordon et al. 2007; Lévesque et al. 2012). Although one Arctic source was categorized under the externally driven

monitoring with data collectors approach, it did not identify key elements of its CBM activity. Similarly, no Arctic sources were identified under the autonomous local monitoring approach, thus, no components were identified for this schemes.

The key elements concerning Arctic and Subarctic regions that were reported in both approaches are: 1) adequate funding, 2) the conduct of explicit agenda setting and preparation activities, 3) local initiatives to build capacity (capacity building), 4) provision of compensation/incentives, 5) evaluation of progress and significance of monitoring activities, 6) provision of ongoing feedback and communication, 7) use of information and communication technologies (ICT), 8) presence of/identification of a local champion/coordinator, 9) establishment of strategic partnerships, 10) inclusion of qualitative methods, 11) use of standardized and simple methods, 12) incorporation of traditional and local ecological knowledge (TLEK) into monitoring activities, and 13) provision of training opportunities for monitors (Table 3). When comparing other sources in the literature gathered, TLEK was a unique component highlighted in Arctic and Subarctic sources and a specific feature observed in studies focusing on Indigenous groups. TLEK refers to the intimate knowledge of Indigenous peoples about the natural resources and ecological systems in their local environment (Johnson et al. 2013). Often, this knowledge is handed down from generation to generation and embedded within a cultural belief system (Johnson et al. 2013). Sources pertaining to Arctic and Subarctic regions described TLEK as a way to understand local environmental changes based on community observations and a source of new information that complemented scientific studies (Brook et al. 2009; Tremblay et al. 2008).

Interpretation and Significance of Findings

A significant amount of research has been conducted around the world on CBM. Some important trends are evident in an analysis of the literature. Over the past 30 years, literature on CBM has been increasing in both peer-reviewed and grey sources. There appears to be a continued increase in the publication of peer-reviewed sources over time but a slight decrease in grey literature (conference proceedings, government publications etc.) since 2006 (Fig. 1). The overall trend of increasing literature on this topic is likely influenced by the growing interest in public 'participation' in monitoring practices that have been documented in various parts of the world, including Canada (Savan, et al. 2003; Whitelaw, et al. 2003; Conrad and Hilchey 2011; Conrad and Daoust 2008; Pollack and Whitelaw 2005), the United States (Bruhn and Soranno 2005; Loperfido et al. 2010; Fernandez-Gimenez et al. 2008), the United Kingdom (Mackechnie et al. 2011), Madagascar (Andrianandrasana et al. 2005), Philippines (Uychiaoco et al. 2005), China (Vernooy et al. 2006) and Africa (Bennun et al. 2005). Many practitioners and researchers are recognizing the limitations and challenges of conventional monitoring programs and are seeking alternative approaches that increase spatial and temporal coverage of monitoring activities and often reduce costs (Vernooy et al. 2006; Bell et al. 2008; Danielsen et al. 2005; De Angelo et al. 2011; Mutimukuru et al. 2006). This trend possibly reflects a shift away from 'professional' monitoring towards an increased reliance on non-experts (i.e. volunteers, local community members) to carry out monitoring activities. Widespread recognition and promotion of citizen science has brought a level of acceptance for non-professionals to collect scientific data, in which CBM is viewed as a form of citizen science in its own right. Overall, the increasing

number of publications suggests an increase in interest in the subject and a potential increase in its importance and value in the environmental research community.

Publications on CBM and associated terms were reported in all continents, except for Antarctica. A large concentration was found in North America. This is likely influenced by two factors. First, both the United States and Canadian governments have provided a significant amount of support for CBM activities as is reflected in the large number of government-funded or managed CBM reports gathered and reviewed in this study (Boylen et al. 2004; Canfield 2002; Loperfido 2010; Simpson 1991; Brandon et al. 2003; Doyle and Lynch 2005; Pollack and Whitelaw 2005; Environment Canada 2010; EPA 1996; Latimore and Steen 2014). In addition, non-governmental organizations and university institutions are also increasingly interested in CBM practices and have made efforts to collect data as documented in the literature review (Bonney et al. 2009; Gouveia et al. 2004; Milne et al. 2006). Secondly, the high proportion could be explained by the fact that the search was only conducted in English and this is where a predominant number of English language research publications are produced in all disciplines annually. The geographic trends in the literature suggest the topic of CBM is being researched and is of interest worldwide, particularly within North America.

