frontiers | Frontiers in Conservation Science

TYPE Review
PUBLISHED 01 September 2023
DOI 10.3389/fcosc.2023.1220521

OPEN ACCESS

EDITED BY
Saleem H. Ali,
University of Delaware, United States

REVIEWED BY
Andrew Luke Skowno,
South African National Biodiversity Institute, South Africa
L. Jen Shaffer,
University of Maryland, College Park, United States

*CORRESPONDENCE
Tom Barry
tom@unak.is

RECEIVED 10 May 2023
ACCEPTED 04 July 2023
PUBLISHED 01 September 2023

CITATION
Barry T, Christensen T, Behe C, Coon C, Culp JM, Vongraven D, Fletcher S, Gill M, Goedkoop W, Hindrum R, Jacobson C, Jones T, Lárusson KF, Lento J, Marissink M, McLennan D, Price C, Rönkä M, Svoboda M, Thaulow I, Taylor J, Wegeberg S, Schmidt NM, Smith R and Petersen Æ (2023) Development of a multi-scale monitoring programme: approaches for the Arctic and lessons learned from the Circumpolar Biodiversity Monitoring Programme 2002-2022. *Front. Conserv. Sci.* 4:1220521. doi: 10.3389/fcosc.2023.1220521

Development of a multi-scale monitoring programme: approaches for the Arctic and lessons learned from the Circumpolar Biodiversity Monitoring Programme 2002-2022

Tom Barry[1,2]*, Tom Christensen[3], Carolina Behe[4], Catherine Coon[5], Joseph M. Culp[6], Dag Vongraven[7], Sierra Fletcher[8], Micheal Gill[9], Willem Goedkoop[10], Reidar Hindrum[11], Cynthia Jacobson[12], Tahzay Jones[13], Kári Fannar Lárusson[14], Jennifer Lento[15], Mark Marissink[16], Donald McLennan[17], Courtney Price[14], Mia Rönkä[18], Michael Svoboda[19], Inge Thaulow[20], Jason Taylor[21], Susse Wegeberg[3], Niels Martin Schmidt[3], Risa Smith[22] and Ævar Petersen[23]

[1]Faculty of Humanities and Social Sciences, University of Akureyri, Akureyri, Iceland, [2]Stefansson Arctic Institute, Akureyri, Iceland, [3]Department of Ecoscience, Aarhus University, Roskilde, Denmark, [4]Independent researcher, Seattle, Washington, DC, United States, [5]Bureau of Ocean Energy Management - Alaska Regional Office, Department of the Interior Region, Anchorage, AK, United States, [6]Department of Biology, and Geography and Environmental Studies, Wilfrid Laurier University, Waterloo, ON, Canada, [7]Norwegian Polar Institute, Tromso, Norway, [8]Nuka Research and Planning Group, Seldovia, AK, United States, [9]Biodiversity Indicators Program, NatureServe, Arlington, VA, United States, [10]Department of Aquatic Sciences and Assessment, Swedish University of Agricultural Sciences, Uppsala, Sweden, [11]Independent researcher, Trondheim, Norway, [12]Innovative Outcomes, Carbondale, CO, United States, [13]National Park Service, Anchorage, AK, United States, [14]Conservation of Arctic Flora and Fauna (CAFF), Akureyri, Iceland, [15]Canadian Rivers Institute and Department of Biology, University of New Brunswick, Fredericton, NB, Canada, [16]Swedish Species Information Centre, The Swedish University of Agricultural Sciences (SLU) Artdatabanken, Uppsala, Sweden, [17]COENOSIS, Martins Brook, NS, Canada, [18]Biodiversity Unit, Faculty of Science, University of Turku, Turku, Finland, [19]Environment and Climate Change, Whitehorse, YT, Canada, [20]Enviromental Affairs, Government of Greenland, Greenland Representation, Copenhagen, Denmark, [21]Aldo Leopold Wilderness Research Institute, University of Montana, Missoula, MT, United States, [22]The International Union for Nature Conservation (IUCN), World Commission on Protected Areas, Gland, Switzerland, [23]Independent, Researcher, Reykjavík, Iceland

The Arctic Council working group, the Conservation of Arctic Flora and Fauna (CAFF) established the Circumpolar Biodiversity Monitoring Programme (CBMP), an international network of scientists, governments, Indigenous organizations, and conservation groups working to harmonize and integrate efforts to extend and develop monitoring and assessment of the Arctic's biodiversity. Its relevance stretches beyond the Arctic to a broad range of regional and global initiatives and agreements. This paper describes the process and approach taken in the last two decades to develop and implement the CBMP. It documents challenges encountered, lessons learnt, and solutions, and considers how it has been a model for national, regional, and global monitoring programmes; explores how it has impacted Arctic biodiversity monitoring, assessment, and policy and concludes with observations on key issues and next steps. The following are overarching prerequisites identified in the implementation of the CBMP: effective coordination,

sufficient and sustained funding, improved standards and protocols, co-production of knowledge and equitable involvement of IK approaches, data management to facilitating regional analysis and comparisons, communication and outreach to raising awareness and engagement in the programme, ensuring resources to engage in international fora to ensuring programme implementation.

KEYWORDS

Ecosystem-Based Management, Indigenous Knowledge, co-production of knowledge, CAFF, Arctic Council, Arctic, conservation

1 Introduction

The Arctic[1] contains over 21,000 species, has a high rate of endemism and is home to globally significant populations of unique cold-adapted species, many of which support traditional cultures and contribute significantly to global biodiversity (Eamer et al., 2013; Meltofte, 2013; ICC-Alaska, 2015). Many of these species are being pressured into a northward migration, described as the "conveyor belt to extinction" (Goedkoop, et al., 2022a), by ongoing warming and increased competition with invasive species. With naturally low diversity and functional redundancy (Post et al., 2009), changes in Arctic biodiversity can have wide-ranging and unpredictable effects (CAFF, 2013a; Meltofte, 2013; CAFF, 2017; Lento et al., 2019). Yet, our ability to detect such changes is hampered because biodiversity monitoring practices in the Arctic are largely fragmented (CAFF, 2001; AMAP-CAFF, 2004; CAFF, 2018; Christensen et al., 2021; Starkweather et al., 2021) and may be focused only on particular (endangered, charismatic, or invasive) species or on bioassessment (detection of ecosystem impairment) rather than estimating biodiversity or taking a holistic ecosystem based approach with connections across geographic and temporal scales.

As the Arctic faces an increasing rate of change, there is an urgency to scale up actions to inform timelier and more effective conservation and improve our collective ability to compile and compare data and detect trends in the environment (Barry et al., 2020a), including the impacts of climate change on biodiversity (Schmitz et al., 2014). An important step is to improve coordination, and harmonization[2] of ongoing biodiversity monitoring capacities e.g., human, data, and infrastructure. Clear agreement(s) are needed amongst States, Indigenous Organisations and NGOs on pathways that lead to enhanced and ultimately, harmonized biodiversity monitoring and data sharing. Without them, our ability to understand and forecast how Arctic ecosystems and biodiversity are affected by drivers such as climate change and human activities, and respond effectively is hampered (CAFF, 2001; Carson & Petersen, 2016; Barry, 2021; Christensen et al., 2021). Recognizing this need, in 2002 the Arctic States agreed "*that enhanced monitoring of biodiversity at the circumpolar level, fully utilizing traditional knowledge, is required to detect the impacts of global changes on biodiversity and to enable Arctic communities to effectively respond and adapt to these changes*" (Arctic Council, 2002). The need for a circumpolar biodiversity monitoring programme was further emphasized in subsequent Arctic Council[3] assessments, notably in the *Arctic Climate Impact Assessment* (ACIA, 2005).

In response, the Arctic Council working group the *Conservation of Arctic Flora and Fauna*[4] (CAFF) established the *Circumpolar*

1 There is no single agreed-upon definition of the Arctic, however, for the CBMP, the CAFF boundary is used to define its operational area. This covers 32.2 million km^2, of which 57% is marine and 43% terrestrial lands and inland waters (Figure 1).

2 Harmonization entails aligning monitoring practices to allow data from different sources to be comparable and allow for common assessments. Standardization is focused on adopting a uniform approach to how monitoring is conducted. Given the variety of jurisdictions, and knowledge-based approaches within which Arctic monitoring occurs, imposing a uniform approach through *standardization* is impossible while *harmonization* is achievable.

3 The Arctic Council is an intergovernmental forum promoting cooperation, coordination, and interaction among Arctic States, Indigenous peoples, and other Arctic inhabitants on issues of common importance. Member States include: Canada, Finland, Iceland, Kingdom of Denmark, Norway, Russia, Sweden, and the US. Six organizations representing Arctic Indigenous Peoples have status as Permanent Participants: Aleut International Association, Arctic Athabaskan Council, Gwich'in Council International, Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North, and the Saami Council. All Council decisions require consensus of the eight Arctic States who are obliged to consult the Permanent Participants on all decisions but ultimately it is the Arctic States who are the final decision makers (Barry et al., 2020a).

4 Biodiversity issues are touched upon across several of the Council's subsidiary bodies, however CAFF is the primary body through which it addresses biodiversity (Barry et al., 2020b). "*It serves as a vehicle to cooperate on species and habitat management and utilization; share information on management techniques and regulatory regimes; and facilitate evidence-based decision making. It provides a mechanism to develop common responses on issues of importance for Arctic ecosystems such as development and economic pressures, conservation opportunities and political commitments*" (CAFF, 2023).

