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- Aleut International Association (AIA)
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Cover photo: Polar bear, Gulf of Boothia, Nunavut, 2009. Photo: Corinne Pomerleau, Fisheries and Oceans Canada
Back cover photo: A Zodiac boat near an iceberg in Scott Inlet, Nunavut, 2013. Photo: Kevin Hedges, Fisheries and Oceans Canada

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CAFF Designated Area

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1. Executive Summary

Climate change, pollution and resource development in the Canadian Arctic are affecting marine biodiversity. Healthy arctic ecosystems are fundamental to the economy and the cultural and spiritual dimensions of arctic residents. Diversity of marine biota throughout this region is significant, poorly known, and potentially at risk from the unprecedented changes affecting the area. There is an urgent need to provide information on arctic marine biodiversity to managers and stakeholders who must adapt to changing conditions as well as make timely and informed decisions regarding human activities.

The Canadian Arctic Marine Biodiversity Plan (Canadian Marine Plan) is the Canadian contribution to the Arctic Council Conservation of Arctic Flora and Fauna's Circumpolar Biodiversity Monitoring Program, Arctic Marine Biodiversity Monitoring Plan. The overall objective of the Canadian Arctic Marine Biodiversity Plan (Canadian Marine Plan) is to improve our ability to detect and understand the causes of long-term changes in the structure and function of Canadian arctic marine ecosystems. The Canadian Marine Plan integrates existing scientific and community-based marine biodiversity data and information. It does not fund or collect new data, but relies on sampling funded by other programs. To date, no funded programs specifically address the urgent need to monitor change in Canadian arctic marine biodiversity.

The Canadian Marine Plan prescribes reporting on a suite of common biological parameters and indicators across trophic levels from microbes to polar bears in six priority marine ecosystems in the Canadian Arctic: 1) Canadian Beaufort Shelf; 2) Lancaster Sound; 3) Western Hudson Bay; 4) Hudson Strait; 5) Southeastern Baffin Bay; and 6) Nares Strait and Northern Baffin Bay. The plan defines key abiotic parameters relevant to marine biodiversity, such as sea ice characteristics and oceanographic parameters. The plan also draws links to other domestic programs (e.g., Beaufort Regional Environmental Assessment and Northern Contaminants Program) that assess and monitor anthropogenic ecosystem stressors, such as impacts of oil and gas development and contaminants arising from global pollution, respectively. The chosen indicators depend primarily on scientific data but some are based on traditional ecological knowledge.

It is hoped that the Canadian Marine Plan will guide the future integration of biodiversity research with development and conservation in Canadian arctic waters, and promote further development of long-term monitoring. Partnerships with various stakeholders nationally and internationally will encourage improvements to spatial and temporal resolution, and sampling protocols. Furthermore, such partnerships will encourage the use of both traditional ecological knowledge and science, as well as the provision of information on arctic marine biodiversity to decision makers.

A pod of killer whales (Orcinus orca). Photo: Steve Ferguson, Fisheries and Oceans Canada

2. Background and Context

2.1 Arctic Marine Biodiversity Monitoring Plan

The Convention on Biological Diversity (CBD) defines biological diversity as the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

In 2011, Arctic Council Ministers endorsed the Arctic Marine Biodiversity Monitoring Plan (Circumpolar Biodiversity Monitoring Program [CBMP]-Marine Plan), a pan-arctic, long-term, integrated plan to assess changes occurring to marine biodiversity (Gill et al. 2011). Approved by the Conservation of Arctic Flora and Fauna (CAFF) working group, the core objective of the plan is to improve scientific understanding of changes in arctic marine biodiversity to inform policy and management decisions at the international, national, regional and local levels.

The objective of the CBMP-Marine Plan is to answer the following questions: What is the status of arctic marine biodiversity? How is it changing and how are we monitoring change? What are the causes of the changes being observed? This objective will be achieved by integrating and analyzing data from different sources to detect change and discover linkages to potential stressors.

The CBMP-Marine Plan identifies relevant existing datasets and priority information gaps (taxonomic, spatial, and/or temporal) (Gill et al. 2011). The plan does not contemplate funding the collection of data; rather it is designed to make use of (and thus add value to) data collected through existing programs. The plan is intended to guide future directions for programs that participate in and/or contribute data to CBMP. The plan also describes an approach to data management, integration, and analysis, focusing on long-term datasets. Analyses of such datasets are expected to be particularly valuable for discriminating natural variability from responses to anthropogenic sources of stress.

2.2 Changes in the Arctic

The Arctic is experiencing some of the fastest and strongest impacts of climate change in the world (IPCC 2013). Average temperatures in the Arctic are rising twice as fast as the global average (IPCC 2007). This warming has already driven multiple changes in the Arctic. One of the greatest impacts is the extensive loss of sea ice in the Arctic Ocean (Stroeve et al. 2007; 2008). The Secretariat of the Convention on Biological Diversity stressed that climate change will affect biodiversity worldwide and especially in the Arctic (CAFF 2013). Many species assemblages in the Arctic, from microbes, to invertebrates, fishes, sea birds and marine mammals, are adapted to sea ice habitats. The warming of the Arctic Ocean and changes in ice regimes through loss of sea ice extent and thickness are affecting food web structures through biophysical and chemical processes. Species endemic to the Arctic are vulnerable to modifications in arctic ecosystems, including prey, and to northward range shifts by warmer-water marine species (Grebmeier 2012). Changes in sea ice are also posing risks to northern residents who use ice to travel and as a platform for fishing and hunting (AMAP 2012). The direct and indirect impacts of climate change are being superimposed on existing and anticipated effects of other anthropogenic stressors arising from human activity and pollution, resulting in cumulative effects.

Another impact related to climate change and specifically the increasing levels of anthropogenic carbon in the atmosphere is Arctic Ocean acidification. Arctic marine waters are experiencing widespread and rapid ocean acidification that is expected to cause significant changes to marine ecosystems (AMAP 2014).

The impacts on arctic ecosystems of global long-range contaminants, including persistent organic pollutants (POPs) and mercury, have been well document along with growing evidence that their effects are being compounded by climate change (AMAP 2009, AMAP 2011, UNEP/AMAP 2011, NCP 2011, and NCP 2013). Contaminants continue to pose ecosystem health risks, particularly for top predators, and human health risks for people who rely on traditional marine foods.

As the Arctic continues to warm, the larger ice-free area and longer ice-free period are permitting more human activities, especially commercial activities such as shipping and resource development, that will impose their own set of stressors on arctic ecosystems. These include disturbance, noise, local pollution, and the potential introduction of aquatic invasive species.

From a human perspective, biodiversity loss can have impacts on food security, contaminant pathways, and in species distributions. More details can be found in the Arctic Biodiversity Assessment (CAFF 2013).

2.3 Canadian Arctic Marine Biodiversity Plan (Canadian Marine Plan)

This document presents an ecosystem-based approach to assess and report on arctic marine biodiversity in Canada. The work undertaken through the Canadian Arctic Marine Biodiversity Plan (Canadian Marine Plan) represents Canada's contribution to the CBMP-Marine Plan; at the same time it is intended to inform national management and policy decision making. The intent of the Plan is not to develop and execute an extensive field-based sampling program, rather, it is expected to use and to add value to existing data collected (and funded) by other programs. Consistent with the CBMP-Marine Plan, the Canadian Marine Plan uses an indicator-based approach to detect changes in key species and biological communities in defined geographical areas, determine the factors driving these changes, and inform effective and proper management in arctic marine environments. Understanding the mechanisms of change provides managers and policy makers with predictive insights with which to mitigate change and ease adaptation by northerners.