CBM appears to be studied and communicated about more in the field of Environmental Sciences than other disciplines. Monitoring data has often provided information to guide decision-making for the management of natural resources and is often the source of data used in environmental assessments and risk assessments (Kreman et al. 1994; Bunn et al. 2010; Lovett et al. 2007; Covello and Merkhofer, 1993). Since monitoring is a dominant activity within environmental management practices, it is not surprising that CBM research is most commonly conducted in regards to the environment

and therefore reported on in the environmental science periodicals. CBM approaches are relevant to other areas of research though as is represented by the small but important representation of CBM papers in other disciplines such as economics and health.

There appears to be a similar number of non-Indigenous and Indigenous focused literature in the database assembled for this study (Fig. 3). The inclusion of conference abstracts has helped increase the proportion of grey literature, making up almost half of the literature focusing on Indigenous groups. Without this inclusion the proportion of Indigenous groups in the grey literature would be significantly lower. Furthermore, there are more publications on First Nations and Inuit focused CBM work than other Indigenous groups (Fig. 4). This trend is most likely influenced by various factors including the considerable attention given and emphasis placed on the gathering of local observations and inclusion of TLEK in Canada, the interest in and emphasis placed on local environmental monitoring for impacts of climate change among communities living in close relationship with the land, as well as the growing recognition and value of engaging Indigenous communities in environmental management, monitoring, and research practices in the Arctic, Subarctic and elsewhere (Usher 2000; Huntington 2008; ITK and NRI 2007; Gofman 2010). For example, collaborations between local Indigenous residents and scientists on monitoring were strongly encouraged and supported by the most recent International Polar Year (IPY) program, an international government-funded initiative focusing research on polar regions of the world (Gearheard et al. 2011; Holm et al. 2006; Di Cenzo et al. 2008; Bortoluzzi and Ferguson 2009; Lévesque et al. 2012). The trend is reflective of either a focused effort on financing and supporting CBM activities in First Nation and Inuit communities or the disproportionate representation of those groups as compared to others. It is likely a combination of these

factors in conjunction with particular emphasis on CBM in particular regions of interest (i.e. the Arctic). This is reflected in the high proportion of Inuit focused literature in the database. The study drew on many online databases, however, one in particular, the Arctic Science and Technology Information System (ASTIS) has worked hard to include publications in its database that focus on research done on and with Indigenous group residing in the Arctic. Overall, engaging with First Nation and Inuit communities in monitoring activities helps respond to the needs and concerns of Indigenous communities as many of these programs are focused on topics in direct response to local needs and concerns (Brook et al. 2009; Larter 2009; Tremblay et al. 2008 and Gearheard et al. 2011). This emphasis on supporting CBM activities in Indigenous communities may represent a growth in recognition of Indigenous rights as well as the disproportionate needs experienced by these communities in terms of receiving support for issues of importance.

When specifically looking at CBM approaches pertaining to Arctic and Subarctic regions, studies were found that were classified as either collaborative monitoring with local data analysis and interpretation, or collaborative monitoring with external data analysis and interpretation. As previously mentioned, this is most likely influenced by the growing interest in and emphasis on directing research financing towards initiatives that recognize and respect local Indigenous concerns, priorities and knowledge on Indigenous lands (Gearheard et al. 2011; Holm et al. 2006; Di Cenzo et al. 2008; Bortoluzzi and Ferguson 2009). Similarly, the same can be said for the engagement of Indigenous community members in research and monitoring practices. These trends are also in accordance with the progress made in research ethics in Northern America respecting Indigenous rights (ITK and NRI 2007).