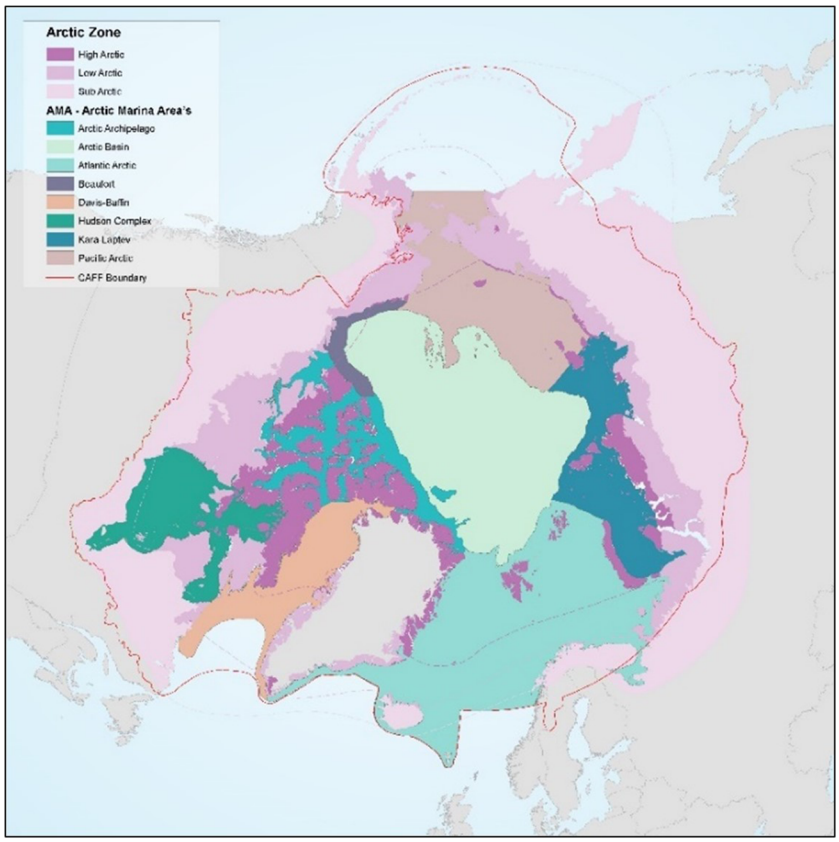

FIGURE 1
The area covered by the CBMP, including Arctic Marine Areas[5].

Biodiversity Monitoring Programme (CBMP) in 2002, as an international network of scientists, governments, Indigenous organizations, and conservation groups working to harmonize and integrate efforts to expand and develop monitoring of the Arctic's biodiversity. A key goal being to facilitate quicker detection, communication, and responses to biodiversity-related trends and pressures affecting the Arctic. Doing so entails addressing gaps in knowledge, new information needs, gathering, integrating, and analysing data, as well as communicating results (CAFF, 2001; Petersen et al., 2004; Gill et al., 2008; Christensen et al., 2021).

This paper describes the approach taken in the intervening two decades to develop and implement this monitoring programme. It documents:

- challenges encountered and lessons learnt;
- considers how the CBMP has been a model for national, regional, and global monitoring programmes;
- explores how it has impacted Arctic biodiversity monitoring and assessment, science, and policy; and
- concludes with observations on key issues and next steps.

2 Methods

The methods informing this review included consultations with officialsand experts with a long history of engagement in the CBMP both as State, Indigenous and Observer experts, as well as reviews by current and previous chairs, leads and members of the CBMP, its monitoring groups and expert networks. These consultations have been ongoing as part of the adaptive management process, including both free-form discussions and periodic directed discussions facilitated by surveys to identify monitoring needs, gaps, and future directions. A key aspect of these consultations revolved around relevance of the programme e.g., how experts felt the programme was relevant to their institutes and reporting obligations e.g. nationally and with regards to global environmental agreements and conventions. Material was also collected by participation in multiple meetings evaluating the status of CBMP implementation between 2008-2022, participation in numerous CBMP and Arctic Council meetings between 2008-2022, and a review of all CAFF publications including all Arctic Council documents referencing biodiversity from 1996-2022.

5 Arctic Marine Areas are areas with similar physical and biogeochemical characteristics which permit useful spatial comparisons across the Arctic and provide a framework by which status and trends can be reported on across the Arctic (Gill et al., 2011).

Document review included an examination of stated goals and outcomes to evaluate effectiveness and identify potential for improvement throughout the development and assessment phases.

3 Development of the CBMP

The first steps toward building the CBMP were taken with approval by the Arctic Council[6] of the *CBMP Framework Document* (Petersen et al., 2004) providing the foundations to harmonize and enhance long-term biodiversity monitoring across the Arctic (Gill et al., 2008). Its development has since been guided by a series of multi-year strategic plans (Gill & Zöckler, 2008; Barry et al., 2013a; CAFF, 2018; Christensen et al., 2021) with implementation organised around four ecosystem-based biodiversity monitoring plans [coastal (Jones et al., 2019), terrestrial (Christensen et al., 2013), freshwater (Culp, et al., 2012a), and marine (Gill et al., 2011)]. These plans represent agreements across Arctic States on how to coordinate and create better results from existing monitoring efforts and identify gaps in knowledge and ongoing monitoring. Their implementation supports efforts to collect, harmonize, and compare results from existing knowledge on biodiversity and ecosystems, and from monitoring efforts (Goedkoop, et al., 2022b; CAFF, 2017; Christensen et al., 2020; Schmidt and Johanesdottir, 2020; Aronsson et al., 2021).

Each plan:

- Established conceptual models of the ecosystem in question;
- Identified Focal Ecosystem Components (FECs) (Annex A), for which changes in attributes are likely to indicate changes in biodiversity and the environment, and which are prioritized targets of monitoring activities for various reasons (e.g., circumpolar distribution, monitoring feasibility, importance to local and Indigenous peoples, available data); and
- Developed approaches for more efficient and powerful sampling strategies that consider existing data, infrastructure, and human capacity along with consideration of areas likely to be undergoing significant change.

The coastal plan also focuses on creating a platform to support co-production of knowledge[7] through bringing together Indigenous Knowledge[8] (IK) and science. This platform approaches monitoring through a food security lens focusing on a socio-ecological structure in support of a holistic and ecosystem-based approach (Anderson et al., 2016; Jones et al., 2019; McClennan et al., 2021). Each of the other monitoring plans also include efforts to engage IK and Indigenous Peoples, however, the sequential development of the plans, with each learning from the previous meant that the Coastal monitoring plan reflects a more comprehensive approach to IK and engagement of Indigenous Peoples in the plan's development and implementation.

Supporting development of the CBMP, CAFF also developed a series of:

- Conservation strategies and action plans for seabird species e.g., Ivory gulls (Gilchrist et al., 2008), Eiders (CAFF, 1997) and Murres (CAFF, 1996c);
- Expert network monitoring plans for Benthos (CAFF, 2013b), World Reindeer Husbandry (CAFF, 2006b), Human-wild rangifer systems (CAFF, 2006a), the International Tundra Experiment (Jónsdóttir, 2004), Rangifers (Russell & Kofinas, 2004), and shorebirds (CAFF, 2003);
- Documents to support monitoring of plastic pollution in seabirds (Baak et al., 2021), development of a monitoring plan for polar bears (CAFF, 2011b), and global and flyway-scale monitoring for Arctic migratory waterbirds (Hagameijer et al., 2004);
- Framework to support a protected areas monitoring network (CAFF, 1996a; CAFF, 2011a; Livingston, 2011);
- Frameworks to support monitoring of species groups e.g., seabirds (Petersen et al., 2008; Irons et al., 2015) and marine mammals (Simpkins et al., 2007); and a
- Scientific papers addressing environmental stressors and population drivers of seabirds e.g (Christenens-Dalsgaard et al., 2019; Frederiksen et al., 2019).
- Strategy for facilitating and promoting Community-Based Monitoring (CBM) (Fleener et al., 2004); Huntington, 2008 However, despite early recognition by Arctic states of the value of CBM as a tool to collect biodiversity data (Arctic Council, 2004; Arctic Council, 2006) it has not since been considered in CBMP implementation.

As CBMP monitoring plans are implemented, regular status reports and workplans detail progress at a circumpolar scale e.g., (CAFF, 2014; Lento et al., 2017; CAFF, 2021a) and at national levels e.g., annual reports provided by States on progress towards implementation of the Marine Monitoring plan (Norwegian

6 Each document developed by the CBMP is subject to peer-review, and approval by Arctic Council member States and Indigenous organizations.

7 Co-production of knowledge brings together IK holders and scientists to equitably work together throughout all phases of work – from the beginning, (i.e. scoping stages, identification of questions, monitoring needs, determining methodologies), through gathering information (i.e. determining what information is needed, how to gather information, agreements on how information will be used and accessed), through data analysis (conducted by all), to output and communication to ensure relevant outputs, culturally appropriate communication, and usable information (Behe and Daniel, 2018).

8 IK is a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive multigenerational observations, lessons, and skills. It developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and passed on from generation to generation (Permanent Participants, 2018).

Environment Agency, 2015). Regular updates are also provided on Expert Network activities (CAFF, 2019a).

CAFF also began developing a suite of headline indices and indicators as early strategic reports on the state of Arctic biodiversity (Gill and Zöckler, 2008). These indicators reflect biodiversity components and services that are globally significant, integral to the functioning and resiliency of Arctic ecosystems, of vital importance to the subsistence and economies of Arctic communities, and representative of current monitoring ability and available data. Given the length of time required to build and implement the CBMP, these indicators were crucial in early implementation stages to demonstrate the potential of the programme; ensure continued support by funders; and highlight the importance of Arctic biodiversity in international negotiations e.g., at the Convention of Biological Diversity (CBD).

Examples include:

- Arctic Biodiversity Trends 2010: Selected indicators of change (CAFF, 2010);
- Protected areas Indicator (Barry and McLennan, 2010; Barry et al., 2017; Barry et al., 2023);
- Arctic Species Trend Index (ASTI) (Bohm et al., 2012; Eamer et al., 2012; McRae et al., 2012; Deinet et al., 2015 Gill et al., 2010; McRae et al., 2010);
- Land Cover Change Index which includes a range of early-warning indicators[9] (Shuchman et al., 2015; Jenkins et al., 2020); and
- Linguistic diversity (Barry, 2010; Barry et al., 2013b).