Six Focal Ecosystem Components (FECs) are proposed in the Canadian Marine Plan, consistent with the CBMP-Marine Plan: sea ice biota, plankton, benthos, fishes, seabirds, and marine mammals. Two of these, sea ice biota and benthos, are based on habitat. Parameters and indicators for each FEC were recommended by Canadian experts participating in the Canadian Science Advisory Secretariat (CSAS) process "Science Advice for Identifying Indicators for Monitoring Arctic Marine Biodiversity in Canada" (DFO 2012). These indicators are presented in greater detail in subsequent sections in this document. Additional details and the rationale behind the indicators are contained in a companion research document (Nelson 2013).

As with the CBMP-Marine Plan, the Canadian Marine Plan makes recommendations concerning desired sampling protocols and spatial and temporal coverage within each of the six priority marine ecosystems (see Fig. 1). The plan identifies specific locations where more than one FEC (and in some locations several) are being sampled. These locations provide opportunities to interpret and understand change in a cross-trophic, ecosystemic context (see Annex 1).

The Canadian Marine Plan also strives to incorporate community-based monitoring in a meaningful way. Several northern organizations and communities have been involved in the design, selection, analysis and interpretation of data, and reporting about Canadian arctic marine biodiversity. The Canadian Marine Plan has two primary objectives for community-based monitoring: 1) to incorporate community-based monitoring information, interpretation, and expertise when detecting, understanding, and reporting on significant biodiversity trends, and 2) to make CBMP data, interpretation, and expertise available to community-based monitoring efforts.

It is also clear that Canadian scientists and traditional ecological knowledge (TEK) holders must collaborate if both scientific data and TEK are to contribute to the implementation of the Canadian Marine Plan. Traditional ecological knowledge may, in particular, offer insights into past conditions and status of biodiversity as well as inform current changes that are not available from academic science.

In addition, implementation of this plan requires collaboration with organizations and programs that monitor stressors on arctic marine ecosystems and biodiversity, such as the Northern Contaminants Program (NCP), which monitors contaminants in physical and biological arctic environments. Ultimately, the goal of the Canadian Marine Plan is to improve our understanding of changes occurring to Canadian arctic marine biodiversity and to provide regular and authoritative assessments that are useful for local, regional, national, and international decision making.

The ongoing and planned sampling activities described in this document are not funded or collected through the Canadian Marine Plan. All sampling activities referred to herein, from species stock assessments to routine oceanographic work and benthic surveys, are conducted through government, university and northern programs that operate and are funded independently of the Canadian Marine Plan.

Some, albeit a minority, of sampling and data collection activities in the Canadian Arctic can be described as true monitoring, i.e., repeated systematic observations at the same location over an extended period of time. However, the majority of the data used to implement the Canadian Marine Plan are associated with research projects. This document describes relevant sampling planned by these other agencies over the next three years, and also highlights the major data and sampling gaps from the perspective of monitoring Canadian arctic marine biodiversity. A major challenge, therefore, will be to determine the usefulness of these disparate datasets and the appropriate spatial and temporal coverage for monitoring purposes.

3. Priority Marine Ecosystems

The CBMP-Marine Plan and the Canadian Marine Plan identify four focal marine areas within the Canadian Arctic that represent distinct large-scale marine ecosystems. These focal marine areas are, from west to east: Beaufort Sea, Canadian Arctic Archipelago, Hudson Bay Complex and Davis Strait/Baffin Bay (Fig. 1). The exact boundaries may change over time to reflect changing biophysical conditions. The focal marine areas are very large, and data is scarce for most of them. This makes it impossible in a practical sense to report fully on marine biodiversity for each area. Therefore, Canadian scientists evaluated the most ecologically important marine ecosystems that also had the greatest availability of data, and selected these for priority attention in the Canadian Marine Plan.

The six priority marine ecosystems are: 1) Canadian Beaufort Shelf, 2) Nares Strait and Northern Baffin Bay, 3) Lancaster Sound, 4) Southern Baffin Bay, 5) Hudson Strait, and 6) Western Hudson Bay (Fig. 1). Several of these are also locations of increasing development and other human activity, e.g., offshore oil and gas exploration in the Beaufort Sea and Baffin Bay, commercial fishing in Hudson Strait, Baffin Bay and Davis Strait, and shipping in Hudson Bay and along the Northwest Passage.

Additional priority marine ecosystems were recommended during the CSAS meeting for future inclusion: Canada Basin, Sanikiluaq/Belcher Island area, Labrador Shelf, Ungava Bay, eastern Southampton Island, Prince Regent Inlet as far as Creswell Bay, Eclipse Sound, and Admiralty Inlet (DFO 2012). Similarly, the region around Cambridge Bay, where the Canadian High Arctic Research Station (CHARS) is planned to open in 2017, is also of considerable interest. These may be adopted in future. However, for the first period of implementation of the Canadian Marine Plan (2014-2017), the focus will be on the original six areas. Assessment and reporting will concentrate on the suite of common parameters and indicators developed by the CBMP-Marine Plan, though regionally specific parameters may also be applied to reflect regional differences in ecosystems.

Section 5 provides greater detail on each of the priority marine ecosystems.

