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COMMUNITY-BASED ENVIRONMENTAL MONITORING (CBEM) FOR MEANINGFUL INCORPORATION OF INDIGENOUS AND LOCAL KNOWLEDGE WITHIN THE CONTEXT OF THE CANADIAN NORTHERN CORRIDOR PROGRAM

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FOREWORD

THE CANADIAN NORTHERN CORRIDOR RESEARCH PROGRAM PAPER SERIES

This paper is part of a special series in *The School of Public Policy Publications*, investigating a concept that would connect the nation's southern infrastructure to a new series of corridors across middle and northern Canada. This paper is an output of the Canadian Northern Corridor Research Program.

The Canadian Northern Corridor Research Program at The School of Public Policy, University of Calgary, is the leading platform for information and analysis on the feasibility, desirability, and acceptability of a connected series of infrastructure corridors throughout Canada. Endorsed by the Senate of Canada, this work responds to the Council of the Federation's July 2019 call for informed discussion of pan-Canadian economic corridors as a key input to strengthening growth across Canada and "a strong, sustainable and environmentally responsible economy." This Research Program will benefit all Canadians, providing recommendations to advance the infrastructure planning and development process in Canada.

All publications can be found at https://www.canadiancorridor.ca/the-research-program/research-publications/.

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Evgeniia (Jen) Sidorova and Luis D. Virla

KEY MESSAGES

- The Canadian Northern Corridor (CNC) extends over various provinces in the Canadian North and near-North and would cross the areas mostly classified as treaty land (historical and modern) on which the rights, needs and priorities of Indigenous and local communities touched by the CNC must be respected and exercised.
- Indigenous and local knowledge (ILK) is a cornerstone for the co-production of sustainable strategies for planning and developing infrastructure across middle and northern Canada. Meaningful incorporation of ILK during planning, execution and monitoring of infrastructure development and operation within the CNC concept must be done to consider the rights, expectations and priorities of the Indigenous and local communities impacted by the development of this concept.
- Community-based environmental monitoring (CBEM) could serve as a powerful strategy to incorporate ILK within the CNC concept because CBEM provides an opportunity for communities to meaningfully engage in identifying existing and potential environmental impacts of infrastructure development. CBEM consists of the gathering and overseeing of environmental, cultural, linguistic and social impacts led and conducted by Indigenous and local community members with or without the involvement of external agencies such as researchers and government agencies. CBEM involving Indigenous Peoples supports commitments made under the *United Nations Declaration on the Rights of Indigenous Peoples Act.*
- Indigenous leadership, technology usage, equal partnership with Indigenous and local communities and availability of institutional guidelines were identified as elements required for the success of CBEM programs within the CNC concept. In addition, technical, organizational, financial and environmental issues were recognized as potential challenges to meeting the goals and objectives of CBEM within the CNC concept.

- The study identified the codes and subcodes that were incorporated into a framework for the assessment of successes and challenges in the implementation of CBEM programs in Canada. The CBEM implementation framework (CBEM-IF) was tested with real-life CBEM case studies conducted in provinces across middle and northern Canada relevant to the CNC: berry pollution monitoring (AB), water quality monitoring (AB, BC, NWT, NT, SK and YT) and caribou monitoring (QC and NL). The resulting analysis indicated that CBEM supports the development of climate change adaptation programs that incorporated ILK. CBEM offers enhanced community relationships between the government and the private sector. CBEM also brings an opportunity to strengthen action plans through the incorporation of non-quantitative elements of ILK such as holistic and spiritual components, otherwise neglected by conventional Western scientific approaches.
- Experiences of the evaluated case studies also emphasized expected challenges associated with lack of adequate administrative and legal structures at the provincial, territorial and federal levels, high reliance on volunteers, lack of standardized methods, focus on specific types of the landscape and general issues with ILK incorporation into science and policy issues due to the incommensurability of Western science and the ILK epistemologies. CBEM implementation strategies for the CNC should include mitigation strategies for these challenges to reduce implementation barriers and negative impacts from CBEM deployment.
- Indigenous-led CBEM projects could help to facilitate reconciliation between Canada and Indigenous Peoples as they provide genuine representations of environmental monitoring, which are deeply rooted in ILK and language, traditional values, legal traditions and practices of environmental management associated with the meaningful exercise of Section 35 rights. This study also identified the other factors that are crucial for the meaningful incorporation of ILK into CBEM programs such as the presence of sufficient short- and long-term funding opportunities for CBEM projects, partnership with bridging organizations, the recognition of ILK as intellectual property and building a legal space for CBEM programs in national and provincial/territorial legislations.
- Further research is required to design the specific CBEM programs that could be adjusted to specific locations and types of infrastructure projects related to the CNC concept.

EXECUTIVE SUMMARY

The Canadian Northern Corridor (CNC) concept is proposed to go over several provinces in the Canadian North and near-North and would cross the territories mainly categorized as treaty land (historical and modern), on which the rights, needs and concerns of Indigenous and local communities affected by the CNC must be respected and exercised. In Canada, the *Constitution Act* (1982) identifies three groups of Indigenous Peoples: First Nations, Inuit and Métis. In Canada, early colonizers established agreements with Indigenous Peoples that listed rights and obligations of all parties involved to maintain a peaceful co-existence. However, for a long time, the treaty rights of Indigenous Peoples have been violated, eroding the principles of the agreements. Section 35 of the *Constitution Act* (1982) and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) recognize and affirm the responsibility to respect and exercise treaty rights and Indigenous rights, and Canadian governments have committed to do so.

Indigenous and local knowledge (ILK) is a foundation for the co-evolution of sustainable approaches for planning and developing infrastructure across middle and northern Canada. In the process of implementation and monitoring of infrastructure development and operation within the CNC concept, the knowledge co-production process must be accomplished with consideration of the rights, expectations and priorities of the impacted Indigenous and local communities. The meaningful incorporation of ILK into the large-scale northern infrastructure development can enhance sustainability practices as knowledge co-production extends the conceptual understanding of nature and brings more opportunities for actions to advance sustainable development goals. Indigenous epistemologies develop from the interconnections between the human world, the spirit and inanimate entities. A relational world view is connected to the idea of a strong emphasis on people and entities coming together to help and support one another in their relationship. ILK systems are knowledge-action-belief complexes and entail different conceptualizations of human-nature connectedness where humans learn from plants and animals by observing what happens in nature, and they treat nature as their teacher.

So-called knowledge integration was unsuccessful in addressing the role of unequal power dynamics, continuing colonial trends and a long history of broken agreements in environmental negotiations. Ensuring only Indigenous participation and inclusion is not enough to address colonialism. Although Indigenous participation is often viewed as a success, Western scientists should investigate their own scientific views and methods. ILK should be treated as expertise, not culture. In many cases, studies on ILK lead to a lack of Indigenous control over the research process or results. Knowledge integration is only one of the steps towards meaningful knowledge co-production, as simply integrating ILK could lead to appropriation or tokenism. Thus, the incorporation of ILK into environmental policy and science needs to take steps beyond knowledge integration.

Community-based environmental monitoring (CBEM) could become a successful approach to incorporate ILK in a meaningful way within the CNC concept. CBEM provides an opportunity for communities to meaningfully participate in recognizing existing and potential impacts of infrastructure development. CBEM includes gathering and overseeing of environmental, cultural, linguistic and social impacts. In the most successful cases, CBEM is led and directed by Indigenous and local community members with or without external agencies such as researchers and government agencies. As part of its contribution to the CNC goal to support economic and social development, CBEM could enhance community engagement and improve the recognition and identification of potential and existing negative impacts of proposed infrastructure projects before, during and after implementation.

This paper reviews the basis of CBEM and its implementation as a tool to meaningfully incorporate ILK in the CNC by evaluating scientific and grey literature and providing the discussion of the benefits and limitations of CBEM. The study recognized the codes and subcodes that are then incorporated into a framework for evaluating successes and challenges in potential projects looking to implement CBEM. The CBEM-implementation framework (CBEM-IF) is applied to three case studies in Canada to illustrate potential challenges and opportunities for CBEM implementation, and recommendations are generated for the CNC.

This study used manual open coding, breaking down, examining, comparing, conceptualizing and categorizing information. The pattern recognition process, which is an element of open manual coding, was used to identify common themes that emerged in the academic literature. This study analyzed 27 articles that presented the case studies of the ILK incorporation into CBEM from various geographical locations across the world without any specific regional focus. The study categorized the data to identify the concepts that seemed to pertain to the same phenomena, and then each category was given a code name.

The CBEM-IF framework was tested with real-life case studies conducted in provinces across middle and northern Canada relevant to the CNC: berry pollution monitoring (AB), water quality monitoring (AB, BC, NWT, NT, SK and YT) and caribou monitoring (QC and NL). The study selected case studies based on the following criteria: a) the geographical location of CBEM studies in Canada's North and near-North relevant to the CNC concept; b) relevance to the CNC large-scale infrastructure development concept (multimodal — road, rail, pipeline, electrical transmission and communication) transportation right-of-way through Canada's North and near-North; and c) the intent to incorporate ILK into CBEM. The framework implementation consisted in identifying elements of success and challenges observed during the implementation of each case study and discussed as lessons learned. Each case study provided data about the practical experience of adopting and implementing CBEM in the Canadian North and near-North.

The evaluation of CBEM literature and case studies indicated that success in CBEM implementation within the CNC concept will require the consideration of key elements, such as Indigenous leadership, appropriate technology integration, an equal partnership of proponents with Indigenous and local communities and the availability and co-development of institutional and project guidelines that state clear rules and objectives for participants. In addition, technical, organizational, financial and environmental issues were recognized as potential challenges to meeting the goals and objectives of CBEM within the CNC concept.

The analysis of Canadian case studies using the CBEM-IF framework indicated that CBEM supports the development of climate change adaptation programs that incorporate ILK. CBEM also offers improved community relationships with the government and the private sector. In addition, CBEM brings an opportunity to enhance action plans by incorporating non-quantitative elements of ILK, such as holistic and spiritual components, often neglected by scientists. Case studies experiences also indicated the common challenges related to the lack of adequate administrative and legal structure at the provincial, territorial and federal levels, high reliance on volunteers, lack of standardized methods, focus on specific types of the landscape and general issues with ILK incorporation into science and policy issues due to the incommensurability of Western science and the ILK epistemologies. CBEM implementation in the CNC should include mitigation strategies for these challenges to reduce implementation obstacles and negative impacts from CBEM deployment.

Indigenous-led CBEM projects could contribute to reconciliation between Canada and Indigenous Peoples as they provide genuine representations of environmental monitoring, which are deeply embedded in ILK and language, traditional values, legal traditions and practices of environmental management associated with the meaningful exercise of Section 35 rights. This study also recognized the other elements that are essential for the meaningful knowledge co-production in CBEM programs, such as the presence of sufficient short- and long-term funding opportunities for CBEM, partnership with bridging organizations, the recognition of ILK as intellectual property and developing special legal acts for CBEM in national and provincial/territorial legislation. The use of technologies (e.g., mapping, GIS and earth observations) improves detection rates and generates more accurate data. Inviting professional consultants might also increase technical legitimacy of data for decision-makers. The training of community members by technical specialists and environmental scientists contributes to the capacity-building level of Indigenous communities.

The study's results suggest that potential policy responses for the design of CBEM could include collaboration with Indigenous governments to provide Indigenous leadership of CBEM programs; creation of funding opportunities for CBEM by public and private stakeholders; co-operation with bridging organizations; recognition of ILK incorporated into CBEM as intellectual property; building a legal space for diverse types of CBEM; and providing guidance for ILK incorporation into national and provincial/territorial legislation in Canada. Additional studies are required to design the specific CBEM programs that could be adjusted to particular geographical locations and infrastructure projects related to the CNC.

ABSTRACT

Meaningful incorporation of Indigenous and local knowledge (ILK) in climate change mitigation and adaptation efforts is key to accelerating effective action plans. This study argues that community-based environmental monitoring (CBEM), if done properly, can be more effective in incorporating ILK than environmental impact and monitoring based only on Western science. The paper examines successful elements, benefits, challenges and limitations in the existing CBEM studies that incorporate ILK to recognize how to design comprehensive CBEM policy for large-scale infrastructure projects such as the Canadian Northern Corridor (CNC) concept.

Based on a proposed framework for CBEM implementation (CBEM-IF), the study examines three Canadian CBEM case studies: berry pollution monitoring (AB), water quality monitoring (AB, BC, NWT, NT, SK and YT) and caribou monitoring (QC and NL), to evaluate lessons learned and to inform future CNC policy development. This study illustrates how knowledge co-production provides more opportunities for actions in sustainable development and incorporates emotional and spiritual components that entail different conceptualizations of human-nature connectedness. CBEM facilitates the incorporation of ILK and science, engages community members in the monitoring process and produces research outcomes which stakeholders perceive as more legitimate and relevant. CBEM can be a powerful tool in land-use conflict resolution, and it represents an inexpensive approach to monitoring the Arctic and near-North. Indigenous leadership, technology incorporation and equal partnership with communities, and availability of institutional guidelines were identified as required to enable the proper implementation of CBEM programs within the CNC. However, certain limitations of CBEM include lack of policy and guidelines; high reliance on volunteers; lack of standardized methods; focus on specific types of a landscape; general issues with TEK incorporation into science; and policy issues due to the incommensurability of Western science and the ILK epistemologies. Such challenges can be generalized as technical, organizational, financial and environmental issues and can be addressed by applying successful elements from previous international and Canadian CBEM studies. The authors suggest a series of policy recommendations to enable the implementation of CBEM as a means for meaningful incorporation of ILK on sustainable development projects and the CNC.