Many key CBM elements identified in the literature are common between all three approaches, and are also found in non-Arctic and Arctic regions (e.g. adequate funding, agenda setting and preparation, capacity building, evaluation, feedback and communication, partnerships, compensation, qualitative methods, and simple and standardized methods etc.). However, TLEK was a specific component highlighted within these sources located in the Arctic and Subarctic and a unique feature observed in studies focusing on Indigenous groups. Specifically, Inuit communities are increasingly demanding that respect and recognition be given to their local knowledge in the context of research and environmental action (Usher 2000; ITK and NRI 2007). This is evident in a case found in the literature where community residents themselves initiated and supported the inclusion of TLEK in local monitoring practices with the support of external partnerships (Gordon et al. 2007). TLEK and observations are reported to contribute to the overall understanding of ecological changes occurring in local environments, as well as serving to complement research and monitoring using measures derived from natural science research (Brook et al. 2009; Tremblay et al. 2008, Gordon et al. 2007).

Although no formal autonomous local monitoring schemes were reported in the gathered literature, this is not to say that this approach does not exist. In fact, many Indigenous cultures, independent monitoring is carried out informally. For example, Inuit in northern Canada have historically recorded and observed the distributions, movement, and abundance of wildlife for human survival and subsistence (Ferguson et al., 1998). This finding suggests that these types of initiatives are the least likely to be connected with academic research. Unlike researchers, community organizations or community members participating in environmental CBM practices may not have a strong interest in

or priority to publish in the academic literature. As such, monitoring results or observations often stay within the community in support of local or regional decision-making only in these cases.

Furthermore, the full range of environmental CBM initiatives taking place in the Arctic and Subarctic regions is not well documented in the literature, as reported by Johnson et al. (2015). In total, only eleven sources giving a detailed description of the CBM approach used were identified in this study (Table 2). Knowing that more CBM activities exist, it is important for these to be documented and reported to share the lessons learned in those cases. More cases are needed to show the process and utility of CBM initiatives in Indigenous and northern communities. Furthermore, very little is understood about the processes behind autonomous local monitoring as it is poorly represented in the literature. Drawing attention to this gap is important in order to better understand the full spectrum of environmental CBM practices.

Overall, the identification of the list of key CBM elements can be used as a framework for academics and practitioners to develop new programs, evaluate existing ones, or enhance current and environmental CBM initiatives. It serves as a resource to identify and understand key components of what is needed to run a CBM initiative based on experiences from elsewhere around the world and as reported in the literature. Future research is needed to ground truth and further enhance or adapt this framework of key CBM elements for evaluative or development purposes. Such studies would help in identifying potential limitations in the framework and aid in gaining a better understanding of the application of environmental CBM programs in the Arctic and Subarctic regions. In addition, future studies should also bring more clarity to the use of TLEK and the ways to facilitate it within environmental CBM activities.

While this paper provides interesting insight into the patterns and trends in the publications on CBM activities around the world, this study was not without limitation. A recognized limitation of this study is publication bias. The systematic literature review only captures observations presented in the peer-reviewed and grey literature; a constraint also echoed by Danielsen (2010). By using academic online databases, the review represents CBM schemes that are typically well-funded and published in academic journals. To overcome this limitation, the inclusion of other sources where CBM information may be available (e.g. reputable websites of CBM initiatives) would be valuable to gather further information on the topic not captured by peer-reviewed and grey literature represented in this study. In addition, the review was confined to a specific number of English-language databases commonly used in the environmental science community but also accessible to the authors. This may have reduced the total number of sources produced on the topic to date, and excluded important literature from other countries in which English is not a dominant language when publishing articles, reports etc. Future research on this topic should consider publications presented in other languages.

Conclusion

This study set out to examine the trends on the topic of CBM in the peer-reviewed and grey literature from 1981 to 2014, and gather and identify key elements of CBM approaches emerging from the literature and identifies those reported on in the Arctic and Subarctic regions. The topic of CBM research is becoming well established in the peer-reviewed and grey literature. An increasing number of publications on CBM have been seen over the past three decades. CBM research has been conducted in various parts of

the world with a high proportion of research taking place in North America. In addition, high numbers of publications have been published in the environmental sciences. A small percentage of all CBM sources speak to the issue of CBM activities in, with or for Indigenous communities. Emphasis in CBM reporting in Indigenous communities exists on First Nations and Inuit groups compared to others.