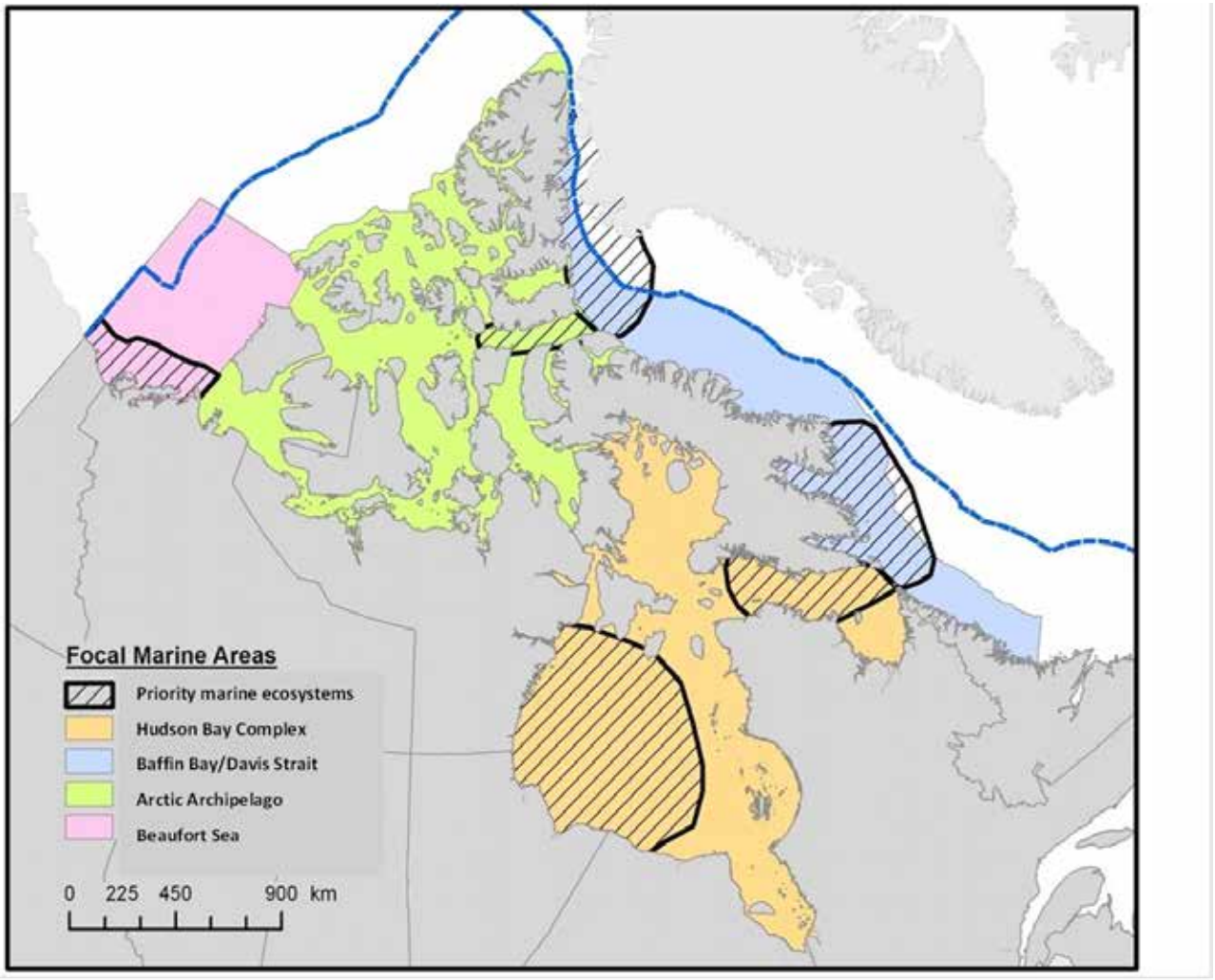


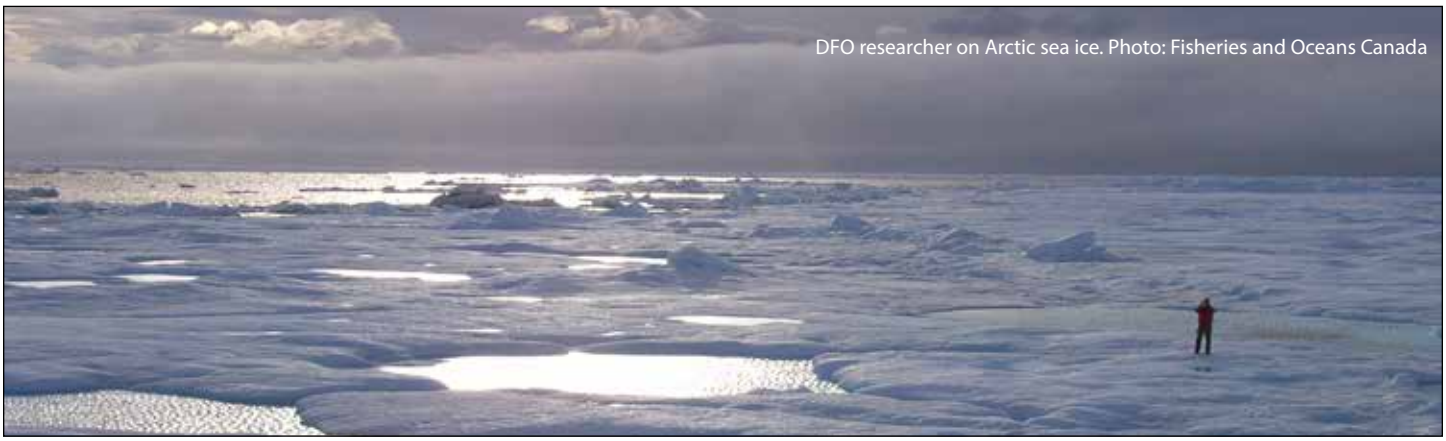
Figure 1: Four focal marine areas and six priority marine ecosystems. Focal marine areas are defined as follows: Beaufort Sea (pink), Canadian Arctic Archipelago (green), Hudson Bay Complex (orange), and Davis Strait/Baffin Bay (blue). Priority marine ecosystems are outlined and hatched in black and comprise the Canadian Beaufort Shelf (pink), Lancaster Sound (green), Western Hudson Bay (orange), Hudson Strait (orange), Nares Strait and Northern Baffin Bay (blue), and Southeastern Baffin Bay (blue) (Nelson 2013).

4. Focal Ecosystem Components

Focal Ecosystem Components (FECs) are considered central to the functioning of an ecosystem, and can be used as proxies of change in the environment (Gill et al. 2011, Levin et al. 2013). Some, such as marine mammals, fishes and seabirds are also directly important to arctic residents. The FEC categories in this plan reflect those in the CBMP-Marine Plan: sea ice biota, plankton, benthos, fishes, seabirds and marine mammals. Briefly, these FECs were chosen based on their sensitivity to stressors such as climate, harvesting, industrial development, contaminants, introduced alien species, tourism, diseases and parasites, scientific research, and shipping (Gill et al. 2011).

The status and changes occurring to these FECs will be assessed using the indicators described in this section. To the extent possible, the parameters and indicators, in addition to considering logistical constraints (e.g., data availability), were selected to be: 1) relevant (i.e., sensitive to drivers and assess an important ecosystem component or components), 2) simple and easily understood by a wide range of end users, 3) scientifically sound, 4) quantitative, which allows for objective assessment and comparisons, and 5) cost effective (O'Connor and Dewling 1986, as identified in Nelson 2013).

Certain parameters and indicators are common to all the FECs, e.g., species abundance, biomass and species composition. Additional details about the selected parameters and indicators can be found in Nelson (2013).



DFO researcher on Arctic sea ice. Photo: Fisheries and Oceans Canada

4.1 Sea Ice Biota

The unique and wide range of physical and chemical conditions in arctic sea ice creates a variety of habitats for a diversity of microbes, protists (single-celled organisms) and ice-associated fauna. These communities are fundamental to the structure and functioning of arctic marine ecosystems.

Sea ice-associated microbes include viruses, archaea and a variety of bacteria, some having the potential to degrade hydrocarbons. Microbial diversity in sea ice is comparable to that in plankton (water column), representing the bulk of biological biodiversity in arctic marine ecosystems. Among the thousands of protist species found in sea ice, ice algae include diatoms, flagellates and dinoflagellates (Poulin et al. 2011). Pennate diatoms are important contributors to the sea ice biota, especially in spring when they typically dominate the ice-associated biomass in first-year ice (Różańska et al. 2009). Diverse protist assemblages also colonize, to a lesser extent, fall and winter sea ice, as well as multi-year ice (Różańska et al. 2009, Niemi et al. 2011). Multi-cellular organisms also live within the ice (referred to as ice meiofauna), including species of crustaceans, nematodes, Acoela, Rotifera and Cnidaria. In addition, meroplanktonic larvae and the juvenile stage of benthic Polychaeta and Gastropoda inhabit the ice for periods of a few weeks to months.

No single indicator can offer a comprehensive view of status and trends in sea ice biota. Key parameters comprise abundance, biomass (e.g., chlorophyll *a*, organic carbon), species composition, size structure, biochemical proxies (e.g., fatty acids, stable isotopes, IP_{25}), productivity, and associate physical and chemical variables such as ice thickness, salinity and temperature. As part of the CBMP-Marine Plan, it is essential to document and monitor changes in these parameters over time at key locations. Key parameters for invertebrates include abundance, biomass, species composition and fauna size structure whereas abundance, compositional stages and reproduction are key indicators for arctic cod.

The rapid decline in sea ice summer extent and in the duration of the ice-covered period puts pressure on ice-associated species that depend on sea ice at least for part of the year or for part of their life cycle. The scope and influence of these changes and the shift from multi-year ice to seasonal sea ice stretch beyond ice-associated biodiversity to affect the structure and functioning of arctic marine ecosystems, with downstream impacts on connected sub-arctic ecosystems.

4.2 Plankton

Plankton live in the water column and drift with the currents; they range from less than one micron to several mm in size. Functionally, plankton are classified as: 1) phytoplankton that fix carbon and energy and are the base of all arctic food webs; chlorophyll concentrations are a proxy for phytoplankton abundance; 2) heterotrophic protists that graze on bacteria and other protists; 3) bacteria and archaea that break down organic matter in the water column and remineralize nutrients; and 4) zooplankton. Zooplankton are multi-cellular and often separated into meso and macrozooplankton; they are important prey for fishes, seabirds, and marine mammals (Welch et al. 1992). Zooplankton often migrate up and down the water column, but cannot swim against currents. The term microzooplankton refers to larger single-celled heterotrophic protists and zooplankton smaller than 200 microns.