The first major outcomes from implementation of the monitoring plans are a series of *State of Arctic Biodiversity Reports* (SABRs) providing an overview of:

- Existing knowledge on status and trends of FECs in marine (CAFF, 2017), freshwater (Lento et al., 2019) and terrestrial (Aronsson et al., 2021)[10] ecosystems;
- Status of monitoring, including gaps in our ability to assess status and trends in biodiversity (Figure 2); and
- Key advice on actions needed to improve monitoring and fill knowledge gaps (CAFF, 2017; CAFF, 2019b; CAFF, 2021c).

The SABRs reflect a significant step in our ability to provide more coordinated and harmonized reporting on the status of Arctic biodiversity and monitoring efforts and respond to recommendations from the Arctic Council to fill gaps in knowledge and detect trends. They are baselines for future change that allow detection of trends across Arctic ecosystems, provide more relevant key findings and advice, and ultimately aim to improve monitoring and assessment of Arctic biodiversity to better support decision making and conservation outcomes (Barry et al., 2020b). SABRs are supported by a number of independent articles e.g., (Berteaux et al., 2017) and two special journal issues: *Terrestrial biodiversity in a rapidly changing Arctic* in *AMBIO* (Schmidt and Johanesdottir, 2020) and *Ecological change in Arctic freshwaters* (Goedkoop, et al., 2022b), which include a thorough treatment of the scientific literature (Taylor et al., 2020) that underpins the *State of the Arctic Terrestrial biodiversity Report* (START), a systematic review of documented IK on Arctic freshwater biodiversity (Knopp, et al., 2022) and an assessment of existing biodiversity data for the *State of the Arctic Freshwater Biodiversity Report* (SAFBR) (Goedkoop, et al., 2022a).

Arctic States have expressed a desire for more targeted products produced in shorter timeframes rather than recreating the broader synthesis provided in the SABRs (Christensen et al., 2021). In response, the first updates to the *State of the Arctic Marine Biodiversity Report* (SAMBR) on seabirds (CAFF, 2021b) and marine mammals (Kovacs et al., 2021) are more focused and targeted. Efforts are underway to consider how to integrate products across ecosystems including biotic and abiotic parameters. Indigenous Organisations also stress the importance of applying a holistic lens rooted in IK in order to secure knowledge of cumulative impacts across abiotic, biotic, social, and cultural elements directly related to biodiversity (Jones et al., 2019; CAFF, 2021d). Building upon this, the CBMP is engaged in an assessment on climate change impacts on Arctic ecosystems and associated climate feedbacks (AMAP/CAFF, 2022). Further, the development of the *Arctic Biodiversity Dashboard* is creating a visualization platform to bring to life the latest information on status and trends in Arctic biodiversity, helping streamline future assessments, target tracking and reporting (Gill et al., 2021).

4 Conceptual framework

Conceptually, the CBMP is informed by three goals (Box 1) and built on a network of networks and integrated adaptive management (question-based) approach to monitoring (Figure 3) (Gill et al., 2008; Navarro et al., 2017; Christensen et al., 2020; Christensen et al., 2021; Culp et al., 2021). To be relevant for decision-making, development of each plan started with an understanding of the information required by target audiences (Arctic States, Indigenous Organizations and communities) and monitoring questions to be addressed (Ims et al., 2013; Lindenmayer and Likens, 2018; Jones et al., 2019; Christensen et al., 2020). These included:

- What is the current status of [ecosystem] biodiversity in the Arctic?
- Can biodiversity and ecological status be measured with simple indicators, and if so, what suite of variables should be measured?
- How and where are these ecosystems, biodiversity and processes changing?
- What are the primary environmental and anthropogenic stressors causing changes in biodiversity and what are the cumulative effects of primary drivers and disturbances?

9 Sea surface temperature; Land surface temperature; Snow covered area; Marine net productivity; Marine chlorophyll-a; Land cover type; and Coloured Dissolved Organic Matter.

10 Work is underway to prepare the first *State of the Arctic Coastal Biodiversity Report*.

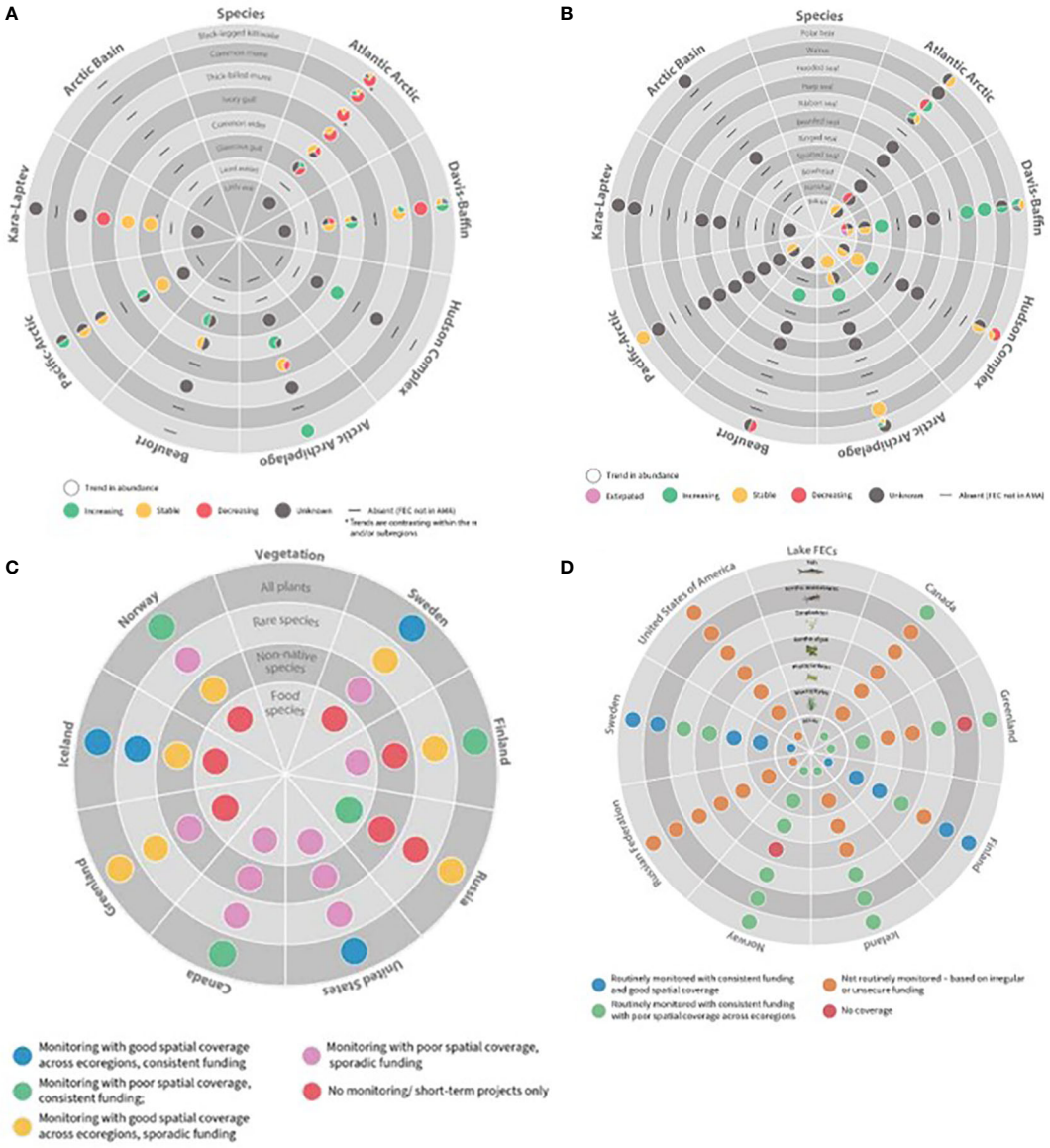

FIGURE 2
(A) Status and Trends in Seabirds (CAFF, 2021a); **(B)** Marine Mammals (Kovacs et al., 2021); **(C)** Status of monitoring of vegetation (Aronsson et al., 2021); **(D)** status of monitoring for lakes (Lento et al., 2019).

- Where are areas of high ecological importance including resilient or vulnerable areas where drivers are having the greatest impact?
- Are biodiversity or Indigenous subsistence food security or food sources impacted by changes in the Arctic, which species are affected, how and where are they affected, and what are the expected effects on populations or food security?
- How will changes in Arctic biodiversity impact the management of biodiversity or other obligations of local, Indigenous, territorial, and federal governments?

Answering these questions generates results to inform policy and management decisions. This user-driven approach inspired and follows the Group on Earth Observations Biodiversity Observation Networks (GEOBON) 9-step Biodiversity Observation Network (BON) design process (Navarro et al., 2017) designed to serve the needs of decision-makers and ensure a user-driven and sustainable monitoring program (Figure 4).

The conceptual ecological models developed for each ecosystem are based on working-hypotheses developed by experts that describe key relationships and functions of each ecosystem (e.g., Figures 5, 6). The Coastal CBMP also developed socio-economic models to describe the distribution of coastscapes around the Arctic[11], characterizing the social-ecological context of each coastscape

11 The term 'coastscape' describes coastal areas with recurring physiographic features, where similar processes interact to create a relatively predictable range of habitats that support characteristic populations of coastal species (Jones et al., 2019).

BOX 1 Goals identified in the CBMP Strategic Plan: 2021-2025.

Goal 1: Remain relevant by providing high quality information about biodiversity trends to support decision-making at global, national, regional, and local levels.
Goal 2: Be an adaptive, integrated monitoring program that provides timely information about status, trends, and changes in Arctic biodiversity and ecosystems.
Goal 3: Be sustainable and its organizational structure facilitates achievement of its goals.