Environmental CBM approaches reported on in Arctic and Subarctic regions were classified under two categories: collaborative monitoring with local data analysis and interpretation, and collaborative monitoring with external data analysis and interpretation. Based on the analysis of the literature, key elements within CBM programs taking place in a northern Indigenous context are: 1) adequate funding, 2) the conduct of explicit agenda setting and preparation activities, 3) local initiatives to build capacity (capacity building), 4) provision of compensation/incentives, 5) evaluation of progress and significance of monitoring activities, 6) provision of ongoing feedback and communication, 7) use of ICT, 8) presence of/identification of a local champion/coordinator, 9) establishment of strategic partnerships, 10) inclusion of qualitative methods, 11) use of standardized and simple methods, 12) incorporation of TLEK into monitoring activities, and 13) provision of training opportunities for monitors.

The identification of key CBM components serves as a resource to help guide and enhance current and future environmental CBM initiatives in the Arctic and Subarctic and elsewhere around the world. Future studies on this topic should contrast and compare literature findings with existing CBM programs on the ground, bring more clarity to the use of TLEK and the ways to facilitate it within CBM activities, as well as provide more case studies to show the process and utility of CBM initiatives.

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Tables

Table 1. Summary of references contributing to the systematic literature review.

Phases	Total # of Sources
Phase 1: Capture Phase of All Search Hits Online Databases Agency Websites	2661 912
Phase 2: Removal of Duplicates Online Databases Agency Websites	902 363
Phase 3: Relevance Assessment Online Databases Agency Websites	479 59
Phase 4: Gathering full PDFs (final database) (combining online database & agency websites) Peer-reviewed Literature Grey Literature	244 177

Table 2. Summary of CBM monitoring approaches (adapted from Danielsen et al. 2009).

Monitoring Approach	Characteristics	Data Collectors	Users of Data	Total # (%) of Arctic & Subarctic	
				Total # (%) of All Sources	Sources
1. Autonomous Local Monitoring	<ul style="list-style-type: none">• Community involved in whole process (from design to use of data)• No direct involvement of external agencies• May exist informally	Local Communities	Local Communities	0 (0%)	0 (0%)
2. Collaborative Monitoring with Local Data Analysis & Interpretation	<ul style="list-style-type: none">• Involves community in data collection, analysis and/or interpretation, as well as management decision making• TLEK is incorporated into monitoring design and activities• External support may assist in facilitation and training.	Local Communities, Experts	Local Communities, Experts	17 (20.2%)	2 (2.3%)

3. Collaborative Monitoring with External Data Analysis & Interpretation	<ul style="list-style-type: none"> • Involves community in data collection and/or some degree of management-orientated decision-making. • May incorporate TLEK into monitoring design and activities • Data analysis, and interpretation are undertaken by external expertise (i.e., scientists, researchers) • Community serves as volunteers and/or paid trainees 	Local Communities, Experts	Local Communities, Experts	28 (33.3%)	8 (9.5%)
4. Externally Driven Monitoring with Data Collectors	<ul style="list-style-type: none"> • Community residents or volunteers are involved only in data collection, or as research assistants • Community data collectors have no influence over design and implementation of program • No TLEK is incorporated into the monitoring scheme 	Local Communities, Volunteers, Experts	Experts	41 (48.8%)	1 (1.1%)

* One specific source is represented in each of the three CBM approaches, thus accounting for 2 extra sources.

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Table 3. Summary of key elements reported under each CBM approach (adapted from Danielsen et al. 2009).

Monitoring Approach	1. Autonomous Local Monitoring	Total # of Sources	2. Collaborative Monitoring with Local Data Analysis & Interpretation	Total # of Sources	3. Collaborative Monitoring with External Data Analysis & Interpretation	Total # of Sources	4. Externally Driven Monitoring with Data Collectors	Total # of Sources
CBM Element	n/a	0	Adequate Funding* Agenda Setting & Preparation* Capacity Building* Compensation/Incentives* Evaluation Feedback & Communication* ICT* Linking Data to Decision-Making Local Champion/Coordinator* Local Interest Partnerships* Qualitative Methods* Standardized & Simple Methods* TLEK* Training*	7 9 5 6 7 10 3 8 1 1 10 12 11 2 11	Adequate Funding* Agenda Setting & Preparation* Capacity Building* Compensation/Incentives* Coordination Evaluation* Feedback & Communication* ICT* Linking Data to Decision-Making Local Champion/Coordinator* Monitoring Team Partnerships* Qualitative Methods* Standardized & Simple Methods* Time TLEK* Training*	13 15 12 11 10 8 18 9 6 8 6 19 19 19 1 8 20	Adequate Funding Compensation/Incentives Coordination Feedback & Communication ICT Linking Data to Decision-Making Monitoring Team Partnerships Standardized & Simple Methods Training	6 5 8 10 11 5 8 12 21 25