Plankton indicators ideally include abundance, biomass and species information. DNA can provide information on the taxonomic identity of and community changes in single-celled organisms (Comeau et al 2011) and for the zooplankton can be used to track populations across regions. Most historic data is on crustacean zooplankton, especially copepods, while less is known about gelatinous zooplankton, which may become more abundant in a warmer climate (Deibel et al. 2005, Deibel and Daly 2007). Latitudinal range shifts of some plankton species have been reported (Beaugrand et al. 2002; Mackas et al. 2007) with warm water zooplankton species, which are usually smaller and less lipid-rich than the arctic species, moving north.

The biodiversity of plankton is much greater than any other taxonomic group, and community composition reflects environmental selection. Monitoring key species over appropriate time scales could provide an index of ecosystem health and direction of environmental change, and should be given high priority within monitoring programs (e.g., Ware and Thompson 2005, Samhouri et al. 2009).

4.3 Benthos

Benthos describes organisms that live on, in, or are dependent on the bottom of the seafloor to live. Benthos includes three categories: 1) benthic fauna, 2) benthic flora and 3) benthic microbes. Benthic fauna include four groups of organisms based on size: megafauna, macrofauna, meiofauna and microbes. There are more than 2500 benthic invertebrates and macroalgae species in the Canadian Arctic (Archambault et al. 2010 and updated since 2010, Archambault personal communication). Benthic flora comprise macroalgae and small algae called microphytobenthos.

Benthic fauna are important nutrient recyclers and an essential prey base for benthic feeding fish, seabirds and marine mammals. Benthos may also recycle sediment-associated contaminants, thereby reintroducing them to the benthic-based food web. It is also recognized that erect sponges and cold water coral could be used as refuge by many animals such fishes.

Key indicators for describing and quantifying benthos include abundance, biomass, diversity measures, species composition and genetic composition. A diverse collection of organisms is associated with benthic substrates in Canadian arctic marine habitats. Benthic microbes and viruses are not well-studied; knowledge of benthic taxa increases with size as the larger taxa are more easily studied.

Some benthic organisms are long-lived and record environmental change; corals and bivalves are an example of bio-archiving animals. Many are sedentary and patterns of community change record environmental conditions both at and above the seabed on spatial and temporal scales. In Europe, benthic communities are a key component of a monitoring program under the Water Framework directive. Because benthic organisms can be long-lived, relatively sedentary, and slow-to-fast growing, benthic fauna are a valuable monitoring tool as long as the sampling is methodologically consistent, spatially-focused and long-term.

Benthic samples. Photo: Alexey Solodov, Shutterstock.com

4.4 Fishes

Fishes can be divided into two categories: 1) pelagic fishes (which live in the water column) and 2) demersal fishes (which live on or near the bottom). Fishes are ecologically important as both predators and prey, and are harvested by humans for commerce and sustenance.

At least 189 species of marine fish are found in the Canadian Arctic (Archambault et al. 2010). Sixteen fish species were identified in the CBMP-Marine Plan (Gill et al. 2011) that are either significant to northern residents, commercially important or a critical part of arctic marine ecosystems. From an ecological perspective function, the most important anadromous and marine species in the Canadian Arctic are arctic char (*Salvelinus* sp.), dolly varden (*Salvelinus malma*), inconnu (*Stenodus leucichthys*), whitefishes (*Coregonus* spp.), arctic cod (*Boreogadus saida*), Greenland cod (*Gadus ogac*), Greenland halibut (*Reinhardtius hippoglossoides*), Greenland shark (*Somniosus microcephalus*), pacific herring (*Clupea pallasi*), and polar cod (*Arctogadus glacialis*).

Key monitoring parameters include species richness and community composition at the ecosystem level, and abundance, biomass, age/size distribution, health condition, genetics, harvest statistics, and life history at the species level. Many commercial fish species have relatively consistent and reliable monitoring data, but less information is available for species that are not harvested. Climate change may lead to greater direct (e.g., increased access for fishing) and indirect (e.g., oil and gas exploration and development) human impacts on fishes, and anticipated changes in abiotic conditions (i.e., water temperatures and primary productivity) will result in range shifts, the establishment of invasive species, new diseases, altered productivity, changes in contaminant biomagnification, and altered phenology.

Common eiders on polynya ice. Photo: Grant Gilchrist, Environment Canada

4.5 Seabirds

Seabirds (also known as marine birds) are birds that have adapted to life within the marine environment. They are important to the arctic marine ecosystem as mid- or top-level predators, and some are harvested and consumed by northern residents.

Since 1993, the CAFF Circumpolar Arctic Seabirds Expert Group has been monitoring seabirds on a regular basis (Petersen et al. 2008). In Canada, three key species have been identified and include the black-legged kittiwake (*Rissa tridactyla*; surface piscivore), murres (diving piscivores) and common eiders (*Somateria mollissima*; benthic feeders). Four additional species will be included as part of the Canadian seabird monitoring: the northern fulmar (*Fulmarus glacialis*; pelagic foraging), ivory gull (*Pagophila eburnea*; ice-associated and Endangered (Committee on the Status of Endangered Wildlife in Canada (COSEWIC)), glaucous gull (*Larus hyperboreus*; omnivore, significant contaminant load), and black guillemot (*Cepphus grylle*; benthic feeder) (Gill et al. 2011).

Monitoring the biodiversity of arctic seabirds is mainly captured by monitoring their distribution and population trends. For colonial species, methods are well-developed; most of the effort is in reaching the colony. Ship- and aerial-based surveys are also used to assess changes in distribution and abundance and will be key for assessing any boundary shifts (e.g., incursions of temperate species into arctic waters). Other key parameters for seabirds are colony size, survivorship, reproductive success, chick diet, harvest statistic and phenology. Survivorship, reproductive success and harvest statistics are useful parameters for understanding why seabird populations may be changing in size or distribution.

Chick diet can explain reproductive success in seabirds, but also indicates change in the prey base. Chick diet, therefore, can be used as an indicator to monitor other FECs, specifically large zooplankters (which are consumed by northern fulmar and kittiwake), and forage fishes (which are consumed by murres) and coastal benthic organisms (which are consumed by eiders). Additionally, ice-associated species can be monitored using murres and ivory gull. Changes in phenology provide a signal of general marine ecosystem change, as seabirds attempt to match the timing of breeding with conditions most suitable to successful breeding. As marine predators, seabirds can accumulate concentrations of contaminants that approach or exceed thresholds for effects (NCP 2011, NCP 2013). Monitoring contaminant concentrations is important for assessing the risk of toxic effects, which may have implications for immune, endocrine, reproductive and neurological systems.

To further understand the current status of the important seabird populations in the Canadian Arctic, monitoring of oceanographic data, productivity and seabird prey (plankton and fishes) should also be performed.

4.6 Marine Mammals

The Canadian Arctic provides seasonal and year-round habitat for several species of marine mammals, many of which are important for subsistence purposes. There are nine species of ice-associated marine mammals in the Canadian Arctic including three species of whale (beluga (*Delphinapterus leucas*), narwhal (*Monodon monoceros*) and bowhead whale (*Balaena mysticetus*)), five species of pinnipeds (walrus (*Odobenus rosmarus*), ringed seal (*Phoca hispida*), bearded seal (*Erignathus barbatus*), harp seal (*Pagophilus groenlandicus*) and hooded seal (*Cystophora cristata*)), and the polar bear (*Ursus maritimus*) (Kovacs et al. 2011). There are also several species (e.g., fin whales, minke whales, humpback whales, grey whales, killer whales, harbour porpoises, sperm whales, bottlenose whales, harbour seals) that occasionally or regularly visit the marginal waters of the Canadian Arctic from more southern regions.