1. INTRODUCTION

The CNC concept considers the development of large-scale transportation infrastructure (road, rail, pipeline, electrical transmission and communication) through Canada's North and near-North (Sulzenko and Fellows 2016). The CNC concept seeks to address constraints in the transport of goods across Canada, increase access to alternative markets and foster economic development in the area. The concept considers the inclusion of policy, regulations and governance structures along with the corridor projects to also support northern and Indigenous social development goals while restricting negative impacts on the environment.

At this moment, the CNC is at a conceptual stage for which regulatory framework, routing and implementation are under consideration (Fellows et al. 2020). The CNC concept could extend around 7,000 kilometres and cover various provinces such as British Columbia, Alberta, Saskatchewan, Manitoba, Quebec, Ontario and Newfoundland and Labrador, along with the Northwest Territories (Sulzenko and Fellows 2016). The areas through which the corridor is proposed to cross are mostly classified as treaty land (Government of Canada 2013).

In Canada, the *Constitution Act* (1982) recognizes three groups of Indigenous Peoples: First Nations, Inuit and Métis. In Canada, early colonizers established agreements with Indigenous Peoples that listed the rights and obligations of all parties involved to maintain a peaceful co-existence (Government of Canada 2020a). However, through centuries, the treaty rights of Indigenous People have been violated, eroding the principles of the agreements (Government of Canada 2020a). Section 35 of the *Constitution Act* (1982) (Government of Canada 2020b) and the United Nations Declaration on the Rights of Indigenous Peoples (United Nations 2007) recognize and affirm the responsibility to respect and exercise treaty rights and/or Indigenous rights, and Canadian governments have committed to do so. Therefore, it is critical to consider that all initiatives associated with the CNC consider the rights, expectations and priorities of the Indigenous and local communities affected by the development of this concept.

On June 21, 2021, the *United Nations Declaration on the Rights of Indigenous Peoples Act* (UN DRIP) received Royal Assent and came into force in Canada. This act provides a roadmap for the government of Canada and Indigenous Peoples to work together to implement the Declaration based on lasting reconciliation, healing and co-operative relations (Government of Canada 2022). The Declaration states that "respect for Indigenous knowledge, cultures and traditional practices contributes to sustainable and equitable development and proper management of the environment." According to Article 31, Indigenous Peoples have the right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions, as well as the manifestations of their sciences, technologies and cultures, including human and genetic resources, seeds, medicines, knowledge of the properties of fauna and flora, oral traditions, literature, designs, sports and traditional games and visual and performing arts (UNDRIP 2007).

Article 26 of UNDRIP states:

1) Indigenous Peoples have the right to the lands, territories, and resources which they have traditionally owned, occupied, or otherwise used or acquired.

2) Indigenous Peoples have the right to own, use, develop and control the lands, territories, and resources that they possess because of traditional ownership or other traditional occupation or use, as well as those which they have otherwise acquired.

3) States shall give legal recognition and protection to these lands, territories, and resources. Such recognition shall be conducted with due respect to the customs, traditions, and land tenure systems of the Indigenous Peoples concerned.

Therefore, the international legal norms UNDRIP imposes require the incorporation of Indigenous and local knowledge into environmental policy decisions in Canada.

On the other hand, we consider local knowledge (LK) as recent generational knowledge developed in a specific area differentiated from Indigenous knowledge (IK) based on history, socio-political context and self-identification of those holding the knowledge (Thompson, Lantz and Ban 2020; Berkes, Berkes and Fast 2007). Indigenous and local knowledge (ILK) is defined as a "cumulative body of knowledge, experience, and wisdom, developing by adaptive processes and transferred across generations by oral traditions of storytelling" (Berkes 2017; Lam et al. 2020). ILK is about the relations of living beings (including humans) with one another and with their environment (Berkes 2017; Lam et al. 2020). It is a system of collective knowledge production as it plays the role of bringing different people working for different institutions closer to a degree of mutual respect for one another's sources of knowledge (Whyte 2013). ILK is locally developed; however, it has the feasibility of being used synoptically over a large area (Madhav Gadgil et al. 2002).

The scholars considered the process of knowledge co-production challenging so far. For example, knowledge integration, which has been a dominant perspective in environmental governance, has been criticized as a one-way track, and the epistemology into which ILK is being integrated holds the power to choose what is relevant and what knowledge system is used to validate new knowledge (Tengö et al. 2014, cited in Chapman and Schott 2020).

Also, knowledge integration failed to adequately address the role of unequal power dynamics, ongoing colonial trends and centuries of broken agreements in environmental negotiations (Chapman and Schott 2020). According to Liboiron (2021), colonialism endures through the presumed universal superiority of "civilized" Western ways of knowing. Local and Indigenous ways of knowing are perceived as insufficient or simply heritage. Scholars sometimes advocate for Indigenous participation in science through citizen science. Yet, Indigenous participation and inclusion are not enough to address colonialism. Even though Indigenous participation is often viewed as development and success, Western scientists should investigate their own scientific practices. Researchers should treat ILK as expertise, not culture (Liboiron 2021). As Castleden, Sloan, Morgan and Neimanis (2010) argue, research is one of the dirtiest words in the Indigenous vocabulary, as in many cases, the Western scientific paradigm implies research on Indigenous communities rather than with them, leading to a lack of Indigenous control over the research process or outcomes.

Chapman and Schott (2020) consider knowledge integration as one of the steps towards knowledge co-evolution, as simply integrating ILK could lead to knowledge appropriation, a loss of some aspects of cultural identity or tokenism and the inclusion of ILK to check the boxes to look good among peers. As Reid et al. (2020) note, the knowledge integration process perceives IK as information to be subsumed into the mainstream of Western science. As a result, IK serves only to strengthen Western science and to concentrate the power in administrative centres rather than in Indigenous communities (Nadasdy 1999, cited in Reed et al. 2020).

Thus, the incorporation of ILK into environmental policy and science requires taking steps beyond knowledge integration. Community-based environmental monitoring could be a promising step toward meaningful incorporation of ILK into large-scale infrastructure projects such as the CNC.

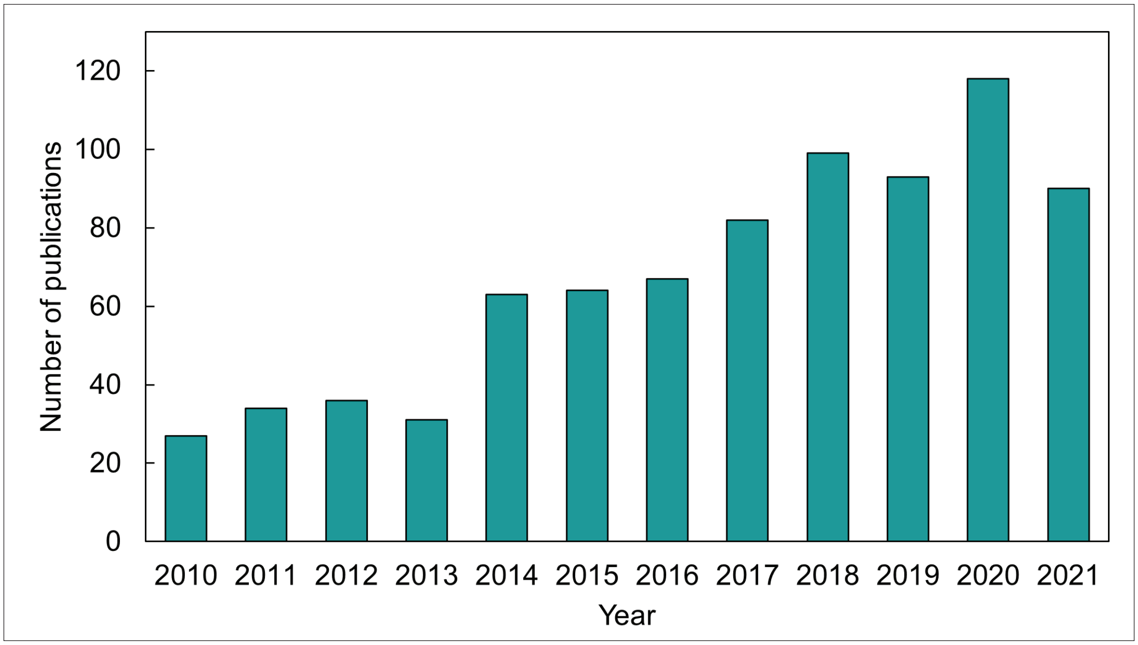
Community-based environmental monitoring (CBEM) is a process of routinely observing environmental or social phenomena. It is led and undertaken by community members and can involve external collaboration and support by visiting researchers and government agencies (Danielsen et al. 2009; Reed, Brunet and Natcher 2020). CBEM is very useful to identify environmental, health and social impacts of human activities in ecosystems, as well as to identify the potential cumulative effects of these activities (McKay and Johnson 2017). Previous studies on CBEM indicate the implementation of this process can capitalize from generational knowledge, empower local communities, energize cultural revitalization and build trust and credibility among stakeholders (Reed, Brunet and Natcher 2020). However, challenges with proper funding, appropriate inclusion of under-represented groups, data credibility and maintaining stakeholder engagement remain as barriers for further implementation of CBEM across areas and projects. Also, some scholars have raised concerns about the negative impact of funding models from government and the private sector for CBEM over Indigenous self-governance and decolonization (Cohen et al. 2021).

In parallel with supporting CBEM, governmental and community organizations have become increasingly interested in including Indigenous and local knowledge (ILK) into Western scientific knowledge in environmental management and monitoring (Hill et al. 2020). Indigenous knowledge (IK) can be defined as “a network of knowledges, beliefs, and traditions intended to preserve, communicate, and contextualize Indigenous relationships with culture and landscape over time” (Bruchac 2014). IK is dynamic and it is conveyed through social encounters, oral traditions, ritual practices and other activities. Indigenous Peoples can be referred to as peoples with “Historical continuity with precolonial or pre-settler societies; strong links to territories and surrounding natural resources; distinct social, economic or political systems; form non-dominant groups of society; resolved to maintain and reproduce their ancestral environments and systems as distinctive peoples and communities" (United Nations Permanent Forum on Indigenous Issues 2004).

When CBEM involves Indigenous Peoples, it supports commitments made under the *United Nations Declaration on the Rights of Indigenous Peoples Act.* CBEM also supports the principle of free, prior and informed consent (FPIC) by supporting Indigenous People to gather the information necessary to make informed decisions regarding large-scale infrastructure projects.