*Key CBM elements reported in sources focused on Arctic and Subarctic regions.

Table 4. Description and importance of key CBM elements.

Key CBM Elements	Description	Importance
Adequate Funding	Financial resources that provide the means to perform and support CBM activities.	<ul style="list-style-type: none">• financially supports training, sampling design, equipment, staff etc. (Uychiaoco et al. 2005; Bennun et al. 2005; Brashares and Sam 2005).
Agenda Setting & Preparation	Preparation activities that occur prior to the implementation of the monitoring program. Typically, it is a visioning and negotiation phase to determine objectives, methodology, participants, communication strategies, cost analysis, etc.	<ul style="list-style-type: none">• ensures monitoring activities are driven by community interests and end-results are of value to them (Dangles et al. 2010).
Capacity Building	Training and outreach activities that aim to strengthen and develop knowledge and skills of an individual or community.	<ul style="list-style-type: none">• communities will be able to conduct monitoring independently from external experts, thereby enhancing project ownership (Tremblay et al. 2008).• fosters interest in monitoring and future careers in science (Brook et al. 2009; Veitch and Kutz, 2006).

		<ul style="list-style-type: none"> • promotes social cohesion, and motivates local monitors (Ortega-Álvarez et al. 2012)
Compensation/ Incentives	<p>A form of honorarium (either monetary or non-monetary value) that is used to award local participants in recognition of their monitoring efforts and time spent collecting data.</p>	<ul style="list-style-type: none"> • helps maintain higher levels of commitment and motivation from participants (Townsend et al. 2005). • provides independent income for participants while gaining experience to be employed by other monitoring programs (Carvalho et al. 2009; Obura 2001).
Coordination	<p>The act of organizing and managing community monitors, data, and analysis in order to fulfill desired goals of the program.</p>	<ul style="list-style-type: none"> • ensures data management and analysis are properly done (Humber et al. 2010). • helps maintain communication and collaborations with communities (McKenzie 2000).
Evaluation	<p>An act of determining the worth and significance behind the CBM program as a whole and/or the contribution of training activities.</p>	<ul style="list-style-type: none"> • ensures goals are being met (Lee 2007). • reveals directions for improved management action (Moyer 2007).

Feedback & Communication	Local participants and experts sharing responses/opinions of a CBM program, as well as the delivering of data results to those involved within monitoring practices, decision-makers and the general public.	<ul style="list-style-type: none">• enhances project transparency, thereby fostering community trust and support of the program (Topp-Jorgensen et al. 2005).• helps maintain momentum, motivation and enthusiasm for project (McKenzie 2000; De Angelo et al. 2011).• ensures that management decisions are based on information and opinions from local communities (Tremblay et al. 2008).• allows for collective understanding and analysis of monitoring data between community monitors, researchers, and district staff (Hamerlynck et al. 2011)• provides opportunities for data validation with local monitors (Ortega-Álvarez et al. 2012)
Information & Communication Technologies (ICT)	Technologies, such as the Internet, GPS, GIS that provide access to information through telecommunications.	<ul style="list-style-type: none">• provides an effective mechanism to enter data, access training tutorials, as well as view data, photographs, reports, published papers, meeting

		<p>notes and videos (Gouveia, et al. 2004; Lee 2007).</p> <ul style="list-style-type: none"> • allows for real time display of results, and project status (Lee 2007) • empowers communities to understand local resources (Penningroth et al. 2013). • promotes transparency of the project (Singh et al. 2014)
Linking Data to Decision Making	The ability of monitoring data to prompt decision-making and action in order to better inform and enhance environmental sustainability of a region.	<ul style="list-style-type: none"> • helps achieve action in support of conservation and environmental management (Uychiaoco, et al. 2005; De Angelo et al. 2011).
Local Champion / Coordinator	A local community member engaged in the monitoring program, serving as a liaison between community members and project scientists.	<ul style="list-style-type: none"> • keep participants informed and engaged in the process (Brook et al. 2009). • facilitates capacity building at a community scale by helping community members take as much responsibility for the project as possible (Tremblay et al. 2008).