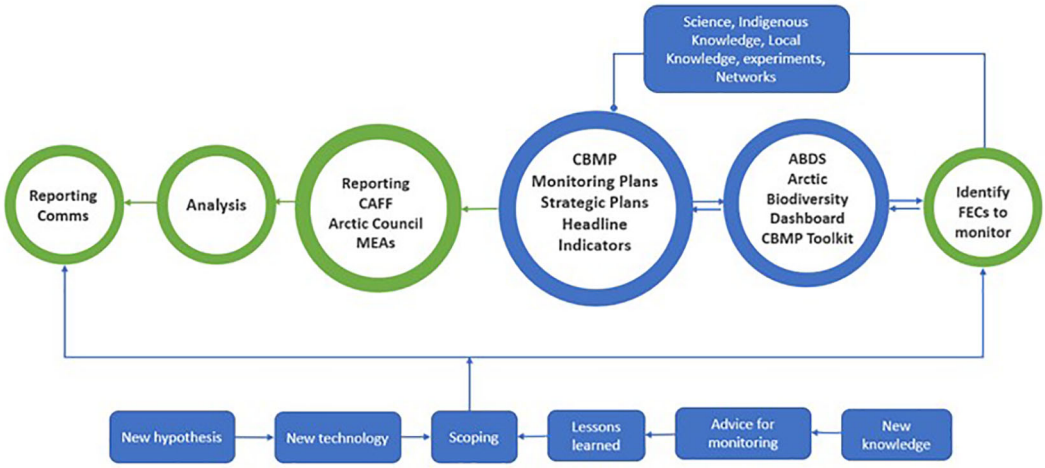

FIGURE 3
CBMP adaptive, ecosystem-based approach to monitoring (Christensen et al., 2021).

(physiography, FECs, key species, environmental processes, and human uses) (CAFF, 2020a). These models provided a common language to elucidate and communicate critical components, processes, functions, and drivers of change and guided selection of FECs (Gill et al., 2011; Ims et al., 2013; Christensen et al., 2020). After conceptual frameworks were developed, next steps included development of the monitoring plans, data collection, analysis, interpretation, reporting and communication. These different steps are linked as an iterative process allowing the CBMP to evolve and respond to key monitoring questions, advice for future monitoring, lessons learnt, and new questions (Figure 3).

5 Process to develop CBMP structural components

Figure 3 shows the different components of the CBMP, each developed through a multi-year, interactive process including workshops attended by participants from Arctic States, non-Arctic States, Indigenous Organizations, and NGOs. Each component helped refine and further develop the existing framework, therefore, some steps happened consecutively while others overlapped. The following sections outline the steps in development of each component.

5.1 Step 1: Establishing the framework to guide creation of the CBMP

The first step was creation of the CBMP *Framework Document* outlining the need for the programme, including adoption of an adaptive and ecosystem-based approach, and the importance of links to relevant global processes, such as the CBD and the Convention on Migratory Species (CMS). This document emphasized key goals and objectives needed to establish the CBMP, including the importance of communication and need to harmonize data standards and management, build capacity, and develop partnerships. It included a list of indicators under consideration by Multilateral Environmental Agreements (MEA) e.g., the CBD, which helped frame discussions on Arctic relevancy. Crucially, it contained an action-plan defining initial and long-term actions starting in 2004 and ending with the *2010 UN Year of Biodiversity*. While challenges in resources (monetary and personnel) led to delays, the *Framework Document* served its purpose of facilitating agreement across Arctic States and inspired a process to develop the CBMP.

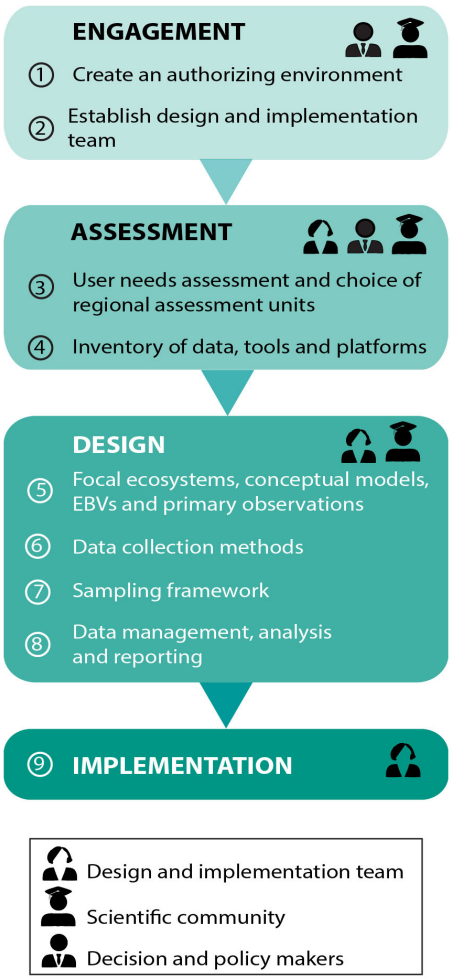

FIGURE 4
GEOBON's 9-step Biodiversity Observation Network design process (Navarro et al., 2017).

5.2 Step 2: Developing strategic plan(s) to guide implementation of the CBMP

After the *Framework*, implementation has been guided by a series of multi-year strategic plans, which supported different aspects of the programme. The first, covering 2008-2013 (Gill et al., 2008), focused on developing and maintaining a comprehensive and cost-effective monitoring program; establishing Coastal, Freshwater, Marine, Terrestrial ecosystem-monitoring groups, and formalising associated Steering Groups and Expert Networks (Figure 7). During this time, three Arctic Biodiversity Monitoring Plans were completed (Gill and Zöckler, 2008; Culp, et al., 2012a; Christensen et al., 2013). The second plan, covering 2013-2017 (Barry et al., 2013a), focused on developing the SAMBR —the first assessment from the CBMP which set a standard for other SABRs —and development of the *Arctic Coastal Biodiversity Monitoring Plan* which informed by experiences with earlier plans focused on enhanced engagement with Indigenous Peoples to chart a path for co-production of knowledge. The third strategic plan, covering 2018-2021 (CAFF, 2018), focused on finalizing the START, coastal monitoring plan and the SAFBR which included accumulation and assessment of data from >9000 sites across the Arctic[12].

Each strategic plan has become more detailed and goal- and action-orientated, allowing for more effective direction, implementation, and evaluation of the programme. This approach culminated in the current *CBMP Strategic Plan: 2021-2025* (Christensen et al., 2021) which defines three overarching goals for the maintenance of the CBMP (Box 1) and further developed the focus and structures from previous strategies, in that for each goal, a series of objectives and activities are identified (see Box 2 for an example). Tracking activities against these goals and objectives provides a framework to improve reports and evaluate progress toward implementation and goal achievement. Building upon previous strategic plans and the SABRS the current plan focuses on:

12 The CBMP-Freshwater database is the first ecosystem-database produced by the CBMP and is being prepared for publication on the ABDS.

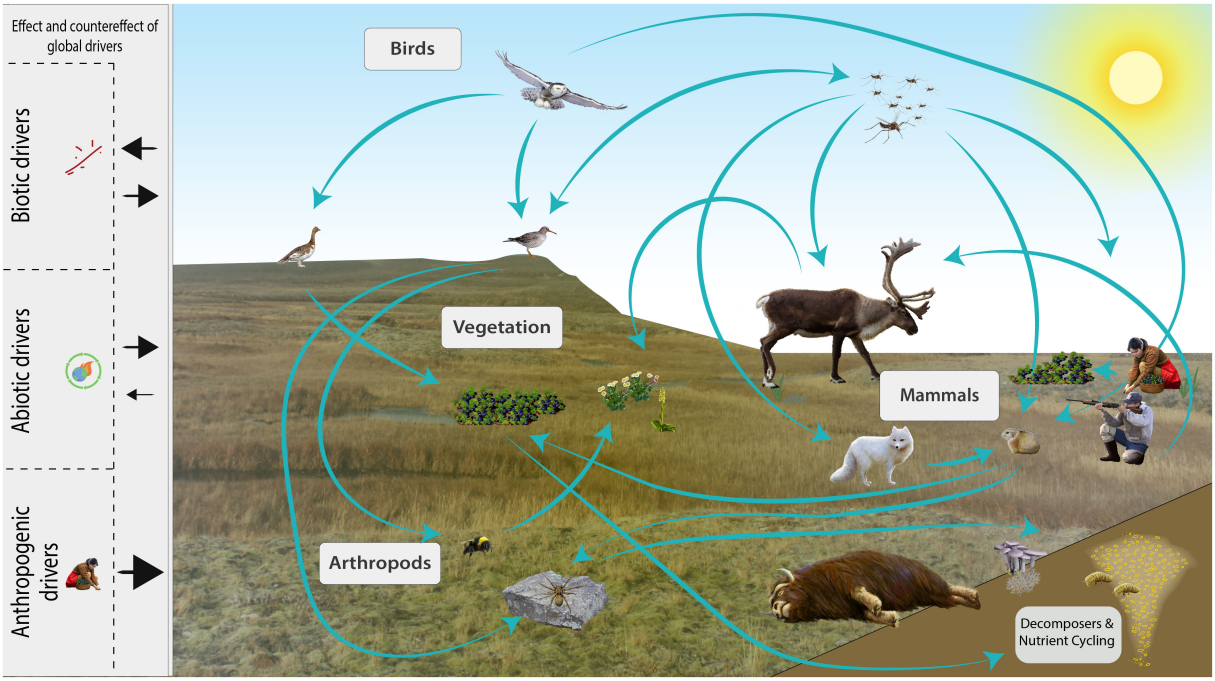

FIGURE 5
Conceptual model of energy flow through the high Arctic terrestrial food web. Arrows to and from driver boxes indicate the relative effect and counter effect of different types of drivers (Aronsson et al., 2021).

- Integrating across ecosystem monitoring groups;
- Supporting and guiding CBMP steering groups and expert networks;
- Ensuring more targeted, integrated, and flexible reporting;
- Identify emerging issues;
- Emphasizing the importance of IK and Local Knowledge to support co-production of knowledge; and
- Ensuring the program is sustainable and relevant to multiple audiences.