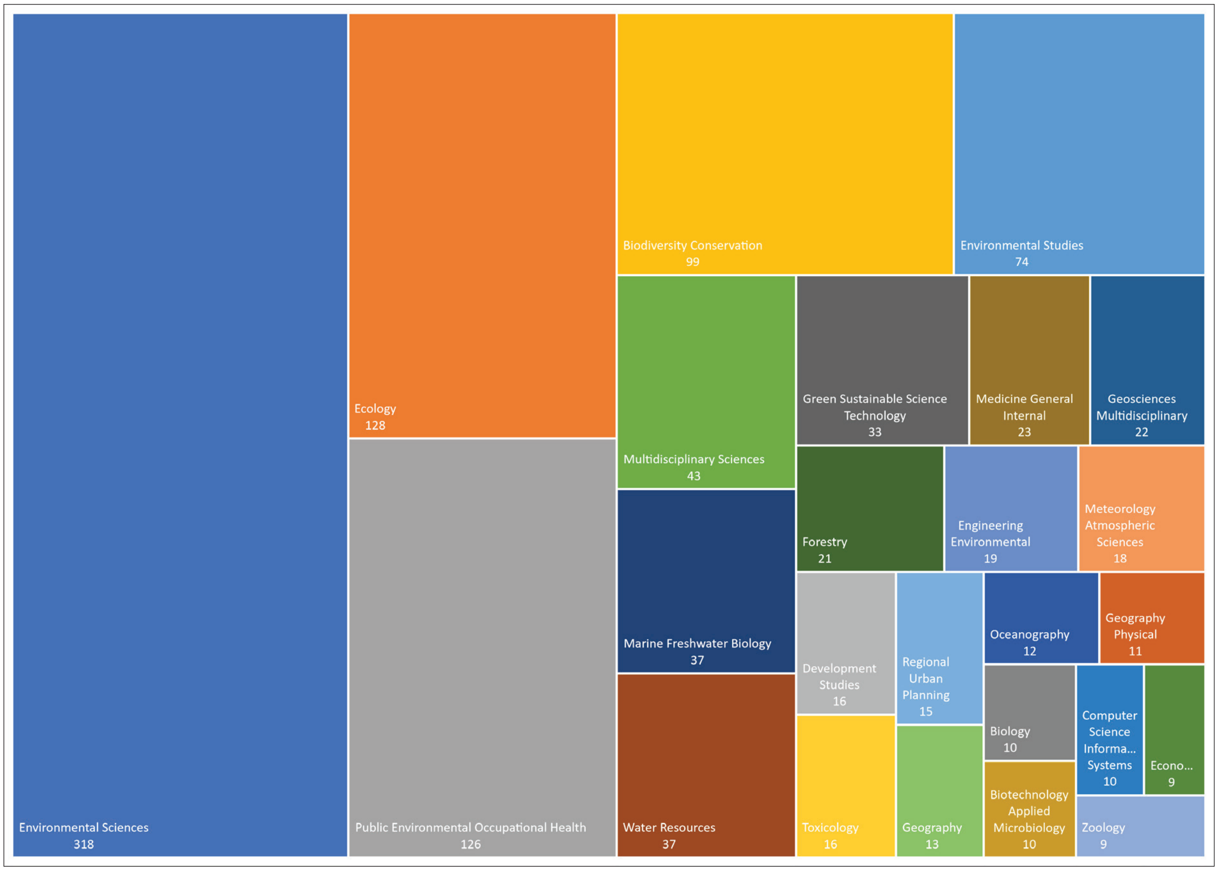
Research around CBEM and its implementation has considerably grown in the last decade. Since 2010, more than 800 articles based on CBEM have been published in academic journals with an incremental trend (Figure 1). A treemap of the main scientific categories in CBEM publications (Figure 2) indicates that CBEM research is mainly focused on environmental and physical sciences while more research in social sciences seems to be necessary to enable wider implementation of CBEM at the policy level. A bibliometric map analysis of academic literature on CBEM (Figure 3) shows the main areas of focus where CBEM has been studied. The largest circle in the map is conservation, followed by management, citizen science, climate change, health and biodiversity. The linkages between these areas suggest that CBEM has a relevant role in enhancing the participatory sciences in environmental and socioeconomic challenges associated with climate change. Canada was the only country with considerable links into the CBEM research associated with Indigenous knowledge and climate change, indicating that significant momentum may be building up in Canada in this area.

Figure 1. Publications Per Year Considering CBEM and its Implementation



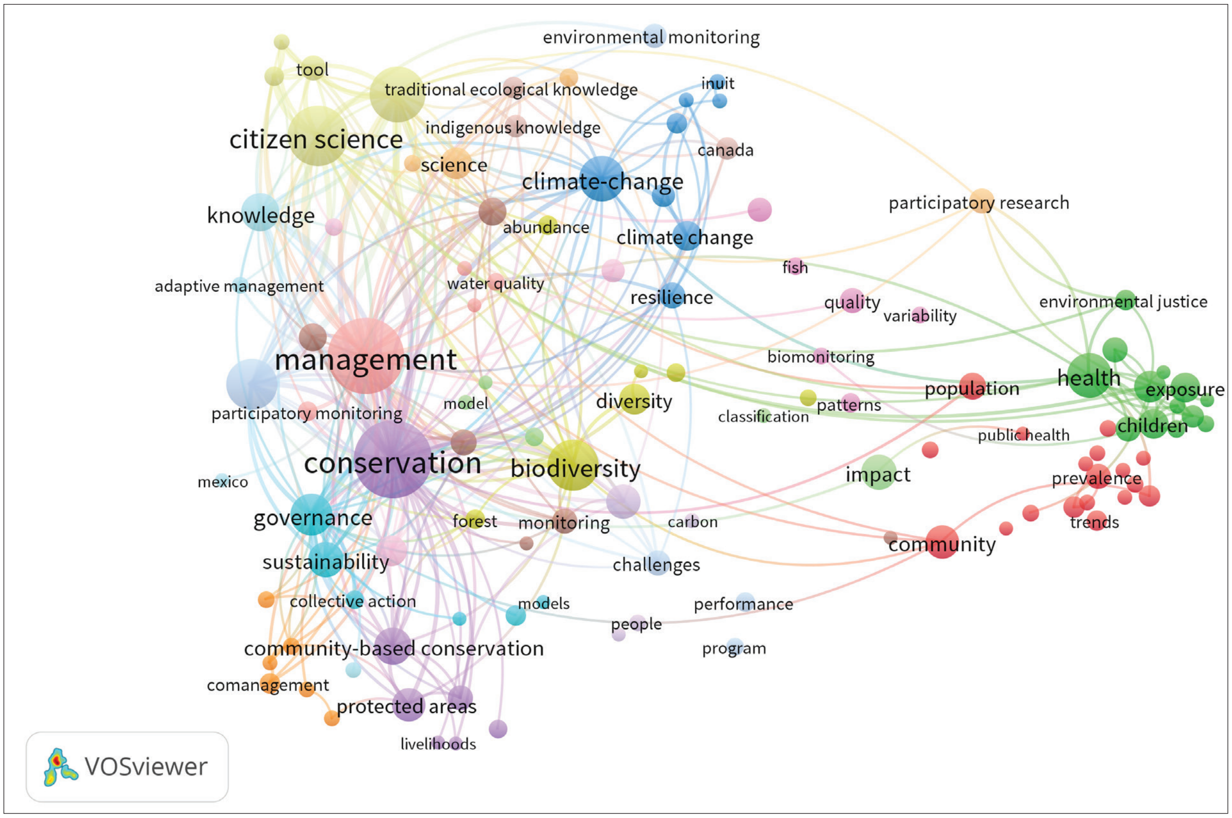
Source: Prepared by authors (2022) based on articles indexed by WoS from 2010 to 2021 (Clarivate 2021).

Figure 2. Treemap of Scientific Categories Considering CBEM Implementation (Clarivate 2021)



Source: Prepared by authors (2022) based on articles indexed by WoS from 2010 to 2021 (Clarivate 2021).

Figure 3. Bibliometric Map of Areas of Study Addressing CBEM



Source: Prepared by authors (2022) based on articles indexed by WoS from 2010 to 2021 (Clarivate 2021). Map was made using VosViewer®. This software groups keywords together in clusters that are related, gives them the same colour and places them closer. The database used for this figure comprises the 115 most often mentioned keywords in the search. The size of the circles is proportional to the number of articles. The search included community-based environmental monitoring (CBEM) with 804 occurrences total. Colours are group topics that are closely related and the lines connect subjects.

If appropriately guided and supported, CBEM could become a powerful vehicle to engage local communities and their ancestral knowledge in the development of sustainable policies, regulations, governance structures and the implementation plans of infrastructure projects. For the CNC to meet its purpose to support economic and social development, CBEM could catalyze community engagement as well as enable the identification of potential negative impacts of proposed projects before, during and after implementation. The CNC presents an opportunity to rethink how infrastructure projects are developed in Canada. Moreover, it offers an opportunity to meaningfully engage stakeholders at an early stage of the projects to maximize the positive impacts of this concept in the communities it will serve.

Incorporating distinct knowledge systems into policy can improve the sustainability transformation discourse and practices because it potentially widens the conceptual understanding and provides more variety for actions to foster just, equitable and sustainable futures (Lam et al. 2020). ILK can also guide the incorporation of emotional and spiritual components into the quite empirical sustainability transformation contexts because ILK systems are knowledge-action-belief complexes and entail different conceptualizations of human-nature connectedness (Gadgil, Berkes and Folke 1993; Reid et al. 2006; Gray 2016; Berkes 2017; Lam et al. 2020). Yet, it has been challenging for various stakeholders, including governmental agencies and industry, to establish culturally appropriate approaches, procedures and participatory methods to facilitate, organize and lead the process of knowledge co-production (Berkes and Folke 1998; Chapin et al. 2010; Thaman et al. 2013; Lyver et al. 2017).

This paper reviews the basis of CBEM and its implementation as a tool to meaningfully incorporate ILK in large-scale infrastructure projects such as the Canadian Northern Corridor. CBEM's benefits and limitations are discussed through an analysis of scientific literature and grey literature. Based on the literature review, a framework for identifying the elements of success and challenges for CBEM's implementation is proposed. This framework is then applied to three Canadian case studies to assess CBEM's impacts and contribution under specific geographies, communities, ecosystems and human perturbances/impacts. The case studies include: 1) berry picking in Alberta's oilsands region; 2) the Mackenzie River Basin water monitoring program (AB, BC, NWT, NT, SK and YT); and 3) the effect of mining on caribou and Indigenous livelihoods in Quebec and the Labrador area. The last section concludes with a reflection of the learning process around CBEM's potential benefits and challenges as well as potential policy strategies to enable the scale-up and growth of CBEM in the Canadian North.

2. METHODS

We analyzed the research experience of scholars who have worked on incorporating ILK into CBEM to identify the best practices (coded as "elements of success"), the advantages of CBEM for the TEK incorporation (coded as "benefits") and situational problems that negatively affect knowledge co-production (coded as "challenges"). To analyze the data, we applied a qualitative content analysis method to identify successful elements of the TEK incorporation in CBEM. Content analysis is a method of analyzing the content of written documents, transcripts and other types of written communication (McNabb 2004).

We used manual open coding. Open coding is the process of breaking down, examining, comparing, conceptualizing and categorizing data (Strauss and Corbin 1990). Coding the data is necessary for data reduction and the ensuing analysis of these data (Luker 2008). As Luker (2008) states, the researchers should ask themselves: "What am I seeing here that could possibly be a pattern?" When the researcher notices that the same themes occur over and over, these themes can be coded. Pattern recognition process helped us to identify common themes that appeared in the academic literature. We analyzed 27 articles that presented the case studies of ILK incorporation into CBEM from various geographical locations across the world without any specific regional focus. Then, we categorized the data by grouping the concepts that seemed to pertain to the same phenomena (Strauss and Corbin 1990) and then gave each category a code name. Following Luker's (2008) and Strauss and Corbin's (1990) approaches, we also noticed variations on a theme, which appeared to be subcodes. These subcodes were included in scale as sub-elements of the elements.

After analyzing 27 articles on CBEM and TEK, following Luker's (2008) instructions, at the end of the process we designed an outline-organized set of codes and subcodes, which we coded as elements and sub-elements of success. The first element is Indigenous-led CBEM. The subcodes for this element are: 1) Indigenous languages usage; and 2) prioritization of the Indigenous community's needs and compensation of community members. The second element of success is technology usage in CBEM studies. The subcodes for this element include: 1) a one-term commitment to develop partnerships with communities; 2) organization of workshops and training for community members; and 3) collaboration with bridging organizations. The third code (element) is the presence of a legal and institutional framework for CBEM and ILK in provincial and federal legislation. The subcodes for this element are: 1) funding for CBEM; 2) translating CBEM outcomes (ILK) into useful formats for policy; 3) building a legal space for CBEM and ILK; and 4) broadening the impact scopes in the design of CBEM programs.

As part of the coding process, we also identified codes that referred to situational issues that negatively influence the ILK incorporation into CBEM. We coded them as technical, organizational and environmental challenges.

From this analysis, we proposed a framework (CBEM-IF) to analyze the implementation of CBEM within provinces and territories across middle and northern Canada and extract elements of success and challenges observed.

We selected the case studies based on these criteria:

- The geographical location of CBEM studies in Canada's North and near-North relevant to the CNC concept. The proposed concept would largely follow the boreal forest in the northern part of the west, with a spur along the Mackenzie Valley, and then southeast from the Churchill area to northern Ontario and the Ring of Fire area; the corridor would then traverse northern Quebec to Labrador, with augmented ports (Sulzenko and Fellows 2016);
- Relevance to the CNC large-scale infrastructure development concept (multimodal — road, rail, pipeline, electrical transmission and communication) transportation right-of-way through Canada's North and near-North;
- The intent to incorporate ILK into CBEM.

Then, we applied the CBEM-IF framework to the three case studies from northern Canada that are relevant to the CNC focus (AB, BC, NWT, NT, SK, YT and QC/NL). Based on the criteria above, we selected three case studies: 1) berry picking in Alberta's oilsands region relevant to pipeline infrastructure (Baker 2017) and geographical location (northern Alberta); 2) the Mackenzie River Basin water monitoring program (AB, BC, NWT, NT, SK and YT) (University of Alberta 2021), as the notional CNC route goes across these provinces and territories. The Mackenzie River Basin is in Canada's North (University of Alberta 2021); and 3) the effect of mining on caribou and Indigenous livelihoods in Quebec and the Labrador area. This is relevant to the CNC as infrastructure for mining includes roads, railway tracks and power lines (Herrmann et al. 2014). The project's geographical location is northern Quebec and Labrador. All selected case studies indicated the intent to incorporate ILK into the CBEM projects.