Local Interest	The desire for communities to manage and monitor aspects of the local environment.	<ul style="list-style-type: none">• ensures long term engagement and motivation of local monitors (Singh et al. 2014)
Monitoring Team	A group of experts (scientists) and non-experts (local community participants, volunteers) responsible for data collection. In some cases monitoring teams are supervised by experts such as technicians.	<ul style="list-style-type: none">• able to cover monitor areas faster (Bristow et al. 1997). ensures data collection is accurate and consistent with proper supervision (Wagner 2004).
Partnerships	Collaborations and networks between individuals or groups that are characterized by mutual responsibility to achieve common goals within a CBM initiative.	<ul style="list-style-type: none">• offers funding for CBM programs, salaries for staff, training, coordination, sample design, transportation, accommodations, equipment and technical expertise (Andrianandrasana et al. 2005; Tremblay et al. 2008; Brook et al. 2009).• networks are able to provide national indicators, in order to collect similar data and directly compare it to national databases (Jiquet et al. 2012).

Qualitative Methods	<p>Research methods (e.g., workshops, meetings, focus groups, semi-structured interviews) that investigate human meaning and experience that help support the design and implementation of a CBM program.</p>	<ul style="list-style-type: none"> • provides opportunities to maximize project transparency, comprehension, and cooperation (Carvalho et al. 2009). • provides important directions for monitoring action that is relevant to and feasible for the community (Larter 2009; De Angelo et al. 2011). • able to gather empirical knowledge of local ecological changes (Gordon et al. 2007; Townsend et al. 2005; Tremblay et al. 2008).
Standardized & Simple Methods	<p>Approaches to data collection and analysis that are peer-reviewed and/or thoroughly tested, yet easily understood by local monitors/researchers. For example, easy-to-complete cards to record data (De Angelo et al. 2011).</p>	<ul style="list-style-type: none"> • reduces sampling errors to improve data reliability (Andrianandrasana et al. 2005; De Angelo et al. 2011; Humber et al. 2010). • allows for easy implementation without the need for an outside expert to oversee data management practices (Townsend et al. 2005). • Keeps local monitors engaged in the project (Singh et al. 2014) • allows for inexpensive apparatus to be used to reduce cost (Ferreira 2012).

Time	Continued progress of monitoring activities for a secured period of time.	<ul style="list-style-type: none">• monitoring requires secured time, in order to be fully implemented (Boissière et al. 2014).• able to access the long-term impact of a monitoring program (Boissière et al. 2014).
Traditional and Local Ecological Knowledge (TLEK)	Knowledge and experience of Indigenous peoples rooted in local/regional ecology. Often involves users of local resources and their knowledge of local species and dynamics in the natural environment. In some cases, this knowledge is handed down from generation to generation.	<ul style="list-style-type: none">• gain better understanding of ecological and biological changes occurring within a community (Tremblay et al. 2008; Larter 2009).• introduce new features to outside researchers that may have been overlooked or remain hidden (Obura 2001).
Training	Organized activity that aims to build an individual’s knowledge and skills.	<ul style="list-style-type: none">• ensures protocols are followed correctly and facilitates better quality and reliability of data, thereby decision makers have confidence in quality of data (Townsend et al. 2005; Doyle and Lynch 2005; Latimore and Steen 2014).

Figures

Fig. 1. Number of publications on CBM (1981-2014) *n.d. – no date.

Fig. 2. Proportion of publications sorted by geographical region with a focus on Arctic and Subarctic regions (1981-2014).

Fig. 3. Proportion of non-Indigenous and Indigenous groups in the peer-reviewed and grey literature (1981-2014).

Fig. 4. Proportion of Indigenous groups within the peer-reviewed and grey literature (1981-2014).