Key parameters to monitor for marine mammals include spatial distribution (telemetry), abundance, population demographics (fecundity and mortality), habitat selection, stock structure (genetics), feeding behaviour, body condition and growth, contaminant load and harvest statistics. Climate change has the potential to strongly affect marine mammals, both directly and indirectly (Moore and Huntington 2008). Some ice-associated marine mammals are already showing distribution shifts, compromised body condition and declines in production/abundance in response to sea ice declines (Laidre et al. 2008). In contrast, temperate marine mammal species are showing northward expansions of their ranges, which are likely to cause competitive pressure on some endemic arctic species, as well as put them at greater risk of predation, disease and parasite infections. Arctic marine mammals also carry relatively high contaminant burdens which can exceed thresholds for effects, to which they may become more sensitive when put under the additional stresses of a changing arctic marine environment. The negative impacts observed to date within arctic marine mammal populations are expected to continue and likely escalate over the coming decade, with continued declines in seasonal coverage of sea ice. This situation presents a significant risk to arctic marine mammals that depend on sea ice for protection, food and reproduction.

Bearded seal. Photo: Steve Ferguson, Fisheries and Oceans Canada

5. Regional Ecosystem-based Approach

The Canadian Marine Plan employs an ecosystem-based approach in the six priority marine ecosystems. A description of the uniqueness of each of these priority ecosystems is presented below, together with its importance to northerners, presence of species at risk and protected areas, the state of the data record, and the stressors and potential stressors acting on the area. This is followed by a description for each priority marine ecosystem of ongoing data collection and sampling efforts (funded and directed by other programs), along with the subset of key parameters and indicators for each FEC (where applicable) being used to implement the Canadian Marine Plan (Annex 1).

Cross-trophic (ecosystem) analysis and interpretation of arctic marine biodiversity will be conducted, where possible, for those priority marine ecosystems for which data exist for several FECs. Many indicators have not yet been tested for sensitivity or their ability to detect change in the Canadian arctic marine environment. It will be necessary to assess the sensitivity of indicators to change as well their ability to distinguish real change from natural variability (signal-to-noise ratios) (DFO 2012).

5.1 Canadian Beaufort Shelf

5.1.1 Description

The Canadian Beaufort Shelf is located in the southern part of the Beaufort Sea region. This priority marine ecosystem is strongly influenced by freshwater inputs from the Mackenzie River and is characterized by high levels of primary production as well as seasonal sea ice: most of the shelf is ice-free in the summer. The edge of the Canadian Beaufort Shelf has steep bathymetry and is characterized by upwelling (Carmack and Macdonald 2002). The high primary productivity of the shelf is associated with the Mackenzie River freshwater plume that extends east into the Amundsen Gulf (Carmack et al. 2004). This area is also characterized by high benthic remineralization, benthic diversity and production. Freshwater input affects biodiversity patterns and the productivity–diversity relationship of all FECs in the area (Archambault et al. 2010).

This area has several hotspots of biological productivity including the Cape Bathurst Polynya (Arrigo and van Dijken 2004) which provides habitat for marine mammals and seabirds (Dickson and Gilchrist 2002). Polar bears feed within this priority marine ecosystem and use the Beaufort Shelf as a migration corridor. It is a known summer feeding area of the Bering-Chukchi-Beaufort bowhead whale population and beluga whales also use the shelf as a migration pathway (Moore and Reeves 1993).

The Canadian Beaufort Shelf waters are accessed by the Inuvialuit who utilize the area to harvest marine mammals and fish as part of a subsistence way of life. Within the Inuvialuit Settlement Region is Canada's first arctic Marine Protected Area; Tarium Niryutait Marine Protected Area (TN MPA) which consists of three individual areas called Niaqunnaq, Okeevik and Kittigaryuit located in the Mackenzie Estuary. The TN MPA was put in place to conserve belugas and their supporting habitat and to maintain one of the world's largest beluga aggregating areas. A second MPA is currently being designated in Darnley Bay (near Paulatuk), Anuniqvia Niqiqyuam.

The Canadian Beaufort Shelf is probably the only region within the Canadian Arctic that has extensive historical and current scientific datasets. Within this priority marine ecosystem, a large proportion of existing data are collected for several FECs through the Beaufort Regional Environmental Assessment (BREA) program. BREA is a multi-stakeholder initiative funded by the federal government; it supports regional environmental and socio-economic research to inform the management of potential offshore oil and gas activities in the Beaufort Sea (http://www.beaufortrea.ca/).

5.1.2 Ongoing and planned data collection and sampling

There is currently no program within this priority marine ecosystem to collect sea ice biota data. However, historical data and unpublished sources do exist.

In terms of plankton, in the past, samples have been collected from ArcticNet research vessels. This work focused primarily on microbial diversity as well as zooplankton species composition, abundance, biomass and biogeography. Both microbes and zooplankton will be sampled in the Amundsen Gulf in late summer 2014 during the ArcticNet and Joint Ocean Ice Study cruises.

Benthic sample collection will also take place during the 2014 ArcticNet cruise. BREA and ArcticNet have both supported benthic sampling in past years. The main indicators being evaluated are species richness, species abundance and biomass, and community composition of benthic organisms.

Offshore marine fishes are being studied as part of the BREA program through multispecies benthic fish surveys supported by the concurrent collection of abiotic data. The main indicators being evaluated are fish species distribution and biodiversity, mostly at depths greater than 200 metres.

Coastally, there have been several long-term fish stock assessment programs led by Fisheries and Oceans Canada (DFO) and the Fisheries Joint Management Committee (FJMC) in partnership with the communities. Key species being assessed are arctic char (*Salvelinus alpinus*), dolly varden trout (*Salvelinus malma*) and broad whitefish (*Coregonus nasus*).

There are currently no ongoing monitoring activities related to seabirds in the Canadian Beaufort Shelf ecosystem with the exception of the Cape Parry Migratory Bird Sanctuary where Environment Canada assesses nests every four years.

In regards to harvested marine mammals, DFO and the FJMC have supported some of the longest marine mammal community-based monitoring programs in the circumpolar Arctic. In particular, ringed seals (*Pusa hispida*) have been monitored for over 30 years in Ulukhaktok (Harwood et al. 2012) and beluga whales (*Delphinapterus leuca*) have been also been monitored for over 30 years in the Mackenzie estuary. These long-standing monitoring programs have established strong collaborations between government and academic researchers, hunters and communities to monitor and study the health status of ringed seals and beluga whales. The beluga monitoring program at Hendrickson Island near Tuktoyaktuk has expanded to include multiple indicators of health including hormones, energetics, diet, contaminant levels, demographic information (e.g., age and sex), body condition and harvest statistics. The NCP is a partner in these community-based monitoring programs and annually monitors contaminants in ringed seals from the Sachs Harbour area and in beluga whales near Hendrickson Island off the Mackenzie Delta. The NCP also funds food web, contaminant pathways, and process research through partnerships with ArcticNet and other programs in the Beaufort Sea and Amundsen Gulf.

A new program, the Inuvialuit Settlement Region Community-based Monitoring Program, which is based in Inuvik, NWT, aims to strengthen collaborative research between traditional knowledge experts and ecology scientists.

5.2 Lancaster Sound

5.2.1 Description

Lancaster Sound is a deep and wide channel that opens onto Baffin Bay from between Devon Island and Baffin Island. It is the eastern gateway of the Northwest Passage. Lancaster Sound is characterized by the presence of polynyas, a high level of biological productivity, high export rates of sea ice algae and important benthic diversity and production (Stirling 1997). It is a major migration corridor for marine mammals including the Eastern High Arctic/Baffin Bay beluga whale population, the Eastern Canada-West Greenland bowhead whale population and the Baffin Bay narwhal population (Cobb et al. 2011). This is a major feeding area for polar bears and contains several haul-out sites for walrus. Over one million seabirds and sea ducks use Lancaster Sound as a nesting and feeding area.

Lancaster Sound is covered by sea ice for approximately nine months of the year and is an important area to local people, especially for traditional harvesting and fishing. Lancaster Sound is attracting numerous development activities including potential oil and gas exploration and exploitation, mining and increased shipping traffic. A national project is underway to create the Lancaster Sound National Marine Conservation Area (44 500 km^2).