The next step was applying the coded set to case studies using content analysis. The deductive coding with the use of the elements of success/challenges set of codes and subcodes involved several stages (based on *Getthematic.com* 2019):

- Finding the peer-reviewed article that mentions TEK or the incorporation of TEK into CBEM;
- Reading through the paper;
- Identifying whether the predefined codes match the qualitative data in the article;
- Drawing a table that shows how elements of success and challenges are reflected in three case studies from northern Canada.

The application of the CBEM-IF framework to case studies as implementation experiences resulted in a set of recommendations for implementing CBEM in the CNC.

Authors' Positionality

First author: I am a Western-trained Indigenous scholar of Sakha descent from the Sakha Republic, Siberia. I speak my native Sakha language fluently and carry a traditional knowledge of herbs in my mother's native village in Siberia.

Second author: I am mestizo cis-male from Venezuela. I see my cultural background heavily influenced by a mix of Indigenous, African and European values resulting from the colonization of the Americas. I was born and raised in the city of Maracaibo, sharing land, culture and family with the Wayúu tribe. I grew up as part of the middle class and racially dominant group in my country. Spanish is my mother tongue and I am fluent in English.

3. BENEFITS AND LIMITATIONS OF CBEM IN KNOWLEDGE CO-PRODUCTION

3.1. BENEFITS

Community-based environmental monitoring suggests three types of benefits to stakeholders in the ILK incorporation, which include political, social and scientific benefits.

Political Benefits of CBEM

Restoration of power imbalance in negotiations between Indigenous/local communities is the first political benefit that CBEM could bring into the ILK incorporation process. Because the CBEM regime involves working with communities, it results in emergence and management of self-governance for Indigenous and local communities involved in monitoring regimes. Yet, the potential for CBEM as a tool for asserting sovereignty and jurisdiction has rarely been explored (Parlee et al. 2012; Kotaska 2013, as cited in Wilson et al. 2018)). As Natcher and Brunet (2020) suggest, although in its basic form CBEM is viewed as an ongoing data collection process, which can in some cases be embedded in Indigenous knowledge, it is also a political act that can, under certain conditions, support self-determination and meaningful co-governance with state governments.

Environmental monitoring can contribute to community strategies to better self-govern their territories (Mena et al. 2020). According to Mena et al. (2020), CBEM does not only help to decrease the inequality of access to information between communities and companies (public or private) in relation to resource extraction in their territories, it also allows local communities to broadly disseminate data about environmental liabilities to relevant external agents, including policy-makers, the mass media and activists. The monitoring of ecosystems, with indicators developed by Indigenous Peoples, suggests ways for involving communities in the attempt to protect and restore nature (Lyver et al. 2017). Parlee (1998) suggests that monitoring is crucial for many northern local communities who are concerned about the negative impacts and potential benefits of resource development in their region (Parlee and Lutsel K'e Dene First Nation 1998). The model for community-based monitoring, developed by Parlee in 1998, suggests how communities can develop knowledge about the impacts of resource development on the natural environment and on their community. With these data, community leaders may have a larger capacity to balance what they see as benefits of development with the priorities and needs of the community (Parlee and Lutsel K'e Dene First Nation 1998). The emergence of CBEM regimes is often associated with the interest of Indigenous communities and governments to hold the government and industry accountable for their actions and policies (Wilson et al. 2018).

Thus, community-based monitoring gives communities the power to interpret the nature observations in their own way (e.g., through spiritual and emotional dimensions) (Lyver et al. 2017). By offering opportunities to monitor ecosystems, CBEM may increase citizen engagement in ecosystem management, contribute to participatory community development and enhance community impact on policy decisions (Pollock and Whitelaw 2005). These community-based indicators can suggest evidence for interpreting conditions, changes and trajectories in the environment (Tengö et al. 2014). Community monitoring also serves a double purpose as it represents an expression of identity and self-governance and infers rights under environmental stewardship arrangements (Agrawal 1995; Bohensky and Maru 2011).

Citizen involvement in CBEM represents an emergent contribution to environmental planning, decision-making and policy implementation (Pollock and Whitelaw 2005). Citizen engagement, which refers to the society's roles and skills, including knowledge, experience, institutions and organizational capabilities, should be acknowledged and embedded in any governance system that aims at improving the capacity to administer the ecosystem's sustainability for human well-being (Fernández-Giménez, Ballard and Sturtevant 2008). Citizen involvement also increases governmental capacity to properly monitor the environment, which has decreased recently due to the rising complexity of environmental conditions and substantial budget cuts in environmental programs. CBEM has provided the government with the potential for a cost-efficient way to increase its monitoring capacity (Yarnell and Gayton 2003, as cited in Fernández-Giménez, Ballard and Sturtevant 2008). Involvement in monitoring increases the likelihood that monitoring information will be acted upon and used to make decisions (Fernández-Giménez, Ballard and Sturtevant 2008).

CBEM in North America is closely related to governance regimes and practices and is connected to implementation of Indigenous land claims (Johnson et al. 2016). In North America, where the term CBEM has more widespread use, land claims in northern regions have led to the development of co-management institutions that mandate the use of ILK alongside scientific knowledge and create a space for direct involvement of communities in decision-making (Johnson et al. 2016). Berkes, Berkes and Fast (2007) argue that the emergence of joint management is closely related to the implementation of Indigenous land claims as community-based monitoring suggests self-government options through citizen engagement. Due to negotiations on land claims agreements, CBEM has been associated with the rising political power of northern Indigenous groups (Berkes et al. 2001, as cited in Berkes, Berkes and Fast 2007).

Social Benefits

Social benefits of CBEM include restoration and revitalization of Indigenous and local knowledge, community-building and developing trust between communities and other stakeholders. Beausoleil et al. (2021) argue that changes observed in nature (air, water or land), including wildlife and vegetation, can alter the behaviour of Indigenous Peoples because of concerns over the access and safety of traditional resources from these environments. Indigenous-led CBEM is not simply monitoring, but also restoring ILK through the revitalization of accessible traditional and cultural practices.

CBEM fosters social learning and builds community. Community involvement in monitoring leads to communication of monitoring findings to the broader audience of policy-makers and industry (Fernández-Giménez, Ballard and Sturtevant 2008). CBEM data have great value for Indigenous governments as they provide information that addresses some of their concerns, needs and priorities, such as water quality monitoring. CBEM of important natural resources such as water monitoring could be viewed as an expression of governance itself based on understanding of kinship and a sacred responsibility of Indigenous communities and governments for protection of nature and wilderness. For example, participants in the Indigenous Observation Network (ION) in Canada (Yukon) and the U.S. (Alaska) reported that they were mainly motivated by the importance of water quality. Their elders told them that water provides life and it is crucial for them to ensure that water is clean and free of contaminants (Wilson et al. 2018).

Scientific Benefits

Scientific benefits involve the collection of long-term data sets and enhanced monitoring of ecosystems. Limited access and the high cost of infrastructure in remote, circumpolar areas can present challenges for scientists seeking long-term, year-round data. Citizens can gather monitoring information that help them to understand environmental change and influence local planning and decision-making (Danielsen et al. 2014, as cited in Johnson et al. 2016; Pollock and Whitelaw 2005). Indigenous communities can apply their skills and capacities to engage in organized and systematic data gathering (Danielsen et al. 2014, as cited in Johnson et al. 2016).

3.2 LIMITATIONS OF CBEM REGIMES

Limitations of current CBEM regimes include: lack of policy and guidelines; data inconsistency due to dependency on volunteers; data inaccuracy (lack of standardized methods, quality control); focus on specific types of landscape; and general TEK incorporation into science and policy issues.

Lack of Policy and Guidelines

The CBEM outcomes often result in the absence of any government policies to make specific use of such information, when the data run the risk of “falling on deaf ears” (Duinker 2007, as quoted in Conrad and Daoust 2008).

Lack of Protection of ILK as an Intellectual Property

Many Indigenous Peoples, local communities and governments request intellectual property (IP) protection for ILK as intangible assets (Government of Canada 2022). An intellectual property right refers to the legal ownership of intellectual creations. The World Intellectual Property Organization defines ILK as: “Knowledge, know-how, skills and practices that are developed, sustained and passed on from generation to generation within a community, often forming part of its cultural or spiritual identity”

(Intellectual Property Institute of Canada 2022). This knowledge can be grounded in areas such as agriculture, science, technology, ecology, medicine or biodiversity.

According to the Intellectual Property Institute of Canada, the Canadian IP system does not adequately protect:

- Collective ownership rights;
- Historical works and oral expression; and
- The continuous and enduring character of ILK.

A fundamental concern related to ILK has been the frequent misuse, misappropriation and stealing of its concepts. Generally, professionals using ILK have wrongfully discounted the validity of the knowledge and thus misinterpreted or completely failed in citing their sources (Assembly of First Nations 2011). Studies that are published using unauthorized ATK disseminate the knowledge to the general public. For First Nations and Indigenous Peoples, the public circulation has resulted in a loss to all legal claims to the ATK (Assembly of First Nations 2011).

The Intellectual Property Institute of Canada (2022) recommends the following best practices while considering ILK as an object of intellectual property rights: 1) discussing with clients how the work was produced to avoid misappropriation; and 2) when required, obtaining consent to use a traditional design, a work or knowledge.

Dependency on Volunteers

High CBEM dependency on volunteers leads to situations where volunteers' loss of interest results in data inaccuracy and non-systematic data collection (Herrmann et al. 2014; McKay and Johnson 2017). In early studies involving citizen science, data gathered by volunteers were too vague to be used, as they represented a range rather than specific numbers, which made it challenging to recognize changes or support conclusions. However, now, the leads of volunteer-based projects are trained to scrutinize the data carefully and be willing to discard suspect or unreliable data (Cohn 2008).

Lack of Standardized Methods

CBEM constraints include the lack of a universal framework in communities and differing design and implementation methods (Conrad and Hilchey 2011; Bonney et al. 2009; Chandler et al. 2017; Dickinson, Zuckerberg and Bonter 2010; Kullenberg and Kasperowski 2016; Toomey 2014; Conrad and Daoust 2008, as cited in Mena et al. 2020). Lack of standardized methods in CBEM could negatively influence the production of accurate data. Unlike a science-based monitoring system, CBEM indicators offer greater diversity of indicators between different regions of a country (Lyver et al. 2017). According to Lyver et al. (2017), Indigenous Peoples typically manage and monitor at a localized or catchment scale, reflecting community values and priorities. This particular feature challenges the capacity to scale up indicators across multiple communities and landscapes and also to evaluate the national state of biological and community well-being. This makes it difficult to compare data and interpretations of the state of biodiversity. While it is likely that congruences in indicators will emerge across communities and locations, with relatively few adaptations required for wider application, others will be location-specific and will be applied and interpreted in slightly distinct ways. The challenge confronting practitioners, therefore, will be to balance the variability that emerges from engaging different spatially specific indicators and the comparativeness of indicators across multiple communities with the informative value of resulting aggregated indicators for assessing the national state of the environment and/or the community's relationship with it (Lyver et al. 2017).

Focus on Specific Types of Landscape

Existing CBEM programs tend to focus on specific types of contamination such as water and air pollution (Beausoleil et al. 2021). Currently, CBEM regimes are less likely to produce reports of land monitoring (including wetlands) and terrestrial wildlife monitoring. However, this does not characterize land and wildlife as less significant, but argues that CBEM approaches support regional monitoring efforts where data are more easily captured in regional-scale models (Beausoleil et al. 2021).

Incommensurability of Western Science and the ILK Epistemologies

Berkes, Berkes and Fast (2007) note that there are potential limits to ILK incorporation because of its qualitative nature and its belief component. Unlike scientists, Indigenous participants tend to use metaphorical language. CBEM, like any other approach to ILK incorporation, has difficulty in establishing standards of verification that would be acceptable both to scientists and ILK holders. Probably the most significant constraint is the difficulty in translating ILK and science into forms that are mutually intelligible, in ways that make it accessible to decision-makers (Berkes, Berkes, and Fast 2007).

As the Potawatomi ethnobotanist, Robin Wall Kimmerer, notes, Indigenous Peoples approach nature in a different way than Western science. In the Western tradition, there is an established hierarchy of beings, with the human being on top. The human being is considered to be the pinnacle of evolution. In Indigenous ways of knowing, humans are viewed as the younger brothers of creation. In comparison with plants and animals, humans have the least experience with how to live and they must look to other species as teachers for guidance. Plants teach humans by example, as they have been on the Earth longer than humans have been (Kimmerer 2013). Thus, Indigenous communities learn from plants and animals, by observing what happens in nature, and they treat nature as their teacher. Similarly, the Syilx scholar, Jeanette Armstrong (2018), argues that the view of Syilx being tmixw (the ecology of the land including all life forms and their relationships with each other) themselves is a necessary element in their philosophy of egalitarianism toward all life forms. Syilx ecological knowledge is based on the wisdom that the ecology of their territory is a living whole system that requires human compliance with the regenerative requirements in order to interact with it in a non-destructive way (Armstrong 2018).