To keep the CBMP relevant for decision-makers, the *CBMP Strategic Plan: 2021-2025* emphasizes engagement within the Arctic Council and relevant global initiatives including the *Kunming-Montreal Global Biodiversity Framework* (GBF) (CBD, 2022). To facilitate this goal the CBMP Strategic Plan is being aligned with CAFF's long-term strategic plan, the *Actions for Arctic Biodiversity 2023-2030* which is currently under development. Furthermore, the strategic plans of CBMP and CAFF are being aligned with the goals of the GBF. Monitoring and assessment activities of CBMP and CAFF can support the calculation of several of the headline, component, and complementary indicators proposed for the GBF, and this will be facilitated through ongoing efforts to map CBMP indicators to global indicators. Integrating the consideration of global and Arctic biodiversity strategies will help position the CBMP as a useful tool to:

- Report on progress toward goals and targets defined in the GBF;
- Support synergies in national monitoring efforts and reporting obligations;
- Provide a framework to evaluate effectiveness of the Council's work on biodiversity; and
- Track biodiversity-related outputs and outcomes.

5.3 Step 3: Developing biodiversity monitoring plans for each ecosystem

The first step in developing each plan entailed a series of workshops with subject-matter experts from Arctic States, non-Arctic States, Indigenous Organizations, NGOs, and invited experts. These workshops helped:

- Collect best practices in monitoring design, existing monitoring inventories and efforts to inform development of practical approaches for each monitoring plan;
- Identify drivers of change, FECs, parameters and indicators, to be incorporated into the monitoring plans;
- Create a set of questions to guide development of the monitoring plans, e.g., what are the status, trends, and distribution of FECs? What are the primary environmental and anthropogenic drivers? How are drivers influencing changes in biodiversity and ecosystems and impacting food security? and
- Identify potential users of the information and management questions the monitoring plans need to be able to answer in order to make the work relevant beyond scientific inquiry (Jones et al., 2019; Christensen et al., 2020).

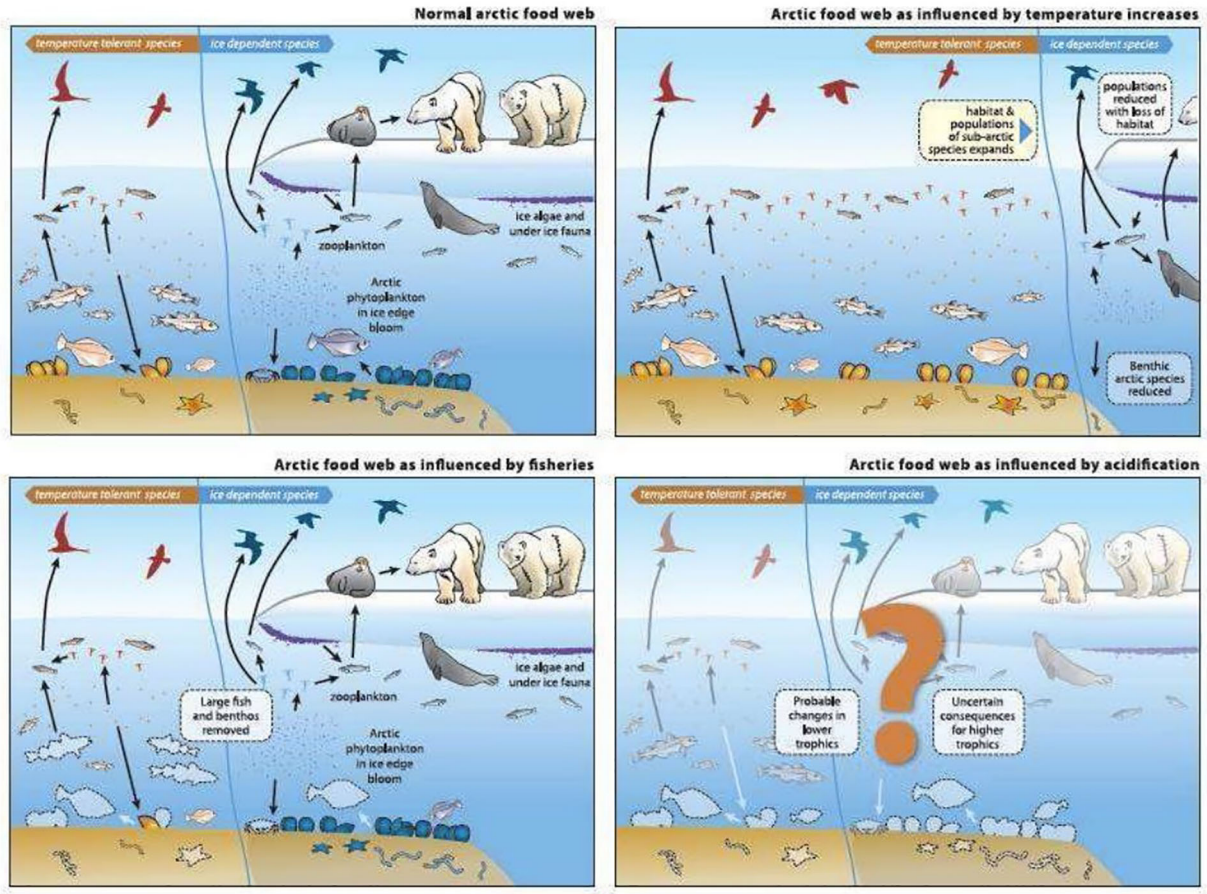

FIGURE 6
Conceptual models showing potential impacts on Arctic marine ecosystems under different scenarios (Gill et al., 2011).

Workshop outcomes were synthesized in a series of reports and background papers which formed the basis for further workshops and consultations with stakeholders to develop each monitoring plan (Vongraven et al., 2009; Culp et al., 2011a; Culp et al., 2011b; Culp, et al., 2012b; McClennan et al., 2016).

During subsequent workshops, expert opinion informed agreement on final FEC lists for each ecosystem, including prioritization of FECs, associated parameters and attributes according to a set of selection criteria (Table 1). In some ecosystems, FECs attributes were further categorized as *essential* or *recommended* based on their importance and feasibility for monitoring. Later, as SABRS were released, FEC lists were refined based on feasibility of reporting due to data availability. For example, in the *SAMBR* only three of twelve fish FECs could be reported on, illustrating that many components of Arctic biodiversity are not being monitored. Whereas FECs are generally biotic, the freshwater plan includes abiotic variables that are sensitive to climate change and key drivers of aquatic biodiversity and are already key components of national monitoring programs (Culp et al 2012a; Lento, et al. 2019; Huser et al., 2022).

While the coastal plan does not explicitly define abiotic FECs, it emphasizes the importance of linking monitoring efforts to abiotic drivers, with FEC attributes and parameters considered through a food security perspective. Similarly, the marine and terrestrial plans refer to future intentions to identify relevant abiotic parameters. A full list of FECs, and their attributes and parameters is provided in Table A1 (Supplementary Material).

5.4 Step 4: Developing a data management system

Access to comprehensive data that can be easily interpreted is a fundamental step towards informed policy and decision-making (Wetzel et al., 2018). While many data exist on the Arctic, the challenge is in finding, accessing, and making sense of these existing, but scattered data. Data that are not always encoded in accordance with international standards or best practices, and often lack the metadata for integration and interpretation (Wilkinson et al., 2016). In response, data generated or aggregated through the CBMP is available on the Arctic Biodiversity Data Service (ABDS - https://www.abds.is), the interoperable data management system for CAFF whose goal is to enhance access to biodiversity data and ensure that reliable data are available to inform decision-making

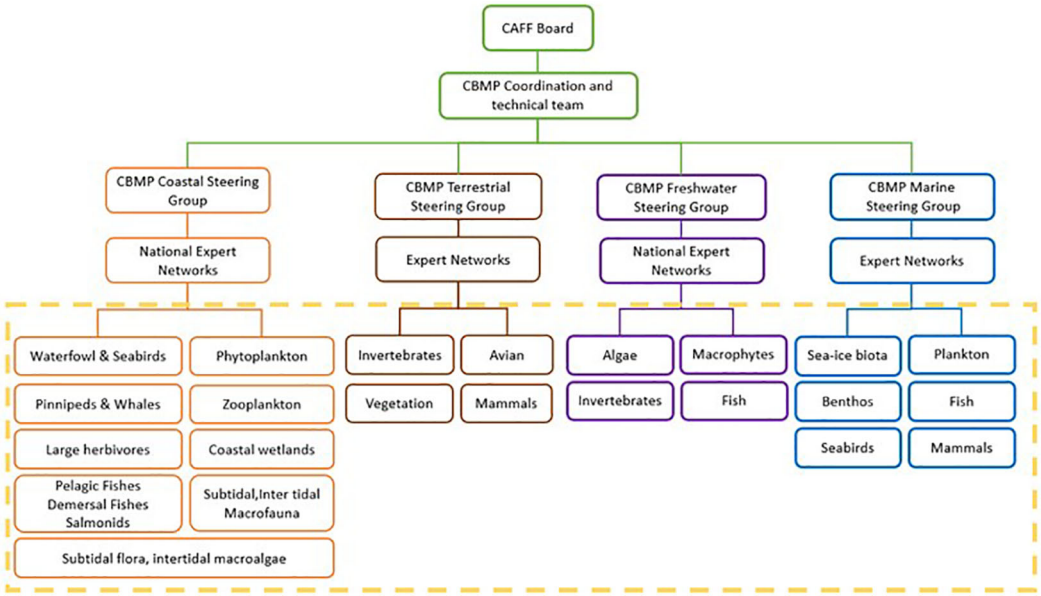

FIGURE 7
CBMP organizational chart. The CAFF Board[13] oversees the CBMP with a team of co-chairs and the CAFF Secretariat responsible for coordination. A Steering Group directs implementation of each monitoring plan with Expert Networks established or identified among existing expert groups under each Steering Group to conduct implementation.

BOX 2 CBMP Goal 2 and associated activities from the CBMP Strategic Plan: 2021-2025.