5.2.2 Ongoing and planned data collection and sampling

Sea ice biota work in the past has taken place in Barrow Strait, near Resolute Bay, just west of Lancaster Sound and has focused on first-year and multi-year ice protist abundance and species dominance together with measurement of physical and chemical variables. Comparing pre-climate change data with recent long-term monitoring datasets is a key research area. Targeted diatom species were *Nitzschia frigida* and *Melosira arctica*. The program ended in 2013 but may continue pending availability of funding.

Plankton (microplankton, phytoplankton and zooplankton) and benthic samples have been collected in Lancaster Sound in the past, and will be collected again in 2014 during the ArcticNet cruise. The main indicators being evaluated for both plankton and benthos are species abundance and biomass, and community composition. Associated with this work, the NCP will be measuring contaminant levels in air, seawater and plankton sampled from the ship.

Arctic fish stock assessments in Lancaster Sound are conducted by DFO via offshore multispecies surveys with benthic trawls. Because of the short duration of ice-free conditions each year in Lancaster Sound, these surveys only occasionally reach the eastern extent of the area. The surveys focus primarily on stock assessments of Greenland halibut and northern and striped shrimp. Data are collected for all species caught (fish, invertebrates, corals and sponges). Supporting abiotic data are collected concurrently.

Environment Canada and Acadia University plan to continue to monitor the breeding ecology of several seabird species including thick-billed murre, northern fulmar and black-legged kittiwake at Prince Leopold Island, which is located in Lancaster Sound at the junction of Prince Regent Inlet and Barrow Strait. The NCP will continue to conduct annual monitoring of contaminants in eggs of thick-billed murres and northern fulmars from the same area. The NCP is also conducting annual monitoring of contaminants

in ringed seals around the Resolute Bay area and is initiating a community-based monitoring program for contaminant levels in seawater of Barrow Strait. The NCP also funds food web and contaminant pathways and process research in the area of Lancaster Sound and Barrow Strait.

DFO has initiated an extensive aerial photographic survey of the eastern Canadian Arctic, including in Lancaster Sound, to enumerate cetacean stocks (e.g., narwhal, bowhead, and beluga) and to develop an interactive platform for the analysis of aerial survey photographs. These aerial surveys provide information on species biogeography and range shifts. Another ongoing activity at DFO is the determination of killer whale movements and diet. Satellite transmitters (telemetry), tissue biopsies, photography, and recording of vocalizations from killer whales have taken place over the last few years and these activities are planned in several locations including Admiralty Inlet and Pond Inlet, two areas adjacent to Lancaster Sound. Finally, Environment Canada is studying the polar bear population genetic structure using analysis of single nucleotide polymorphisms.

5.3 Western Hudson Bay

5.3.1 Description

Western Hudson Bay is part of the larger Hudson Bay Complex region. This priority marine ecosystem is the most southerly in the Canadian Marine Plan and is the area where sea ice lasts the longest within Hudson Bay (Galbraith and Larouche 2011). Western Hudson Bay encompasses several river estuaries (Seal, Churchill and Nelson rivers) and the offshore boundary of Western Hudson Bay coincides with a persistent summer sea-surface temperature front, which creates a consistent frontal zone (Ingram and Prinsenberg 1998; Galbraith and Larouche 2011).

Western Hudson Bay is a productive area, especially for benthos, which is characterized by high diversity and production (Kenchington et al. 2011). It is a feeding zone and migration corridor for arctic char (Sprules 1952). The river estuaries in Western Hudson Bay constitute one of the largest summer aggregation of beluga whales in the world. Further, this priority marine ecosystem is home to the Western Hudson Bay polar bear population. The Western Hudson Bay and Southern Hudson Bay polar bear populations use this area during the spring ice break-up period primarily for feeding (Castro de la Guardia et al. 2013). Sea ice is a critical habitat for the rearing and survival of polar bear cubs and for the overall fitness of both populations (Stirling and Derocher 2012). Changes in sea ice cover are negatively affecting polar bears, allowing increased shipping in Hudson Bay and extending the length of the shipping season. The major prey of polar bears, ringed seals, is also experiencing negative changes in population demography (Ferguson et al. 2005).

5.3.2 Ongoing and planned data collection and sampling

Sea ice monitoring has taken place in the past within the extended region of the Churchill River with a focus on first-year ice protist abundance and species dominance along with concurrent measurements of physical and chemical variables. The main targeted species is *Nitzschia frigida*. This monitoring program is expected to be re-instated in 2014.

There are no known current monitoring activities in Western Hudson Bay for plankton, benthos or fishes. However, a research program for primary production, plankton and benthos is presently being developed by the University of Manitoba (David Barber and CJ Mundy) and Manitoba Hydro witih funding from Natural Sciences and Engineering Research Council (NSERC) Collaborative Research and Development (CRD) Grants to sample some areas in Hudson Bay in the near future.

In terms of seabirds, Environment Canada plans to conduct fieldwork in Wapusk National Park and in La Perouse Bay as part of the ongoing Hudson Bay project on ecosystem studies and the conservation of coastal arctic tundra.

An ongoing research activity by DFO is a ringed seal population abundance study based on aerial surveys of Western Hudson Bay. In 2015, DFO also plans to conduct an aerial survey of Hudson Bay for belugas and narwhals. Beluga whale tagging work is also planned for 2015 in conjunction with the aerial survey to assess availability of whales at the ocean surface to aerial observation. DFO is continuing community-based tissue collection efforts in Arviat and Sanikiluaq for beluga and ringed seals; these have provided more than a decade of continuous data monitoring.

Environment Canada is monitoring polar bear diet, contaminant levels, genetics and movements. NCP is conducting annual monitoring of contaminants in ringed seal collected from the Arviat area and polar bears from Western Hudson Bay in cooperation with DFO and Environment Canada. Though not in Western Hudson Bay, NCP in cooperation with DFO is also monitoring beluga whales for contaminants annually near Sanikiluaq.

5.4 Hudson Strait

5.4.1 Description

Hudson Strait is part of the Hudson Bay Complex. The strait is about 720 km long and is located between Nunavik (Northern Québec) and Baffin Island; it opens into Davis Strait and the Atlantic Ocean. Hudson Strait is a channel for arctic waters but experiences periodic intrusions of atlantic waters; the western side of the strait is characterized by stronger currents than the eastern side (Drinkwater 1986).

Hudson Strait is an important marine mammal migration corridor and an area for seabird colonies and sea duck nesting and foraging. Bowhead whales and belugas from both the Western and Eastern Hudson Bay populations are known to overwinter and migrate through Hudson Strait (COSEWIC 2004). There are several haul-out sites for the northern Hudson Bay-Davis Strait Atlantic walrus population. This area is also characterized by rich epibenthic habitat including sponges and corals and a large biomass of northern and striped shrimp (Kenchington et al. 2011).

5.4.2 Ongoing and planned data collection and sampling

Currently no existing or future biodiversity monitoring activities are planned for sea ice biota, plankton or benthos in Hudson Strait. Arctic stock assessments of fishes and shrimp are conducted via offshore multispecies surveys with benthic trawls. These surveys focus primarily on Greenland halibut, and northern and striped shrimp. Additionally, data are collected for all species (fishes, invertebrates, corals, and sponges) encountered. Abiotic data are collected concurrently.

Environment Canada is planning to monitor common eider and thick-billed murre population trends and movements, habitat use, foraging range and migration patterns. The NCP conducts annual monitoring of contaminant levels in the eggs of thick-billed murres from Coats Island, in cooperation with Environment Canada.

Fisheries and Oceans Canada will continue their extensive Eastern Arctic aerial photographic survey to enumerate cetacean stocks (e.g., narwhal, bowhead, and beluga) and to develop an interactive platform for the analysis of aerial survey photographs. A survey of walrus in southeastern Hudson Bay and Hudson Strait is planned for 2014 to assess population abundance and haul-out locations. Environment Canada is also monitoring polar bear diet, contaminant levels, genetics and movements in Hudson Strait.