The Cree researcher, Michael Hart (2010), states that Indigenous epistemology emerges from the interconnections between the human world, the spirit and inanimate entities. Relational world view refers to the notion of a strong focus on people and entities coming together to help and support one another in their relationship. Paul Nadasdy (1999) notes that for the Kluane First Nation hunters, sheep are not numbers. As these hunters observed, certain species play a more essential role in the sheep community. Sheep have social structure, and the disruption of this structure by killing species that play a tremendous role in the sheep community can do at least as much damage to their population as the deaths of hordes of potential offspring, who exist only as numbers in reports. Understanding of animals' thinking and behaviour is as important as counting the numbers of species, as biologists do. Yet, for scientific resource managers, it is not always possible to accumulate the information about animals' behaviour (Nadasdy 1999). Reid et al. (2020) note Western science is based on the approach that humans are in control of nature and Indigenous world views refer to the idea that humans are part of the ecosystems.

Hence, Western scientific approaches and Indigenous ways of knowing have different epistemological stands and, therefore, knowledge co-production is quite challenging. Some scholars suggest alternative ways of looking at the knowledge co-production process that could address both differences in epistemologies and power imbalance. For example, according to Reid et al. (2020), Two-eyed seeing remedies power relations, respects distinctions and upholds unique advantages instream with its uniting of knowledges and ways of knowing. Two-eyed seeing values collective over individual action where once polarized groups or knowledge-holders are combined and learn from one another. It puts emphasis on the process rather than the result. The two-eyed seeing approach does not mean that any of these approaches are superior to another or that these approaches are impossible to combine. It brings the idea that these approaches should come in parallel, given their individual strengths in specific contexts (Reid et al. 2020).

4. MEANINGFUL INCORPORATION OF ILK THROUGH CBEM — AN IMPLEMENTATION FRAMEWORK (CBEM-IF)

4.1 ELEMENTS OF SUCCESS

CBEM Led by Indigenous Communities (ICBEM)

According to several authors, CBEM is the most successful when it is developed, facilitated, studied and reported on by Indigenous communities, based on community priorities seeking to answer community concerns (Beausoleil et al. 2021; Wilson et al. 2018; Natcher and Brunet 2020; Reed, Brunet and Natcher 2020).

Beausoleil et al. (2021) argued that in Indigenous-led CBEM (ICBEM), the lead community may include Western scientists to support technical parts of the project, but the Indigenous community itself is responsible for the creation, planning and implementation of the CBEM. Genuine representations of environmental monitoring are Indigenous-led and deeply rooted in ILK and language, traditional values, legal traditions and practices of environmental management associated with the meaningful exercise of Section 35 rights. In this context, ICBEM is not simply monitoring, but also restoring ILK through the revitalization of accessible traditional and cultural practices (Beausoleil et al. 2021). When planned properly, ICBEM programs can improve the efficiency and relevance of environmental monitoring, linking physical and chemical factors (e.g., land disturbance and contamination) with culturally significant indicators (pathway responses and valued components) and addressing community needs, priorities and issues (Beausoleil et al. 2021; Natcher and Brunet 2020).

ICBEM also could be seen as a tool for asserting Indigenous sovereignty and jurisdiction, and as a way of understanding CBEM as more than data collection but rather as a form of Indigenous governance (Beausoleil et al. 2021). Indigenous communities involved in ICBEM used it to honour their responsibilities to protect their ancestral lands and waters (Natcher and Brunet 2020). Thus, Indigenous governments must be leaders in CBEM programs (Beausoleil et al. 2021). ICBEM can be developed using a bridging organization, and ICBEM programs should be combined with Indigenous environmental governance strategies and priorities (Wilson et al. 2018). Yet, according to some scholars, ICBEM can prevent Indigenous communities from exercising sustainable self-determination as the current ICBEM framework mimics state functions instead of honouring Indigenous sustainable relationships with their lands (Reed, Brunet and Natcher 2020). There is an academic debate whether the ICBEM institutional framework allows communities to exercise their jurisdiction over the lands to protect them from environmental pollution. Consultations with Indigenous governments are required to resolve this issue.

Subcomponents

a) Indigenous languages usage (e.g., in determining original place names) is useful for transmission of ILK and investigation of place names. The concept of transferring knowledge through language becomes a process that relies on opportunities to engage on that territory over many generations. Indigenous languages are central to both Indigenous epistemologies and ontologies, and thus views and perceptions of life on Earth. Both language and humans are reliant on land as a spiritual and material source of sustenance (Ferguson and Weaselboy 2020).

   The process of transferring ILK through the use of Indigenous place names connects Indigenous communities with their nature. Place names can tell stories, provide clues about the landscape and describe how people lived and associated with that landscape (Wilder et al. 2016, as cited in Beausoleil et al. 2021). Place names can also help to reaffirm the Indigenous language that evolved there (Henshaw 2006; Sousa et al. 2010; Wong et al. 2020, as cited in Beausoleil et al. 2021). To improve best practices in CBEM, efforts should include the use of Indigenous place names or place-naming activities (Beausoleil et al. 2021).

   The recent study by Henson et al. (2021) showed that grizzly bear and human groups have been shaped by the landscape in similar ways, creating a convergence of grizzly bear genetic and human linguistic diversity. Although this co-localization does not explicitly show any relationship between grizzly bear and human groupings, it does imply that the same landscape pressures that shaped Indigenous language families, should they be resource or geographically mediated, also could have shaped grizzly bear genetic groups.

   Indigenous languages demonstrate the close relationships between nature and Indigenous world views. Indigenous Peoples talk about the world as being alive, as of spirit, and this notion is reflected daily in the language (Kovach 2009). For example, Margaret Kovach (2009) notes that learning about the structure of Cree language gives her an understanding of how fluent Cree speakers would have related to their world. Thus, Indigenous languages reflect Indigenous holistic views of nature, which are often expressed through storytelling techniques.

b) Prioritization of Indigenous communities' needs and compensation of community members**:** Another subcomponent in Indigenous-led CBEM is ensuring that they address the needs and priorities of community members. Gathering information about the community helps to create knowledge to design CBEM that is unique to each community's values, vision and interests. It provides the opportunity for both citizens and decision-makers to articulate their information needs and future goals (Wilson et al. 2018). To make participation easier and more attractive, it could be helpful to build programs around activities that community members are already doing on a regular basis, such as hunting trips (Johnson et al. 2016). Collaborating scientists should share data and information with communities on a timely basis, which will help address concerns about the utility of CBEM programs for addressing community information needs (Johnson et al. 2016).

To support sustained involvement of key individuals, programs should create a paid co-ordinator role and ensure that community members are adequately compensated for their time and effort. For a few projects, compensation was viewed as a barrier to long-term sustainability because it necessitated renewed funding from outside sources. Often, citizen science initiatives rely on volunteers to engage in limited data collection. Compensation is rarely provided in these arrangements. Yet, while paying community members is generally considered to be a requirement for sustained initiatives, some caveats were expressed. For example, some CBEM practitioners point out the need to ensure that those involved in ILK documentation initiatives have significant experience and knowledge, as opposed to those less qualified and motivated primarily for monetary compensation (Johnson et al. 2016).

Technology Usage in CBEM Studies

Hermann et al. (2014) included the usage of three GPS trackers in a CBEM study that improved the research outcomes. The data collected by Sami herders and Cree and Naskapi hunters using RenGIS, Cree GeoPortal and CyberTracker provided detailed, dynamic, geo-referenced information, addressing issues both at the local level and with a landscape perspective, which is necessary when communicating the complex land-use form of reindeer husbandry and caribou hunting in the Arctic. They also allowed for a deeper understanding of human–environment relationships over time and space that could otherwise not be collected.

CBEM processes based on technology (i.e., cellphones, apps, drones) increased detection rates of environmental liabilities. Use of the technological package generated an accurate, reliable and easily transmittable set of information. Meaningful change was achieved by providing local communities with the evidence and arguments to hold extractive industries accountable for their actions and, in the long term, by providing a systematized environmental record that could be used by communities, state authorities and civil society (Mena et al. 2020). CBEM program design should include technical capacities (e.g., ground water monitoring) through strong collaborative relationships with consultancy agencies, research institutions and universities, especially in remote areas with no access to road infrastructure (Wilson et al. 2018; Hunsberger 2004). Technically challenging activities that need expensive equipment, such as ground water monitoring, may be beyond the reach of CBEM. Strengthening technical capacity by inviting professional consultants or affiliating with a university or research institution is necessary for building legitimacy for citizen monitoring activities (Hunsberger 2004).

Subcomponents

a) Making research methodology accessible to communities — the data indicators applied within a CBEM must be relevant and trusted by Indigenous and local communities (Lyver et al. 2017)

b) Keeping data in reliable long-term storage (Herrmann et al. 2014).

c) Maintaining quality and consistency of data; planning for long-term data storage and accessibility; continually examining, interpreting and presenting the monitoring data; and including monitoring within an integrated research program (Johnson et al. 2015).

Building Partnerships with Indigenous and Local Communities

Partnership means building equal, trustful and meaningful relationships between scientific communities, governmental specialists and communities, which is considered to be crucial for CBEM programs. Partners can provide strong co-ordination, credibility, educational opportunities toward sustainability and technical advice to CBEM (McKay and Johnson 2017; Wilson et al. 2018).

Being equal partners and including local expertise in community management includes developing trust and respectful and meaningful engagement with communities (Berkes, Berkes and Fast 2007). Since needs or priorities for communities are usually reflected in their traditional subsistence practices, the perfect environmental monitoring regime is one where community members can report on ecosystems based on their undisturbed routines (Mena et al. 2020). A community's interest and investment in the natural environment contributes to CBEM success (McKay and Johnson 2017).

To establish successful partnerships, CBEM projects need to involve a well-organized system of co-ordination and management behind the community aspect of environmental monitoring (Mena et al. 2020). Participation of community representatives in all CBEM activities also contributes to building partnerships (Wilson et al. 2018). Not all projects that involved community members throughout the monitoring process were highly successful. In some cases, this was because the project was among the first collaborative monitoring efforts the CBEM undertook (Wilson et al. 2018). The presence of financial support, as well as sufficient time and accumulation of experience, was also critical to the establishment of extensive and effective CBEM activities (Mena et al. 2020).

Partnerships with policy-makers (e.g., through agreements) can enhance mutual understanding and acceptance of CBEM protocols and outcomes. Engaging decision-makers early in the design process can give vision to the program, recognizing crucial environmental indicators for monitoring and appropriate approaches (McKay and Johnson 2017).

Subcomponents

a) Existence of long-term commitment to develop partnerships with communities (Johnson et al. 2015): Increased communication and collaboration among community groups, government agencies and the general public will take persistence, practice and sensitivity to all stakeholder interests. All partnerships involve a certain level of trust and co-operation by those involved, and such trust can only be earned with time (Day and Litke 2005, as cited in Conrad and Daoust 2008).

b) Organization of workshops and training for community members: While CBEM regimes may incorporate methods training for community collaborators, it can be challenging to provide a required level of technical skills for community members. This lack of skill can lead to issues with data collection that will be revealed later, slowing progress and creating gaps in data (Johnson et al. 2015). Training community members is a capacity-building element that supports building partnership relationships with communities.

c) Collaborating with bridging organizations: Bridging organizations' work serves to mediate connections between previously unconnected actors or actor groups, including different levels of governance and resource and knowledge systems (Berkes 2007). By occupying a mediating position, bridging organizations can play an important role in capacity building by facilitating co-ordinated actions between actors and groups who lack the trust, capacity, resources, mandates or interest in connecting directly (Armitage and Plummer 2010; Rathwell and Peterson 2012, as cited in Pollock and Whitelaw 2005). The involvement of bridging organizations could help to establish better co-ordination of community meetings (e,g., through roundtables) and transparency in interactions between stakeholders. Co-ordinators reported that roundtables, or other arenas that work toward transparency, neutrality and openness, provided a forum in which ecological monitoring for local sustainability could be discussed most productively (Wilson et al. 2018).

Presence of Legal and Institutional Framework for CBEM and ILK in Provincial and Federal Legislation

The greatest challenge facing CBEM groups, in terms of community involvement and capacity, is the willingness and readiness of decision-makers and management institutions to work with citizens and community stakeholders for stewardship and sustainability (Day and Litke 2005, as cited in Conrad and Daoust 2008).

CBEM data are often not used to inform policy-makers. Some scientists and decision-makers may be unsure about the accuracy of data collected through CBEM methods (Conrad and Daoust 2008). More commonly, ILK, which is a large component of CBEM data, is not used due to the lack of incorporation of ILK into existing wildlife management systems. The clear and direct instructions on knowledge co-production would suggest a clear mechanism for uptake by policy-makers.