Goal 2: *The CBMP is an adaptive, integrated monitoring program that provides timely information about status, trends, and changes in Arctic biodiversity and ecosystems.*
Objective 2.1: Integrate lessons learned and advice for monitoring outlined in the SABRs into next steps of CBMP.
Activity 1: After completion of major products such as SABRs, initiate a process to evaluate and prioritize FECs as indicators of change. This process using lessons learned and SABR key findings and advice will result in a revised monitoring or long-term implementation plan.
Activity 2: Review and consider lessons learnt, when developing work-plans.

(Barry et al., 2021). The SABRs are a means by which these datasets are identified, compiled, and analysed.

The ABDS uses open-source solutions[14] to facilitate information sharing, search data, combine distributed map services, publish data, and schedule metadata harvesting from other catalogues. It is embedded within regional data frameworks e.g., the Arctic Spatial Data Infrastructure (Arctic SDI), and global frameworks such as GEOBON, Ocean Biodiversity Information System (OBIS) (UNESCO, 2023), and the Global Biodiversity Information Facility (GBIF, 2023), and as an associate data unit to the International Oceanographic Data and Information Exchange (IODE, 2015) (Figure 8). As nodes within GBIF and OBIS, any data in the ABDS are automatically harvested and accessible within both frameworks making it more accessible and useable. The increased use of CBMP data accessed through GBIF can be seen in the growth of citations referencing CBMP from 4 in 2017 to 92 in 2021 (GBIF, 2023). It is anticipated that information generated will be used by States, Indigenous Organisations, NGOs and the scientific community to inform sub-global and global assessments e.g., contributing to GEOBON's Global Biodiversity Observation System, CBD Global Biodiversity Outlooks and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) assessments, helping to bring monitoring data collected at the local scale into international reporting (Barry et al., 2021).

As biodiversity monitoring seeks to amalgamate and integrate scientific data for rapid assessments of dispersed data, there is an increasing need to facilitate the production and accessibility of IK. There are growing numbers of examples of IK production projects that showcase the strength of long-term monitoring and reporting e.g., (Gagnon et al., 2023). The success and continued development of such programs will increase the impact of biodiversity reporting and assessments, enhancing the capacity of IK producers to promote conservation and make meaning from continued production of biodiversity knowledge.

13 CAFF is governed by a Board of representatives delegated by each Arctic Council State and Permanent Participant.

14 GeoServer, GeoNetwork, an Integrated Publishing Toolkit and a PostgreSQL PostGIS database.

TABLE 1 Criteria used to select and prioritise FECs for inclusion in each monitoring plan.

Marine: 2011	Freshwater: 2012	Terrestrial: 2013	Coastal: 2019
Sensitivity to natural or anthropogenic drivers	Sensitivity to natural or anthropogenic drivers	Sensitivity to natural or anthropogenic drivers	Sensitivity to climate driven ecosystem drivers
			Potential for causing ecosystem change
			Sensitivity to anthropogenic stressor drivers
Scientific validity (i.e., rigorous methodology and ability to detect change)	Scientific validity (i.e., rigorous methodology and ability to detect change)	Validity (rigorous methodology; ability to detect change)	Validity (rigorous methodology; ability to detect change)
Relevance to and resonance with diverse audiences (local communities, decision makers, global public)	Relevance to and resonance with diverse audiences (local communities, decision makers, global public)	Relevance to management and legislation	Relevance to management questions
		Relevance to Arctic Indigenous and non-Indigenous peoples	Significance for supporting community food security
		Relevance to IK-based management	Relevance to legislation
			Relevance to diverse audiences
		Relevance to decision and policy maker	Cultural and/or science relevance
Ecological relevance (occurrence across Arctic Marine Areas)	Ecological relevance (lakes and rivers)	Ecological relevance (scalability)	Pan-Arctic distribution
			Occurrence across coastscapes
			Relative importance of the coastscape
Sustainability of monitoring capacity	Sustainability of monitoring capacity	Availability and sustainability of monitoring capacity and expertise	Presently being adequately monitored
			Sustainability of monitoring capacity, expertise, and protocols
			Ability to access existing data
Subject to targets and thresholds	Subject to targets and thresholds	Relevance to targets and thresholds	Relevance to targets and management questions
Practicality	Practicality/feasibility	Practicality, cost effective; Relies on accessible data; Technically feasible to measure; Representative of multiple species, ecosystems and/or habitats.	Practicality
		Easily understandable and communicated	

5.5 Step 5: Ensuring relevancy

A critical issue for the future of the CBMP is maintaining relevancy and interoperability. To increase relevancy, programme outputs should feed into national reporting needs and support reporting obligations to international fora, particularly the goals and objectives of the GBF (Figure 9) but also other Arctic-relevant MEAs e.g., Ramsar. To facilitate this, FECs for each ecosystem should be mapped to relevant indicators e.g., the Essential Biodiversity Variables (EBV) (Pereira et al., 2013). This would allow future assessments of biodiversity status and trends to facilitate reporting on how the Arctic, as a region, and Arctic areas of individual states are progressing towards achieving global biodiversity goals. This would also support alignment of CBMP outputs to existing and developing GBF headline, component, and complementary indicators, thereby helping ensure consistency and streamline the process for reporting and indicator production. As part

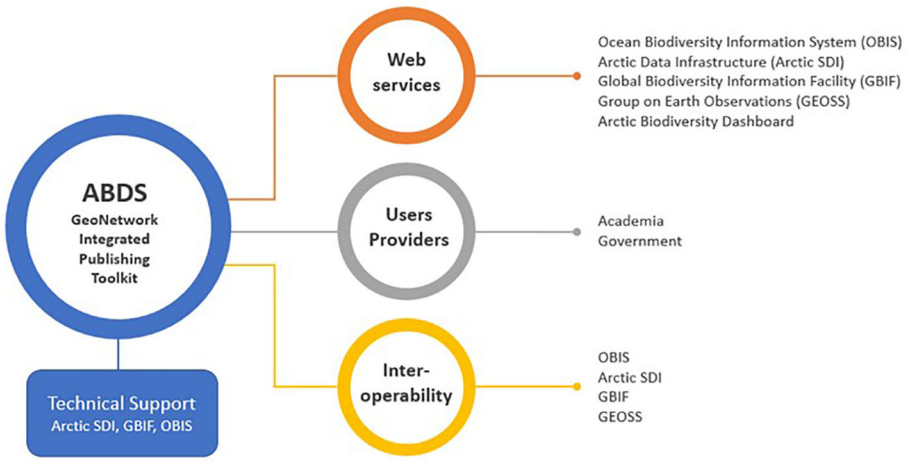

FIGURE 8
ABDS structure.

of these efforts an *Arctic Biodiversity Dashboard* is under development to help streamline reporting on biodiversity status and trends and strengthen global, circumpolar, and national target tracking, and better serve MEAs and related global initiatives such as the *Sustainable Development Goals* (CAFF, 2023a, Gill, Barry et al., 2021).

The first monitoring plans are more than ten-years old, and integrating new monitoring methodologies will need to be considered as well as ensuring plans remain flexible, updated, and easy to access. CAFF is developing an online *Arctic Biodiversity Toolkit* to improve access to CBMP materials, tools, recommended monitoring methodologies and guide users in implementation of the plans (CAFF, 2023b). This toolkit will allow users to search FECs and select those relevant for their particular field station/monitoring effort and access relevant methodologies, publications, and data sources.

6 Impacts of the CBMP

While the Arctic Council has provided a home for CBMP outputs as well as a mandate, constraints imposed by its decision structure also affect possible impacts and influence it may have on Arctic monitoring, management, and policy. Decisions by the Council are consensus-based requiring unanimous agreement by all Arctic States in consultation with the Permanent Participants. This can make it challenging to reach agreement, as illustrated in the inability to reach consensus on how to describe climate change at the 2019 Arctic Council Ministerial, leading to a failure to issue a ministerial declaration for the first time in its history (Barry et al., 2020b). While the Council provides an umbrella mandate for coordinated biodiversity monitoring, actual impacts from the

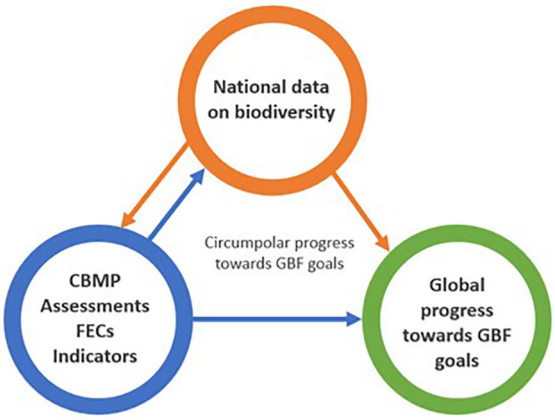

FIGURE 9
Example of the flow of knowledge on status and trends in biodiversity from the CBMP to States and the GBF.

CBMP are more likely to be realized at national scales, where management and conservation decisions are made.

Pathways through which the CBMP can influence change include identifying actions and key advice needed in response to issues of concern, e.g., as outlined in the SABRs. These can help inform changes in programs, regulation, and policy to improve monitoring programs to better understand changes in biodiversity. A positive example can be seen in how increasing cooperation between States in implementing the marine plan resulted in identification of time and cost-effective possibilities for benthos monitoring. This led to the addition of a benthic monitoring component to existing annual monitoring for commercial fish-stocks in three States (Greenland, Iceland, and Norway), thus improving overall biodiversity monitoring with marginal extra costs (CAFF, 2013c; Barry, 2017a). Although this solution may appear straightforward, it might not have occurred without the CBMP facilitating recognition of a knowledge gap, bringing different disciplines together, and communicating the need to States to facilitate gathering and exchange of knowledge (Barry et al., 2020b). Further examples include realignment of plankton surveys in the Davis Strait through coordination between Greenland/Canada and more aligned monitoring between the US Fish and Wildlife Service, Bureau of Land Management, and US National Park Service in Alaska – informed by opportunities for more efficient and coordinated monitoring revealed by the CBMP.