5.5 Southeastern Baffin Bay

5.5.1 Description

The Southeastern Baffin Bay area is characterized by a counter-clockwise ocean current system formed by polar water mixed with atlantic-influenced water flowing from the south along the western Greenland coast and cold water coming from the north via Nares Strait and flowing southward along the coast of Baffin Island (Ingram et al. 2002). The southern portion of Baffin Bay, as well as the northern part, encompasses well-defined shelves on both the Canadian and Greenland sides. This priority marine ecosystem has seasonal sea ice that persists longer along the coast of Baffin Island compared to further east. Southern Baffin Bay is an important area for narwhals and bowhead whales. Both species overwinter within this region and use it as a foraging ground. This is also a rich epibenthic area characterized by black corals (Kenchington et al. 2011).

This priority marine ecosystem encompasses the Ninginganiq National Wildlife Area which was designated in 2010. This protected area is located 120 km south of Clyde River on the coast of Baffin Island. This area, Isabella Bay, is a known aggregation area for bowhead whales, especially in summer.

5.5.2 Ongoing and planned data collection and sampling

No biodiversity monitoring activities currently take place or are planned in Southeast Baffin Bay for sea ice biota. Plankton samples for microplankton and bacterioplankton have been collected in this area in previous years and will be collected during the upcoming ArcticNet cruise in July 2014. The main indicators are species composition, abundance, biomass and community composition.

For benthos, the program GreenEdge may go forward in 2015. Offshore surveys and multispecies benthic fish surveys are conducted to support stock assessments of Greenland halibut, northern shrimp, and striped shrimp. The survey depths and specific locations are selected for these species, but data are collected for all species (fish, invertebrates, corals and sponges) encountered. Abiotic data are collected concurrently.

Exploratory inshore fish surveys have been conducted along the east coast of Baffin Island since 2011. The primary focus of these surveys is to support the development of new community-based fisheries (primarily targeting Greenland halibut); a secondary objective, however, is to conduct a general marine biodiversity survey. No monitoring activities related to seabirds are ongoing in the southeastern Baffin Bay priority marine ecosystem.

DFO will continue their extensive Eastern Arctic aerial photographic survey in Southeastern Baffin Bay to enumerate several cetacean stocks (e.g., narwhals, bowheads, and belugas) and will develop an interactive platform to analyze aerial survey photographs. Another planned research activity is to determine killer whale movements and diet. Satellite transmitters (telemetry), tissue biopsies, photography, and recording of vocalizations from killer whales are planned in several locations including Cumberland Sound on the east side of Baffin Island. A planned survey of Cumberland Sound beluga whales will add to the trend analysis of changes in abundance of this threatened population. A study is also ongoing of bowhead whale foraging behaviour in Cumberland Sound. The NCP is conducting annual monitoring of contaminant levels in beluga whales near Pangnirtung in cooperation with DFO, and is also funding contaminant food web research within that area.

5.6 Nares Strait and Northern Baffin Bay

5.6.1 Description

The Nares Strait and Northern Baffin Bay priority marine ecosystem encompasses the North Water Polynya (NOW; 85 000 km^2), which is the largest and most productive area of water in the Arctic that remains open year-round (Stirling 1997). Nares Strait is located between Ellesmere Island and Greenland. One of the unique characteristics of Northern Baffin Bay is the aggregation of large sea pens and the richness of the epibenthic habitat (Kenchington et al. 2011).

The North Water Polynya is characterized by high biological productivity and high benthic diversity and production. It is a key area for nesting and foraging of numerous seabird colonies such as dovekie and thick-billed murres. This priority marine ecosystem is home to most of the Canadian population of the endangered ivory gull.

Narwhals, belugas, bowhead whales and polar bears utilize Nares Strait and Northern Baffin Bay for resting and overwintering and as feeding areas. Walruses use this area as a migration corridor and for hauling-out in summer and winter. Polar bears also feed in this area.

The Nirjutiqavvik National Wildlife Area (Coburg Island) is located near Grise Fiord. This National Wildlife Area is home to large seabird nesting areas and is also important for several marine mammal species such as polar bear, walrus, ringed seals, bearded seals, belugas and narwhals.

5.6.2 Ongoing and planned data collection and sampling

Sea ice biota sampling has been taking place in the North Water Polynya. Monitoring is focused on first-year and multi-year ice algal abundance and species dominance supported by measurements of physical and chemical variables. Comparing pre-climate change data with recent assessments of long-term monitoring time series is a key research area, targeting the diatom species *Nitzschia frigida* and *Melosira arctica*.

Micro and bacterioplankton samples will continue to be collected during the summer 2014 ArcticNet cruise, together with benthic samples to characterize species assemblages and community composition. Offshore and multispecies benthic fish surveys will continue to be conducted for Greenland halibut and the northern and striped shrimp. The sampling depths and locations are optimized for those species, but data are collected for all species (fish, invertebrates, corals and sponges) encountered. Abiotic data are collected concurrently.

Exploratory in-shore fish surveys have been conducted along the east coast of Baffin Island since 2011. The primary focus of these surveys is to support fisheries development but the secondary goal is to conduct a general marine biodiversity survey. Environment Canada will monitor thick-billed murre movements, habitat use, foraging range and migration patterns at Cape Graham Moore. DFO will conduct an aerial survey to estimate the abundance of the Baffin Bay narwhal population and to assess the seasonal range and movement patterns of Jones Sound narwhals through a telemetry study.

5.7 Summary of ongoing activities and existing gaps

Not all FECs will be monitored within each of the six priority marine ecosystems over the next three years. There are significant gaps in sampling and data collection activities, which are often related to insufficient funding. Only a few of the current and planned activities can truly be considered monitoring while the majority of data are associated with research programs.

For sea ice biota, the primary gaps are in the Canadian Beaufort Shelf, Hudson Strait and Southeastern Baffin Bay. For plankton, there are major sampling gaps for Hudson Strait while in Western Hudson Bay sampling will depend on the success of funding applications. Benthos activities are similar to those for plankton with significant gaps in Hudson Strait. Future sampling in southern Baffin Bay and in Hudson Bay depend on obtaining funding approval (GreenEdge and University of Manitoba/Manitoba Hydro). In terms of fishes, there is a significant gap in Western Hudson Bay. Gaps for seabird data exist for the Canadian Beaufort Shelf and in Southeastern Baffin Bay. Data and samples are being collected for marine mammals on an ongoing basis in all six priority marine ecosystems.

6. Data Management

The CBMP-Marine Plan established Marine Expert Networks composed of experts across the circumpolar Arctic for each FEC. Each network is responsible for developing databases for their respective FEC and for aggregating relevant data across the circumpolar region. Significant information technology and GIS support is being provided by CAFF (e.g., Arctic Biodiversity Data Service, and Arctic Spatial Data Infrastructure; http://www.abds.is/). Metadata for existing and earlier data are being added to the Polar Data Catalogue (https://www.polardata.ca/). Some participating countries (e.g., USA) are also creating national databases covering multiple trophic levels.

CAFF will continue to support Marine Expert Network endeavours to develop databases, share data, improve data access, and display and manipulate data (e.g., visuals). All Expert Networks are being encouraged to use and adapt the data sharing agreement developed by the Benthos Expert Network to share unpublished data.

Within Canada, in addition to participating in the circumpolar data management effort, DFO collaborators are being encouraged to incorporate their data and metadata into DFO databases (e.g., Biochem).