Due to distinctions in epistemology and the use of metaphorical language, translation of ILK into scientific and decision-makers' language remains a great challenge. Not all ILK data are easily translatable into policy (Berkes, Berkes and Fast 2007). In the Canadian legislation, CBEM is driven by Section 35 rights of the Constitution Act (1982), which recognizes that ILK is maintained, transmitted and developed by Indigenous Peoples through lived experience on the land (Beausoleil et al. 2021). Provincial regulations mention ILK in CBEM guidelines but the ILK incorporation in CBEM is merely a recommendation. For example, the Oil Sands Monitoring Program Operational Framework Agreement, released by the government of Alberta in collaboration with the government of Canada, includes incorporation of Indigenous knowledge in CBEM as part of core principles of CBEM, but does not provide specific guidance on how to meaningfully incorporate ILK in CBEM and policy (Dube et al. 2018). Similarly, the NWT Water Stewardship Strategy, Northern Voices, Northern Waters, names ILK as "best available knowledge" but does not provide any detailed instructions on how to incorporate ILK into existing policy framework (Government of Northwest Territories 2011). NWT-wide community-based water quality monitoring results from 2013 demonstrate scientific findings from the CBEM but it is unclear whether ILK has been included in the report (Government of Northwest Territories 2013). Thus, the AB and NWT provincial reports on CBEM demonstrate a lip-service trend (or tokenism) when TEK is incorporated only with the purpose to meet the formal requirements of the study (Chapman and Schott 2020). For example, in the intergovernmental organization, the Arctic Council, lip service in scientific reports and assessments is expressed through noting ILK benefits and value, as well as with an expression of respect for the Indigenous communities. Lip service has become quite common in scientific reports and assessments (Sidorova 2020).

Besides a lip-service trend in knowledge co-production, CBEM programs are very specific — they only refer to particular environmental issues such as oilsands development impacts or water quality monitoring. Social benefits and costs of infrastructure development should also be reflected in CBEM. Large-scale infrastructure project proposals have featured intertwined issues of impact on the natural environment and impact on Indigenous Peoples (Sulzenko and Fellows 2016). Focusing on specific types of impacts in the CBEM policy development is too narrow and requires reconsideration.

Subcomponents

a) Funding for CBEM: The funding infrastructure in northern and Arctic regions does not support the long-term nature of CBEM programs. There is a need for long-term funding commitments for CBEM initiatives to ensure that programs can build sustainable practices and gather data over time; this will enhance the value of the data to decision-makers (Johnson et al. 2016).

b) Translating CBEM outcomes (ILK) into useful formats for policy: Mapping out these connections during the program design phase can help ensure that data are translated into useful formats and delivered to interested parties (Conrad and Daoust 2008).

c) Building a legal space for CBEM and ILK: The ILK generated from CBEM can be effectively incorporated into natural resource management (NRM) policy and action, but it requires institutions to evolve the concept of environmental management to allow for unique cultural interpretations of place. NRM practitioners are recognizing the need for community-based knowledge to be incorporated into planning and action, but without a wider policy framework for Indigenous monitoring and comprehensive methodologies for engagement, approaches are restricted in scope (Wiseman and Bardsley 2016).

d) Broadening the impact scopes in the design of CBEM programs: Including not only specific impacts of resource development (i.e., oilsands, water pollution), but also addressing the cumulative impacts of large-scale infrastructure in CBEM design would benefit the CBEM outcomes.

4.2 CHALLENGES IN CBEM PROGRAMS

Unlike CBEM shortfalls (gaps), which are mostly the systemic, regular issues, challenges in CBEM refer to the situational problems that negatively influence knowledge co-production, which might be overcome in the process.

Technical Challenges

Lack of experience with CBEM might result in technical issues and issues related to unfamiliarity with local conditions such as lack of access to technology in the North (Fernández-Giménez, Ballard and Sturtevant 2008; Johnson et al. 2015). Due to infrastructural inequalities, access to technology remains a problem, and internet speed is considerably slower in higher latitudes than in lower latitudes of Arctic nations because of infrastructural inequities (Johnson et al. 2015). Challenges related to technology infrastructure also shape how CBEM and ILK are managed. These considerations need to be reflected in the development of plans for storing and sharing data, particularly under the northern climatic conditions.

Organizational Challenges

Not all CBEM projects were highly successful, as in some cases the project was among the first collaborative monitoring efforts. Consequently, significant learning about the technical and organizational aspects of collaborative monitoring occurred, and that learning has been applied to subsequent monitoring projects by the same CBEM with clearer beneficial outcomes (Fernández-Giménez, Ballard and Sturtevant 2008). The lack of familiarity with ILK and knowledge co-production can result in interoperability. Interoperability has been defined as “circulation of data across diverse technical platforms, organizational environments, disciplines and institutions” (Millerand and Bowker 2009, 150, as cited in Johnson et al. 2015). Interoperability issues occur at three levels: 1) data storage format, which includes issues in exchanging different formats and the use of different character sets (e.g., syllabics); 2) data structure, which includes how the data are organized (in flat files or relational databases, for example); and 3) data semantics and semantic interoperability. The last issue relates to the fact that data sets are in fact references to larger systems of meaning and understanding (Sillitoe 1998; Wellen and Sieber 2013, as cited in Johnson et al. 2015) and is perhaps the most difficult aspect of data management to address.

Data ownership issues often pose a serious challenge to researchers. Effective data management in initiatives that involve ILK and respond to locally identified environmental management challenges requires both sensitivity and technical skill. ILK documentation often removes this knowledge from the context in which it was developed, raising questions about the feasibility and desirability of knowledge integration (Agrawal 2002, as cited in Johnson et al. 2015). Data must be managed in a culturally sensitive way that promotes sharing when appropriate, while ensuring that knowledge-holders and communities retain control of their knowledge.

Financial Challenges

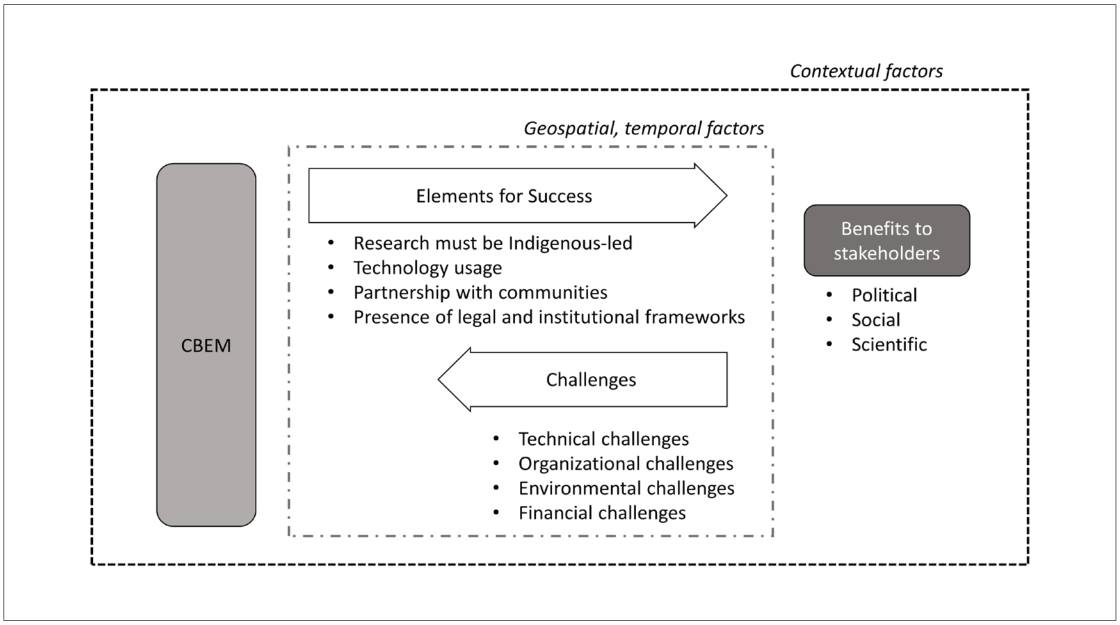
Lack of funding is a key resource for successful implementation of CBEM, along with other resources such as capacity and quality assurance of data. The lack of funding can result in CBEM limitations (McKay and Johnson 2017).

Environmental Challenges

Weather changes can affect the CBEM results by creating monitoring challenges in the rangelands. Ecosystems within semi-arid rangelands are dependent upon extremely variable rainfall events and consequent water flows (Ludwig and Tongway 1997; Stafford-Smith et al. 2009, as cited in Wiseman and Bardsley 2016). This stochasticity both in space and in time presents difficulties for maintaining monitoring consistency and detecting significant changes or causal relationships (Ludwig and Tongway 1996; Morton et al. 2011; White et al. 2012; Waudby et al. 2013, as cited in Wiseman and Bardsley 2016). A difference of days between observations before or after major rainfall events can mean the difference between a landscape that appears degraded and one that is lush and seemingly full of wildlife (Box et al. 2008, as cited in Wiseman and Bardsley 2016). The positioning of monitoring sites in the landscape can also give widely varying results depending on differences in local water flow and catchment-scale succession processes (Pringle et al. 2006, as cited in Wiseman and Bardsley 2016).

A graphic representation of the dynamics of elements of success and challenges for meaningful incorporation of ILK through CBEM and potential benefits to stakeholders is presented in Figure 4. Contextual factors in Figure 4 refer to elements that impact the CBEM program that are inherent to the governance, funding, organization and objective of the CBEM during design stage. Also, geospatial and temporal factors refer to elements specific to the geography, community, ecosystem and time scale for implementation and impact monitoring considered part of the CBEM before its implementation. Such factors are considered to influence the CBEM design and execution based on specific needs and priorities of the stakeholders involved in the program. A summary of the elements of success and challenges along with their corresponding subcomponents are shown in Table S1 and Table S2 in the Supplementary Information.

Figure 4. Schematic Framework for the Assessment of CBEM Implementation (CBEM-IF)



Source: Prepared by the authors (2022). CBEM-IF highlights the elements of success and challenges for ILK meaningful incorporation through CBEM and its potential benefits to stakeholders.

5. LESSONS LEARNED — CBEM CASE STUDIES IN PROVINCES AND TERRITORIES ACROSS MIDDLE AND NORTHERN CANADA

Three case studies from Canada were examined to assess ILK incorporation and lessons learned with respect to benefits to stakeholders through CBEM. Different geographies, ecosystems and communities were selected to evaluate the proposed framework in a variety of contexts. The CBEM-IF framework implementation consisted of identifying elements of success and challenges observed during the implementation of each case study and discussed as lessons learned. Each case study provided the data on the practical experience of adopting and implementing CBEM in the Canadian North and near-North. The Canadian provinces that comprise the selected case studies, as well as the type of infrastructure referred to as part of human disturbances in these studies (such as mining, railroads, roads, urban expansion), are all within the scope of the CNC concept. The selected case studies could serve as an example of potential CBEM programs that could be deployed as part of impact assessment and deployment plans for proposed CNC infrastructure.

5.1 BERRY PICKING IN ALBERTA'S OILSANDS REGION (ALBERTA)

Janelle Baker worked on a research project with Fort McKay and the Wood Buffalo Environmental Association (WBEA), a non-profit organization that has been monitoring air quality in the Athabasca oilsands region since 2011 (Baker 2018). The project was funded by the Canada-Alberta Joint Oil Sands Agreement and supported technically by WBEA (Baker 2018; Baker and The Fort McKay Berry Group 2017). The WBEA erected passive air monitoring stations in each of the berry patches and started assessing berries tested for nutritional value and contaminants. The berry group continued to assist with maintaining the air monitoring stations, changing the filters, doing regular readings and collecting berries for testing (Baker 2016). The berry project started in 2011 and the project members decided to start visiting berry patches in 2012 (Baker 2018).

Baker (2018) views this Indigenous-led project as a perfect form of community-based research because it is collaborative and involves berry picking together with community members. The research was "vegetalized" (Myers 2015, as cited in Baker 2018) as they grew slowly, sensing the air, soil and rain, and also one another (Baker 2018; Baker 2021). After some time, the project members learned to assess and observe the quality of berries and other land-based features (Baker 2018). Rather than just harvesting and analyzing plants, they perceived them as kin, as members learned about respect and care, as well as about neglect and harm through the community stories (Baker 2018; Baker 2021; Baker and The Fort McKay Berry Group 2017).

Baker and WBEA ensured that the following methodologies were employed in the WBEA-Fort McKay Berry Focus Group Project (WBEA 2021):

- Community-based Research: This research method is required to work with the community of Fort McKay. In the context of this project, the Fort McKay Sustainability Department hired a focus group of specialists for this project (WBEA 2021).The focus group, in general, guided the process through meetings, and also elected two team members to make logistical and final decisions for the research team regarding project design.
- Informed Consent: In order to meet Fort McKay requirements and professional ethical standards in social science research, informed consent was given before recording or sharing any information gathered during the research.
- Participant Observation : In the case of the berry project, it meant being engaged with the research group, harvesting berries, supporting project logistics, learning the languages and getting acknowledged with the focus group members.
- Informal Interviews: For example, regarding berry contamination, researchers asked which berries were considered to be contaminated and why. Information interviews were ad hoc, held in the field and open-ended.
- Information Recording: Whenever consent was given and the setting was appropriate, activities and interviews were recorded with a flip video camera, digital camera and GPS handheld device.
- Verification: For this project, a verification meeting was held during which the project results were presented to the focus group and Fort McKay Sustainability Department.