A particularly important point is that the absence of obligated national reporting on changes and trends in biodiversity from Arctic States to the Arctic Council has led to a lack of transparency regarding how, or even if, States act on outcomes from the Council. While the CBMP has had impacts at the global scale, impacts at national or local levels are difficult to identify and report. Voluntary reporting only reflects issues and actions that States are willing to address collectively within the Council. It does not necessarily capture changes in policy or regulations in response to a recommendation, or more localized responses. The influence of such soft power is not always effective, as in the absence of obligatory requirements (e.g., fines due to inaction) they may be easily ignored. Arctic biodiversity monitoring and assessment could benefit from more formal reporting obligations to the Council, strengthening the role of CAFF with regards to international initiatives focused on Arctic biodiversity. Additionally, synergies with other national and international reporting duties should be considered to see, how existing reporting duties could benefit Arctic biodiversity monitoring and assessment (Barry et al., 2020b).

However, despite the Council's lack of authority to engage directly in implementation, it can influence behaviour and movement towards desired actions through building knowledge, facilitating dialogue, identifying, and communicating knowledge gaps, enhancing capacity, making data accessible, supporting regional and global frameworks, and providing advice to decision makers (Barry et al., 2020b). Examples can be seen in how the CBMP is being looked to as a guide for how to:

- Approach global coordination of monitoring and assessment e.g., as in GEOBON and thematic BONs such as Freshwater BON (Walters & Scholes, 2017);
- Develop of regional and site-based monitoring programmes e.g., in the RIF field station, Iceland (RIF, 2018), Canadian High Arctic Research Station (CHARS) (McLennan, 2017); development of a marine monitoring programme in the Falkland Islands (Barry, 2017b); and
- Helping develop capacity for research and monitoring e.g., hub-and-spoke monitoring programmes; and finding ways to incorporate extreme events into circumpolar monitoring efforts through the International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT, 2023).

An important aspect of successfully implementing the CBMP and ensuring its relevance to decision-makers revolves around ensuring CBMP outcomes are aligned with global biodiversity targets. In order to facilitate this CAFF established a series of agreements with global conventions and initiatives relevant for Arctic biodiversity (CAFF and APECS, 2009; CAFF and CBD, 2009; CAFF and CMS, 2013; CAFF and EAAF, 2013; CAFF and Ramsar, 2013; CAFF and OBIS, 2015; CAFF and GBIF, 2016). These have been useful tools to ensure flow of information and recommendations on Arctic biodiversity issues into these global fora. The CBMP plays a central role in these agreements, explicitly designated as a key mechanism through which information can be generated to inform and support decisions related to Arctic biodiversity in global contexts. For instance, release of the *Arctic Biodiversity Trends 2010* report at CBD COP10 led to:

- Recognition of Arctic biodiversity as an emerging issue (CBD, 2010);
- Invitation for CAFF to provide information, with the CBMP highlighted as a key information provider and important knowledge-generation mechanism on Arctic biodiversity (CBD, 2010; CBD, 2012);
- Organisation of side events at COPs to ensure Arctic issues are visible;
- Delivery of information to the CBD, with CBMP generated knowledge forming the core of these reports (CBD, 2011a; CAFF, 2020b); and
- Decisions from COPs on Arctic biodiversity (CBD, 2011b).

While some Arctic states reference the need to support the CBMP in national reporting to MEAs e.g., the CBD (Greenland, 2014; Ahokumpu et al., 2015) there has been limited use of CAFF products in national reporting to MEAs. Such national reporting draws data from the same sources as the CBMP and the lack of reference to the CBMP may in part be due to the level of detailed required. There are however exceptions e.g., Canada used data from ASTI to report on status and trends of Arctic ecosystems and species in its 2014 CBD national report (Canada, 2014). Further alignment and cross-linkages may be facilitated through implementation of the *Arctic Biodiversity Dashboard* which will include both pan-Arctic visualizations of status and trends in biodiversity, alongside country profiles that allow for the tracking of indicators and issues specific to each Arctic state. Of the six Indigenous Organisations in the Arctic Council, ICC (ICC, 2010) and the Saami Council (Sámi Council, 2009) have Arctic strategies which while they do not explicitly refer to the

CBMP, emphasize the importance of developing Community-based Monitoring (CBM) and integrating IK in monitoring.

Although less formal than engagement with the CBD, information produced by the CBMP has been provided to IPBES through providing reviews of IPBES reports and delivering Arctic Council biodiversity reports (IPBES, 2023). However, without a formal agreement or organizational status under IPBES, it has been less coordinated than with the CBD. A further example of how CAFF programmes have potential to have an impact can be seen in how CAFFs *Arctic Migratory Birds Initiative* (AMBI) supported the creation of a Taskforce on Illegal Hunting along the East-Asian Australasian Flyway. Prior to CAFFs efforts on this issue States in this flyway were unable to agree on how to address this issue despite recognizing that illegal hunting was a key threat (Barry et al., 2020b). As CBMP strategic plans have become increasingly more precise, and action orientated, it is becoming easier for CBMP-generated information to support assessment of progress towards national, regional, and global biodiversity goals and targets.

7 Lessons learnt

The following are overarching lessons derived from implementation of the CBMP which may be relevant for those engaged in developing regional and global monitoring programmes. These lessons were derived from workshops, questionnaires, and consultations with experts engaged in the CBMP. Lessons learnt through implementing the monitoring plans are captured in Box 3 and are applicable across monitoring plans. These have also been used to guide the design of biodiversity observation systems in other parts of the world (Scholes et al., 2016; Navarro et al., 2017).

7.1 Effective coordination is essential

Implementation of a monitoring programme entails collaboration across diverse disciplines, organizations, nationalities, and knowledge systems. Given this complexity, it is crucial to ensure that all Arctic States, Indigenous Organisations, relevant non-Arctic States, and NGOs are represented on Steering Groups and Expert Networks. It is also increasingly important to ensure coordination across Arctic Council Working Groups to facilitate discussion on how to best target and prioritize future monitoring efforts, which could result in improved use of resources and streamline reporting requirements, ensuring monitoring results are available for diverse projects.

When developing larger products such as the SABRs, it is important to clearly identify roles, responsibilities, and deadlines between a core group of writers and editors. For example, during the SAMBR writing process, more synthesis discussion between expert groups would have helped in relation to an integrated analysis. Development of the SAFBR and START benefited from having science coordinators to manage data, provide context and support for analyses by experts, facilitate communication between lead writers, and bring together ideas and concepts from different thematic assessments. Ideally, these science coordinators can also contribute with their own scientific expertise, rather than just being a coordinator.

For many States and Organisations, the same experts are involved across different Arctic monitoring initiatives both within and outside the Arctic Council. High demands on experts' time and resources reinforces the underlying need to streamline CBMP implementation with national and international monitoring and reporting obligations and provide adequate and centralised coordination support to reduce administrative burden on experts' participation. Ensuring this requires a central, sufficiently resourced, and well-connected coordinating team that has the diverse skill set necessary to drive programme implementation. However, support for centralised coordination is often challenging to obtain.

7.2 Ensure sufficient and sustained funding

The majority of resources committed to the CBMP are in-kind and its activities are funded on a voluntary basis by individual Arctic States. States do not necessarily contribute to every CBMP activity, or support core functions of the programme such as central coordination, administration, data management, communication activities, and report development. Arctic Council Ministerial declarations also repeatedly emphasize the

BOX 3 Advice learnt from developing and implementing the CBMP (Scholes et al., 2016; Navarro et al., 2017; Christensen, et al., 2020; Christensen, et al., 2021).

- Be creative and flexible;
- Start small, maintain focus & prioritize;
- Keep it simple (simple, efficient internal organization);
- Build on existing monitoring capacity & information;
- Be adaptable when developing a monitoring programme at an international scale;
- Plan and budget for data management and analysis.
- Prepare communication products to feed into relevant local, regional, and international fora.
- Start small and build on success.
- Be Relevant:
  - Link to reporting mandates (involve decision-makers & funders in development); and
  - For decision-makers (answers to questions otherwise unanswered).
- Focus on gradients of change.
- Show value-added of integration:
  - For scientists/experts (access to data, tools, network funding, greater publication potential)
  - For decision-makers (answers to questions otherwise unanswered)

importance of meaningful engagement of Indigenous Peoples and their knowledge in monitoring. However, resources to do so are not provided in a coordinated manner and are challenging to secure.

This voluntary approach to funding means that the ability to implement CBMP Strategic Plans can be limited and unbalanced depending upon availability and continuity of team-members, and prevailing interests of funders. In effect workplans can be ambitious laundry-lists without adequate resources for full implementation. This can lead to inequalities in influence, where countries willing to provide resources are able to push their priorities simply by funding them, even if these might not be priorities for the programme as a whole. It can also push the program to act on lower priorities simply because they receive funding, while high-priority actions may be halted or delayed because of a lack of funding (Barry et al., 2020a). For example, despite unanimous agreement amongst Arctic States and being reflected in several Ministerial Declarations e.g., (Arctic Council, 2009; Arctic Council, 2011) it took three years for the *Arctic Biodiversity Assessment* proposal which provides the baseline for CBMP to work from, to be approved and another five before it was completed. In addition, funders tend to place emphasis on delivery of products or workshops rather than supporting core components necessary for an effective monitoring programme e.g., coordination, data, and analysis. This funding model hinders the CBMP's ability to fulfil its goals in accordance with agreed upon timelines. This, in turn, hinders its ability to inform timely and effective decisions in the face of cumulative and accelerating environmental change in the Arctic.

Each CBMP monitoring group is assigned a science-coordinator tasked with supporting that groups activities and a constant challenge has been ensuring funding to support these roles. Initially these were filled within the CAFF Secretariat, however as CBMP implementation progressed and became more complex additional resources were needed. Different approaches have been tested e.g., contracting individual coordinators, state experts allocated percentages of their time, and contracting companies to fill these positions. While each of these approaches were effective in terms of coordination, the lesson learnt has been that to ensure no loss of institutional knowledge and secure continued state support for the programme, monitoring group coordinators should ideally be drawn from the CAFF Secretariat or state employees granted a percentage of their time. The future ability of the CBMP to more effectively harmonize and integrate knowledge on Arctic biodiversity will, to an extent, reflect the willingness of Arctic States to support more monitoring including a sustainable funding framework for the programme and their national experts (Barry, 2021).

7.3 Improve standards and protocols

While implementation of the CBMP has resulted in improved collaboration amongst Arctic biodiversity monitoring professionals, there remains a need to refine and harmonise monitoring protocols and standards to facilitate greater comparability and standardised reporting amongst Arctic States. This does not mean a standard set of protocols must be adopted by all, but rather, monitoring protocols should be assessed for commonalities and differences to determine comparability of methods and design guidelines for adaptations that can be made to improve our ability to integrate and assess monitoring data across a circumpolar scale while maintaining national programs and time series. Another important priority are clear guidelines on how to better bridge the knowledge gained from national biodiversity monitoring programs with IK systems, and how to co-produce IK and scientific monitoring.

Additionally, due to different monitoring strategies the monitoring plans do not all use the same terminology meaning that the way FECs are classified can differ across plans. For example, the marine plan identifies particular species as FECs whereas the freshwater plan approaches monitoring from the scale of assemblages rather than species (e.g., fish is one FEC). This can affect reporting from CAFF and impact efforts to adopt a more integrated approach for future cross-ecosystem assessments, particularly when addressing FECs that are found in more than one plan.

An opportunity to harmonize monitoring approaches between the monitoring plans lies in cross-walking FECs to EBV classes (Pereira et al., 2013) which represent a set of independent but complementary measures that cover all dimensions of biodiversity. The EBV framework is being used to harmonize biodiversity observations globally providing a flexible framework that allows data derived *via* different methods to be scaled, aggregated, and disaggregated (Walters and Scholes, 2017). Moving forward, the CBMP, as a regional Biodiversity Observation Network of GEOBON could benefit from this harmonized and standardized approach.

7.4 Co-production of knowledge and equitable involvement of IK approaches are essential

The importance of meaningfully engaging Indigenous Peoples in the CBMP has long been acknowledged, with numerous Arctic Council reports and Ministerial Declarations calling for improved production and application of IK in knowledge production. Examples of indigenous-based biodiversity monitoring and assessments are rare (Knopp et al., 2022) but are becoming more frequent as governments and communities realize the positive potential for partnering through science-IK partnerships. For example, the *SmartICE* programme has spread across communities in the Canadian Arctic and builds on IK of local ice conditions, identification of critical sea-ice information needs, and Indigenous capabilities to operate and maintain complex instruments safely in dangerous environments to generate useful sea ice information to inform safe-travel (SmartICE, 2023). The *Indigenous Guardians* program also growing across the Canadian North is engaging Indigenous youth in CBM programs that meet community needs in rapidly changing environments (Government of Canada, 2023).

The value of IK can also be seen in how a review of IK on freshwater biodiversity, conducted as part of the special journal issue supporting the *SAFBR* (Lento et al., 2019) recorded seventeen

freshwater or anadromous fish species that were not found in the circumpolar fish monitoring data collected by the CBMP (Knopp et al., 2022). To allow for inclusion of IK and facilitate co-production of knowledge an important priority is providing clear guidelines (or standardised protocols) on how to co-produce IK and scientific monitoring. While the CBMP Coastal Group has demonstrated that knowledge can be co-produced in the context of the CBMP monitoring plans e.g., in the identification of FECs, this requires extensive time, funding and relationship building. Investments for IK production may also contribute to reconciliation with Indigenous ways of knowing.

7.5 Data management is integral to facilitating regional analysis and comparisons

There is a continuous need to improve data harmonization and management to allow for circumpolar conclusions to be made on status and trends of Arctic biodiversity. For example, a lack of harmonised data in the START resulted in difficulties determining baselines and/or trends for some species. Available data often do not follow international standards and lack sufficient metadata to allow data to be compared. Furthermore, the SAFBR, identified a need for further standardization and "add-ons" to current methodologies in order to provide better estimates of biodiversity including use of remote sensing. This includes newly packaged products from space agencies, biodiversity models and other novel/emerging techniques that can predict and identify monitoring gaps and tools for streamlined/automated indicator production.

The ABDS is playing an increasingly important role in ensuring outcomes from the CBMP are accessible and useable, and making the programme more attractive to funders given that data management is an increasing requirement from funders. The ABDS would benefit from development of a data sharing plan and agreements between States and Indigenous Organisations, ensuring metadata records are complete. Developing tools that make it easier and more attractive for experts to provide data will also improve access to relevant and timely information to aid in biodiversity status and trends reporting for decision-making. Additionally, it is crucial to ensure data adherence to the FAIR principles (Findable, Accessible, Interoperable, Reusable) (Wilkinson et al., 2016).

7.6 Communication and outreach are crucial to raising awareness and engagement in the programme

Increasingly a key aspect of CBMP implementation is finding ways to communicate the programme and its output in a more interactive and user-friendly manner. Communication of findings should reflect the needs of stakeholders for which products are targeted, to ensure such efforts are effective and relevant to users:

- Alongside production of reports to the Arctic Council, future reporting should consist of short updates and targeted products with a continued focus on adding to scientific literature and creating products suited to securing expert engagement and maintaining scientific robustness;
- There should be a stronger focus on evaluating progress towards implementation of recommendations. Presentation of the programme and products at relevant national, regional, and global fora is important to contribute towards awareness of the dramatic biodiversity changes taking place in many Arctic ecosystems, and these fora's engagement in CBMP; and
- There is a need for more focus on science communication directed towards management (i.e., state, federal, local) so that the results can be implemented, and the program becomes a better-known and supported source of information. If this is combined with an element of public outreach, then the potential for funding support and ongoing commitment will increase.

7.7 Ensuring resources to engage in international fora is crucial to ensuring programme implementation

A key challenge with regards to Arctic biodiversity not getting enough prominence in international fora e.g., in IPBES assessments and Global Biodiversity Outlook reports, is simply the lack of sustained engagement in these processes. It's difficult to build a high profile without committing time/personnel into the development of these assessments and without visibility in such fora the programme's relevancy can be questioned. Efforts to address this should receive increased resources and attention. For example:

- Alignment of CBMP data and monitoring to produce indicators that reflect GBF headline, indicators;
- Visualization of these indicators on the *Arctic Biodiversity Dashboard* as a streamlined target tracking and reporting tool; and
- Participating in global reports both as authors and reviewers.

8 Conclusions

The CBMP is an Arctic Council programme whose relevance stretches beyond the Council to a broad range of circumpolar and global initiatives and agreements:

- *Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean* (DFO, 2018) addresses IK; cooperating in science and research; establishing conservation and management measures; ensuring the engagement and participation of Indigenous Peoples. Many of these are tasks also conducted by the CBMP. How can we avoid overlap and benefit from synergies?
- *Agreement on the conservation and sustainable use of marine Biological diversity of areas Beyond National Jurisdiction* (BBNJ) (UN, 2023) may have significant impacts on how the Council deals with Arctic biodiversity. What role might the CBMP play in its implementation? For example, OBIS has been proposed as the data framework for the BBNJ (UNESCO, 2020). How can the CBMP build upon the role of the ABDS as the Arctic node in OBIS?

- *EU funded Arctic initiatives* have contributed to expanding knowledge on the Arctic and are a significant source of funding for Arctic monitoring and research. Policy advice aimed at enhancing the EU's Arctic policy impact has recommended creating a stronger EU institutional presence in the work of CAFF. Including support for a new *Arctic Biodiversity Assessment* as the 2013 assessment may be outdated due to climate change impacts and expanding knowledge on the Arctic (Koivorova et al., 2021). How can the CBMP build upon current engagement with EU programmes to the benefit of enhancing Arctic Biodiversity monitoring and assessment?

Keeping such issues in mind while demonstrating relevancy is critical to ensuring programme sustainability. As the CBMP evolves, key tasks to support programme sustainability will be to:

- Follow-up on outcomes and lessons learnt from the SABRs;
- Ensure that the program remains relevant to multiple audiences through targeted, integrated, and flexible reporting across ecosystems;
- Improve integration across the monitoring groups and expert networks;
- Ensure program resources are sustainable;
- Explore the use of technology to improve monitoring, including making use of freely available technology, best practices, and tools from others;
- Consider how to further facilitate implementation of CBMP across Arctic research stations taking the impacts of extreme events into account (Van Beest et al., 2022); and
- Include IK and co-production in future programme development. To effectively do so requires addressing Indigenous Peoples concerns directly and involve them in developing and conducting monitoring and assessments.

Finally, a caveat regarding the war in the Ukraine which is having extensive impacts on the work of the Arctic Council including restricting progress towards implementing the CBMP. Russia covers 32.25% (10.5 million km^2) of the Arctic, 27.3% of CAFFs marine area and 38.7% of its terrestrial areas lie within Russia, which is home to most of the Arctic's human population (Figure 10). Current restrictions on cooperation between Arctic States under the Arctic Council as a result of the invasion of the Ukraine by the Russian Federation[15], will have

15 The countries other than Russia that make up the Arctic Council: Canada, Finland, Iceland, Kingdom of Denmark, Norway, Sweden, United States are not engaging in activities where Russia is involved.

FIGURE 10
Map of Arctic areas covered by Russia.

long term consequences for our ability to understand changes happening across the Arctic. As a result of these restrictions, the importance of the CBMP has been emphasized as a visible and crucial mechanism that is central to fulfilling the goals of the Council regarding biodiversity.

Author contributions

TB was the lead author, who compiled data, conducted review of material for inclusion, developed paper structure and content and coordinated review. TC provided substantial input into paper development including data and analysis. CB, CC, JC, SF, MG, WG, RH, CJ, TJ, KL, JL, MM, DM, CP, MR, MS, IT, JT, SW, NS, and RS all provided review and input throughout the development of the paper. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcosc.2023.1220521/full#supplementary-material

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