Most challenges presented in previous sections, including technical, organizational, financial and environmental, were either not reported or overcome by researchers. As WBEA provided technical support, challenges related to the lack of access to technology did not present an issue. Because the funding was provided by the Canada-Alberta Joint Oil Sands Agreement, financial challenges were also overcome. The project did not encounter organizational challenges because the project was Indigenous-led; interoperability caused by the lack of knowledge about ILK was not an issue. As participants gave informed consent, and the project lead organized a verification meeting where the outcomes of the study were presented to the focus group, data ownership issues did not occur. The project lead did not report environmental challenges such as weather changes.

The additional challenge that the researchers encountered included the lack of legal and institutional framework for the inclusion of ILK in Alberta and Canada, which also can be considered a limitation in the existing legal system in Canada. The ILK on berries in Fort McKay was not reflected in Alberta legislation. This was a challenge because ILK in Canada is not actually being seriously considered in environmental decision-making as it is only perceived as legitimate when it has been adapted to the specialized narrative of science. Statements that support conventional environmental science are used to show the progressive bend of industry and the government, while at the same time knowledge that does not align with Western-style decision-making is ignored (Baker 2021).

As Baker notes, including ILK in assessments has not served to improve the status of Indigenous views (Povinelli 1995, as cited in Baker 2021). Although environmental impact assessments include traditional land-use assessments, "the evaluative apparatus of national or international economic policy has been little influenced by non-Western understandings of human-environmental relations" (Baker 2021).

Lessons Learned

ICBEM format, the presence of a bridging organization (WBEA) and funding from the government made the project successful and accountable to community members. The information about berry contamination was not included in current policy frameworks due to the lack of space for meaningful incorporation of ILK into provincial and federal policies and guidelines. As noted above, only those elements of ILK that fit scientific outcomes are usually included in the reports.

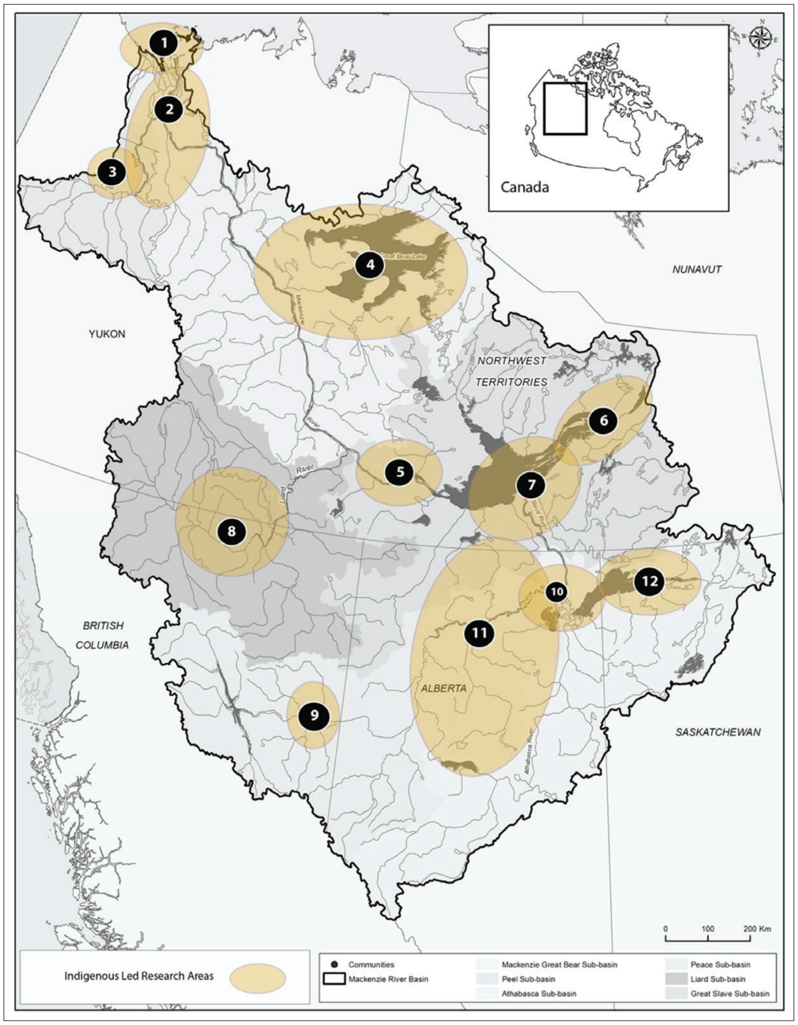
As Baker (2018) also notes, the duty to consult with Indigenous communities has not been implemented in a meaningful way in Alberta. First Nations were not consulted about the creation of the very consultation policy and guidelines they were expected to comply with. The Alberta government and the Crown are the final arbitrators regarding the adequacy of their own consultations, not the judiciary. The process used by the province treats both First Nations and all non-Indigenous peoples in the same way, reducing the constitutional rights of First Nations to the level of stakeholders. Furthermore, these processes are often facilitated by private entities, leading to Alberta's dependence on the private sector to respect constitutional obligations. Finally, Indigenous People were not involved in pre-2005 decision-making regarding natural resource development or related policies, and so have wholly rejected the Alberta Consultation Policy (Baker 2018).

5.2 MACKENZIE RIVER BASIN WATER MONITORING PROGRAM (ALBERTA, BRITISH COLUMBIA, NORTHWEST TERRITORIES, NUNAVUT, SASKATCHEWAN AND YUKON)

The Mackenzie River Basin (MRB) drains about one-fifth of the total land area of Canada (1.8 million km^2), spanning six Canadian provinces and territories: Alberta, British Columbia, the Northwest Territories, Nunavut, Saskatchewan and Yukon. It is the largest river basin in Canada and one of the biggest in the world. This basin covers plains, wetlands, lakes, grasslands, boreal and subarctic forests and tundra (Woo and Thorne 2003). The MRB is home to more than 400,000 people. First Nations, Métis and Inuvialuit are spread across numerous cities, towns, villages, hamlets and settlements where 11 Indigenous languages are spoken (Mackenzie River Basin Board 2021; Parlee et al. 2021). The goal of the project was to strengthen the voices of subsistence fishers and Indigenous communities in the governance of major freshwater ecosystems. Brenda Parlee and Tracy Howlett led this project. Indigenous communities in the Mackenzie River Basin who fish were involved in this project. The Tracking Change project was funded by the Social Sciences Humanities Research Council of Canada and led by the University of Alberta, the Traditional Knowledge Steering Committee of the Mackenzie River Basin Board, the government of the Northwest Territories and other partner organizations (University of Alberta 2021).

The Tracking Change project was conducted from 2016 to 2018, led by 12 Indigenous governments and organizations (see Figure 5) (University of Alberta 2021). Indicators and methods for tracking change in aquatic ecosystems and fishing livelihoods were co-developed among participants. Indigenous leaders and representatives developed a framework for community-led projects to include the health of the aquatic environment, the health of fish species, sustainability of fishing livelihoods and integrated perspectives among the basin. Within this framework, 30 community-led projects were within MRB. Regional meetings, workshops and knowledge sharing among participants were conducted to develop research capacity among communities. Also, youth knowledge fairs (grades 10–11) were created to share learning opportunities and connect elders with other youth (Parlee et al. 2021). The project resulted in the design of a research toolkit for future CBEM studies, several peer-reviewed publications and a series of webinars on ILK in fishing livelihoods (University of Alberta 2021).

Figure 5. Map of Study Area for Selected Indigenous-led Studies Within the Tracking Change Project



Source: Reproduced with permission from Parlee et al. (2021).

The monitoring data were collected via semi-structured interviews for individuals and households, youth training, experiential learning, elder-youth knowledge sharing and participatory mapping. In addition, each community developed their own methods for observation and record of changes along with their own indicators; for example, total and health of fish harvest, contribution to subsistence, migration patterns, water levels, water quality and climate risks (Martin, Parlee and Neyelle 2020; Stenekes, Parlee and Seixas 2020). The project was designed based on the characteristics of each community. The integration of qualitative and quantitative indicators from both Western-scientific and ILK was approached via a "methodological bricolage" framing which involves co-development, CBEM, capacity building, network learning and digital platforms. Research capacity was not homogenous among communities. Therefore, necessary support was needed to meet the project goals (Parlee et al. 2021).

Lessons Learned

The lessons from monitoring aquatic ecosystems were strongly related to practices to live off the land and current concerns on safety, food security and travel routes. Indicators used by Indigenous hunters overlapped in about 50 per cent of those used in biological sciences. However, Indigenous indicators were more numerous, qualitative and implemented with a system approach. A dynamic connection between knowledge generation and social learning was key to expanding the positive impacts of the findings. Also, CBEM approaches could contribute to decolonization, incorporate a diversity of knowledge and perspectives and provide effective strategies for monitoring watersheds and other large-scale societal challenges (Parlee et al. 2021).

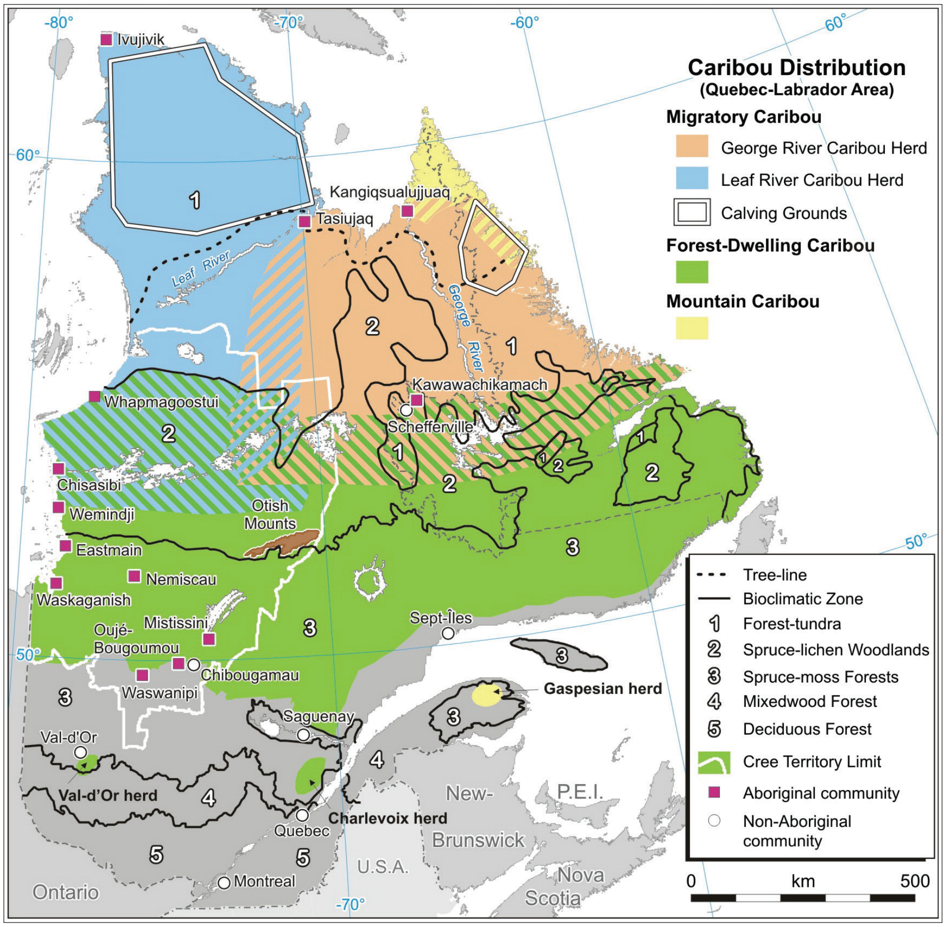
The 2018-2019 Tracking Change Report on Local and Traditional Knowledge in Watershed Governance indicated that the recognition of ILK as a source for informed decision-making varies across the provinces and territories involved in the project. In some jurisdictions, governments have created a clear role for traditional knowledge in decision-making regarding water resources. As the report states, where there is greater respect for ILK, resource conflicts are fewer. For example, in the NWT respectful inclusion of ILK is embedded in the NWT Water Stewardship Strategy. In B.C., where resource conflicts and uncertainties about natural resources are more common, there is little to no recognition of ILK (Tracking Change 2020). Hence, success of CBEM ILK incorporation depends on the provincial policy regarding ILK recognition.

5.3 EFFECT OF MINING ON CARIBOU POPULATIONS AND INDIGENOUS LIVELIHOODS (QUEBEC AND LABRADOR)

The barren-ground caribou, *Rangifer tarandus*, is a member of the deer family found in Arctic and sub-Arctic zones. This species is characterized by living in large groups and long migrations (COSEWIC 2016). The barren-ground caribou is a keystone species that plays a critical role in the northern ecosystem. Caribou harvesting is strongly linked to socioeconomic well-being and the cultural identity of numerous northern societies (Herrmann et al. 2014). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) classified barren-ground caribou as threatened since their population has significantly decreased in the last few years due to increased forest fires and growth in industrial infrastructure (COSEWIC 2016). Changes in the number and distribution of caribou ranges have socioeconomic and cultural implications for the communities in the area (Mameamskum 2013).

This caribou CBEM project, led by Thora Martina Herrmann from the Université de Montréal, aimed to assess the impacts of climate change and human activities associated with mining in the Arctic on caribou, the land and Naskapi Nation of Kawawachikamach (Herrmann et al. 2014; Mameamskum 2013). Co-development with community members, geospatial information tools for field data collection, workshops and interviews enabled the development of indicators and understanding of the impacts of changes in caribou health and behaviour over food security, habitat and socioeconomic well-being. Community-based monitoring was integrated with a CyberTracker GPS tool customized for community members to register geo-referenced caribou data that were compiled and represented in map formats. Community research assistants received training in caribou survey techniques, data collection and participatory research methods. In addition, workshops and in-depth interviews were carried out to document observed changes in caribou migration patterns, health, behaviour, habitat and resulting impacts on the community's livelihood. Figure 6 shows a map of the different caribou ranges and communities in the area located in northern Quebec and Labrador.

Figure 6. Caribou Distribution in Northern Quebec/Labrador (Canada)



Source: Reproduced with permission from Herrmann et al. (2014).

This study found that human disturbances affected caribou habitats, migration routes and northern livelihoods. These disturbances were broad and varied across caribou subspecies, seasons and type of activity. Infrastructure for mining, such as roads, railway tracks and power lines, created fragmented habitats that led to habitat loss and altered migration routes. These changes have a direct impact on hunting practices, and therefore affect the culture, identity and traditional ways of living of Arctic communities. However, the impacts studied are case-specific and affected by multidimensional factors. There are many contextual factors that define the level and extent of these impacts which must be assessed for each case. The authors argue that the impacts observed are not due to mining alone. Instead, cumulative effects and interaction between hydroelectric development, forestry, roads, increased predator numbers and climate intensify the negative impacts on caribou population and habitat (Herrmann et al. 2014).

Lessons Learned

Through the implementation of CBEM, this project improved the understanding of how human activities and climate change affect northern livelihoods, the potential of cumulative effects and how Indigenous subsistence activities operate within the region. The project also offered opportunities for enhancing the integration of Indigenous knowledge and Western science, increased learning opportunities among participants, bridged communication between communities and other stakeholders and demonstrated how co-developed tools foster more effective action plans for co-operation and mitigation of negative impacts on the environment. As a result, this project provided the Naskapi community with a climate change adaptation plan to apply to animals, hunting, travelling, health, well-being, culture and learning. The project helped to raise awareness on climate change and health issues such as emergency response, health protection, programs on food security and diseases.

Table 1. Summary of Success Elements and Challenges for Three Canadian Case Studies Involving Community-based Monitoring for the Evaluation of Impact of Infrastructure Projects

Case Study	Berry Picking in AB's Oilsands Region (AB)	Mackenzie River Basin Water Monitoring Program (AB, BC, NWT, NT, SK and YT)	Effect of Mining on Caribou Populations and Indigenous Livelihoods (QC/NL)
Successful Elements			
Research Must Be Indigenous-led	Indigenous-led research with holistic approach; the collaboration with the INGO (WBEA); the involvement of the Indigenous government (the Fort McKay Sustainability Department).	Indigenous-led community-based monitoring; supported by methodology co-development as part of the Tracking Changes project. https://trackingchange.ca/about/annual-reports/	Joint initiative of the Naskapi Nation of Kawawachikamach, Natalie D'Astous, Atmacinta and the Université de Montréal; the project was led and mainly executed by the Naskapi Nation of Kawawachikamach, supported by Western scientists.

Case Study	Berry Picking in AB's Oilsands Region (AB)	Mackenzie River Basin Water Monitoring Program (AB, BC, NWT, NT, SK and YT)	Effect of Mining on Caribou Populations and Indigenous Livelihoods (QC/NL)
Technology Usage	The use of technology, including laboratory testing, recording of activities and interviews with a flip video camera, digital camera and GPS handheld device, resulted in the collection of accurate and timely high-quality data to ensure regional stakeholders had the information they needed to make environmental policy decisions (WBEA 2021).	Blending or braiding TEK with Western science-based indicators (Martin 2020), use of mapping and quantitative methods contributed a more comprehensive consideration of the cultural landscape in cumulative impact assessments (Proverbs et al. 2020).	Knowledge co-production was based on Naskapi and non-Indigenous perspectives. Mapping and meteorological data were incorporated into Naskapi traditional knowledge. A geospatial data tool, Cyber Tracker, based on GPS, was customized to enable rapid and accurate recording of observations of caribou and their tracks. Technology usage contributed to the collection of geographical information on human-environment interactions over time and space in a land use conflict setting. In addition, community mapping and GIS aimed to empower Indigenous communities to participate in decision-making.
Partnership with Communities	The use of informed consent; focus group engagement; interviews; collaborative project with communities; the application of participant observation.	Indigenous steering committee; 12 volunteering communities involved; terms of reference co-developed on participatory workshops; community-based participatory research (CBPR) approach and insurgent research approach; semi-structured interviews; knowledge dissemination in plan language; and culturally appropriate content.	Community workshops; participatory mapping; interviews; capacity building; and training of Naskapi research assistants on qualitative and quantitative methods.
Policy Translation and Implementation — Adequate Administrative and Legal Structure	As the project lead stated, the study outcomes were not incorporated into provincial (AB) and federal legislation due to the lack of adequate legal structure. The project was funded by the federal and provincial governments and technical support was provided by WBEA.	The success of ILK incorporation depends on the provincial policy regarding ILK recognition. NWT policy was considered to be more respectful toward ILK, whereas B.C. policy did not recognize ILK to a great extent; project funded primarily through a federal grant (SSHRC) to the University of Alberta (the Tracking Change project); funding in support of the project was also received from the government of the NWT (e.g., through the Aboriginal Steering Committee of the Northwest Territories Water Stewardship Strategy), the government of AB and the University of Alberta with other in-kind contributions to projects led by Indigenous partners.	The project leads did not report how the study outcomes informed decision-making. The project was funded by OURANOS (non-profit organization), Aboriginal Affairs and Northern Development Canada, the QC Centre for Biodiversity Science, Le Groupe Hémisphère and TaTa Steel (New Millennium Iron Corp.)

Case Study	Berry Picking in AB's Oilsands Region (AB)	Mackenzie River Basin Water Monitoring Program (AB, BC, NWT, NT, SK and YT)	Effect of Mining on Caribou Populations and Indigenous Livelihoods (QC/NL)
Challenges			
Technical Challenges (e.g., the lack of access to technology in the North that could negatively affect scientific measurements; the lack of training for volunteers that could result in the production of inaccurate data).	No issues related to technology usage as the WBEA provided technical support and participant training. The participants learned how to collect samples for laboratory testing.	Changes in biodiversity are associated with many aspects, with complex interactions such as industrial/urban development, climate change, change in consumer patterns and unfavourable regulations.	Cyber Tracker tool only allowed pictorial information; long time required for compiling and distributing data to other researchers and the general public.
Organizational Challenges	Not reported.	Research capacities varied across the communities in MRB. Research guidelines and research support were provided to build further capacity among the communities. Alignment of governance structure for the communities and territorial, provincial and federal government is not present in all jurisdictions and could restrict incorporation of ILK. Restricted access to key fishing and cultural areas due to provincial government regulations.	Guaranteed long-term community participation; direct consultation of communities on environmental and social impacts is essential to occur as a first step.
Environmental Challenges	Not reported.	Observations of reduced water levels as a potential consequence of climate change. Lower water levels limited access to certain areas for monitoring. Environmental degradation, warming water temperature and increased forest fires affected fish habitats and populations. Limited access to healthy water and fishing resources endangers the continuity of traditional knowledge.	Changes in ice and snow conditions, ice thinning and earlier melt and later freeze are unsafe for hunters and travellers to move through land. Changes in environmental conditions may hinder community participation.
Financial Challenges	No issues, the project was funded by the governments.	High cost for fishing gear and transportation.	Not mentioned.
Additional Challenges	Lack of legal and institutional framework for ILK incorporation in AB and Canada.	Monitoring results and experiences is intellectual property that belongs to the communities. Communities determine how to use this information. CBEM perceived as too simple and small in scale to offer relevant insights to large-scale environmental and socioeconomic problems.	

6. CBEM IMPLEMENTATION WITHIN THE CANADIAN NORTHERN CORRIDOR

There are several advantages to the process of ILK incorporation within CBEM programs, many of which are of particular relevance in northern and Arctic communities:

- They can facilitate the incorporation of ILK and science;
- They engage community members in the monitoring process — from indicator selection to data analysis;
- They produce outcomes that stakeholders perceive as more rigorous, legitimate and relevant;
- They can be a powerful instrument in land-use conflict resolution; and
- They represent an inexpensive approach to monitoring the circumpolar North (Herrmann et al. 2014).

CBEM helps to increase environmental justice by systematizing ILK and new observations into data that are readable and usable for stakeholders, as opposed to anecdotal and sporadic evidence (Mena et al. 2020).

In the Canadian context, several CBEM studies provided opportunities to learn how CBEM programs can contribute to the knowledge co-production in northern and Arctic Canada. Knowledge co-production within CBEM could enhance the recognition of environmental impacts of the large-scale infrastructure projects, such as the CNC, on Indigenous and local communities in the North and near-North. Significant overlap between scientific and community indicators was found, which increases the legitimacy of the findings. The absence of CBEM in provincial and federal guidelines, however, led to the lack of inclusion and incorporation of these findings in new regulatory frameworks.

For the CNC, a meaningful incorporation of ILK through CBEM and other strategies is key to succeed where other projects have fallen short because of tokenism, lack of meaningful engagement with communities, power imbalance between Western science and ILK and other factors. Incorporating ILK as a core element at an early stage would enhance the knowledge co-development process. The proposed CBEM-IF framework outlines necessary elements to incorporate for the design of appropriate CBEM programs within the CNC. Indigenous leadership, technology incorporation, equal partnership with communities and availability of institutional guidelines are required to enable proper implementation of CBEM programs. To reduce the impact of barriers associated with access to proper training and to reduce capacity gaps, adequate and clear collaboration agreements between participants, planning for seasonal access to the areas of interest and proper funding for the implementation and continuity of the program must be in place when developing CBEM programs within CNC. In addition, alignment with provincial and federal policies is required to reduce potential barriers and conflicts along with the current or future policy mix.

CBEM could support ILK incorporation in CNC but limitations, such as including lack of policy, high reliance on volunteers, lack of standardized methods, focus on specific types of landscape, general issues with TEK incorporation into science and policy issues due to incommensurability of Western science and the ILK epistemologies, must be addressed. Other challenges for CBEM knowledge co-production include technical, organizational, financial and environmental issues. Some of these limitations and challenges can be addressed through the application of successful elements from previous international and Canadian CBEM studies.

From the three case studies examined, it was possible to identify that CBEM programs lead to initiatives, strategies and action plans as a result of the learning process. The use of technologies (e.g., mapping, GIS and earth observations) increases detection rates and generates more accurate data. Inviting professional consultants might also increase the technical legitimacy of data for decision-makers. The community member training by technical specialists and environmental scientists contributes to the capacity-building level of Indigenous communities.

7. CONCLUSION

The CNC's deployment will touch several Indigenous communities in the Canadian North and near-North. Important elements of the CNC include enhancement of the prospects for northern and Indigenous development, improvements in environmental monitoring in the North, increases in transportation options for trade expansion and diversification and support for northern security objectives. Indigenous and local knowledge can be key for the identification of potential socioeconomic and environmental risks. ILK can also function as a valuable resource in planning and managing major projects. This paper evaluated CBEM as a more effective vehicle for ILK incorporation in adaptation and mitigation planning for environmental change due to human disturbances.

Incorporating ILK into large-scale northern infrastructure development can improve the sustainability practices because knowledge co-production broadens conceptual understanding and provides more opportunity for actions to foster sustainable futures (Lam et al. 2020). The emotional and spiritual components of ILK benefit sustainability transformation contexts because ILK systems are knowledge-action-belief complexes and entail different conceptualizations of human-nature connectedness (Gadgil et al. 1993; Reid et al. 2006; Gray 2016; Berkes 2018, cited in Lam et al. 2020).

The outcomes from this study advise that potential policy responses for the design of CBEM could include collaboration with Indigenous governments and Indigenous leadership of CBEM programs; creation of funding opportunities for CBEM by public and private stakeholders; co-operation with bridging organizations; recognition of CBEM outcomes as intellectual property; building a legal space for diverse types of CBEM; and providing guidance for ILK incorporation in national and provincial/territorial legislation in Canada.

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