7. Deliverables

Over the three-year period of this plan, focus will be placed on the following:

- construction and management of metadata, data, databases and data nodes for fish, marine mammals, and other trophic levels
- development, use and reporting of scientific and traditional ecological knowledge indicators of arctic marine biodiversity for marine mammals, fish and other trophic levels, including spatial distributions and time series of some indicators
- discerning and understanding the causes behind observed changes in arctic marine biodiversity in Canada
- recommending standardized data/sample collection protocols
- producing publications and presentations for decision makers and scientists, nationally and internationally, as well as scientists, and contribution to the CAFF "State of the Arctic Marine Biodiversity" report
- communications, especially for non-specialists and northerners
- scientific publications

Cardigan Strait from Canadian research vessel. Photo: Fisheries and Oceans Canada

8. Recommendations

The overall objective of the Canadian Arctic Marine Biodiversity Plan (Canadian Marine Plan) is to improve our ability to detect and understand the causes of long-term changes in the composition, structure and function of Canadian arctic ecosystems. In order to help coordinate biodiversity monitoring and conservation efforts in Canadian arctic marine waters, we have developed three recommendations:

1. There is a need to generate new funding and new partnerships to address shortfalls in our ability to monitor arctic marine biodiversity. Strengthening existing partnerships and building new ones with various stakeholders will improve spatial and temporal resolution of sampling activities, and facilitate bringing results to decision makers.
2. In order to overcome gaps and prevent overlaps, there is a need to better integrate existing and future datasets. We encourage the scientific community to communicate, plan, and combine efforts in their biodiversity monitoring activities.
3. It is of fundamental importance to engage northern communities in monitoring-related activities in all priority marine ecosystems of the Canadian Arctic and to include traditional ecological knowledge wherever possible.

The Arctic is fundamental to Canada as many Aboriginal and other northerners, together with a large diversity of arctic-adapted animals and plants, live in this vast area. Healthy arctic ecosystems are fundamental to the economy and the cultural and spiritual lives of arctic residents. Diversity of marine biota throughout this region is significant, poorly known, and potentially at risk from the unprecedented changes affecting the area. Climate change, human population increases, resource exploration and development, and shipping, among other stressors, are contributing to these changes, which have implications for marine biodiversity, and the value it holds for Canadian and circumpolar societies. Arctic ecosystems must remain healthy as the Arctic plays a critical role in the Earth's physical, chemical and biological balance. (For more information, please visit the CBMP-Marine Plan: Canadian Implementation website http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/cbmp-psbc/index-eng.html.)

Collecting samples. Photo: Fisheries and Oceans Canada

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10. Annex 1

Ongoing monitoring and sampling efforts (funded by other programs) in each of the six priority marine ecosystems for each FEC, where applicable.

FECs	Canadian Beaufort Shelf	Lancaster Sound	Western Hudson Bay	Hudson Strait	Southeastern Baffin Bay	Nares Strait and Northern Baffin Bay
Sea ice biota	• Existing historical datasets • No current program – requires funding	• First-year ice protists – abundance around Resolute Bay • Physico-chemical variables • Pre-climate change data and recent assessments • Diatom species: *Nitzschia frigida, Melosira arctica* • Program ended in 2013 • Funding sought for maintenance of monitoring program	• Extended region of Churchill • First-year ice protists – abundance and species dominance • Physico-chemical variables • Targeted diatom species: *Nitzschia frigida* • Program should be re-instated	• No biodiversity monitoring planned	• No biodiversity monitoring planned	• Region of the North Water Polynya (NOW) • First-year (multi-year) ice algal abundance and species dominance • Physico-chemical data • Pre-climate change data and recent assessments • Targeted diatom species: *Nitzschia frigida, Melosira arctica* • Funding sought for maintenance of monitoring program
Plankton	• Sample collection during ArcticNet cruise • Microbial biodiversity during DFO-Institute of Ocean Sciences cruise	• Samples collection during ArcticNet cruise	• Pending funding approval of the University of Manitoba and Manitoba Hydro (NSERC CRD grant) • Species composition/ communities of plankton	• No biodiversity monitoring planned	• Sample collection during ArcticNet cruise	• Sample collection during ArcticNet cruise
Benthos	• Sample collection during ArcticNet cruise • Sample collection as part of BREA program • Species composition/ communities of benthos	• Samples collection during ArcticNet cruise • Species composition/ communities of benthos	• Pending funding approval of University of Manitoba and Manitoba Hydro (NSERC CRD grant) • Species composition/ communities of benthos	• No biodiversity monitoring planned	• Pending funding approval of the Green Edge Program (2015) • Species composition/ communities of benthos	• Sample collection during ArcticNet cruise • Pending funding approval of the Green Edge Program (2015) • Species composition/ communities of benthos

FECs	Canadian Beaufort Shelf	Lancaster Sound	Western Hudson Bay	Hudson Strait	Southeastern Baffin Bay	Nares Strait and Northern Baffin Bay
Fish	• BREA multispecies benthic fish survey • Species distributions and biodiversity (>200 m) • NCP – baseline contaminants in arctic cod • FJMC – arctic char, dolly varden, broad whitefish	• DFO – Arctic stock assessment offshore survey • DFO – Multispecies benthic fish survey Only eastern Lancaster Sound • DFO – Greenland halibut, northern and striped shrimp • DFO – Stock assessment and data are collected for all species	• No biodiversity monitoring planned	• DFO – Arctic stock assessment offshore survey • DFO – Multispecies benthic fish survey • DFO – Primarily eastern Hudson Strait • DFO – Greenland halibut, northern and striped shrimp • DFO – Stock assessment and data are collected for all species	• DFO – Arctic stock assessment offshore survey • DFO – Greenland halibut, northern and striped shrimp • DFO – Stock assessment and data for all species • DFO – Arctic stock assessment inshore surveys (exploratory) • DFO – General biodiversity survey and multispecies surveys	• DFO – Arctic stock assessment offshore survey • DFO – Greenland halibut, northern and striped shrimp • DFO – Stock assessment and data for all species • DFO – Arctic stock assessment in-shore surveys • DFO – Multispecies benthic fish surveys
Seabirds	• No biodiversity monitoring planned	• NCP – Contaminants in eggs of thick- billed murre and northern fulmars from Prince Leopold Island • EC /Acadia U – northern fulmar, thick-billed murre, and black-legged kittiwake at Prince Leopold Island	• EC – monitoring work in Wapusk National Park and La Perouse Bay	• NCP – eggs of thick-billed murre from Coats Island • EC – common eider, thick-billed murre movement, habitat, foraging • EC – common eider, thick-billed murre population trends, migration	• No biodiversity monitoring planned	• EC – movement, habitat, foraging and seasonal migration of thick-billed murre at Cape Graham Moore

FECs	Canadian Beaufort Shelf	Lancaster Sound	Western Hudson Bay	Hudson Strait	Southeastern Baffin Bay	Nares Strait and Northern Baffin Bay
Marine Mammals	• FJMC – ringed seal and beluga whales • NCP – ringed seal in Sachs Harbour. • NCP – beluga from the Mackenzie Delta	• DFO – stock assessment of narwhal, bowhead, beluga • DFO – interactive platform aerial survey photography • DFO – killer whale movements and diet • NCP – contaminants in ringed seal in Resolute • EC – polar bear population genetic structure	• DFO – ringed seal abundance from aerial survey • DFO – 2015 aerial survey for beluga and narwhal • DFO – 2014 aerial survey for walrus • DFO – 2015 beluga tagging in Western Hudson Bay • DFO – community-based tissue collection of beluga and ringed seal in Arviat and Sanikiluaq • NCP – ringed seal collected from Arviat • NCP – beluga from Sanikiluaq • NCP – polar bears from western Hudson Bay • EC – polar bear diet, contaminants, genetics, movements	• DFO – stock assessment of narwhal, bowhead, beluga • DFO – 2014 aerial survey of walrus • EC – polar bear diet, contaminants, genetics and movements.	• DFO – stock assessment of narwhal, bowhead, beluga • DFO – killer whale movements and diet • DFO – 2014 aerial survey of Cumberland Sound beluga • DFO – 2015 beluga tagging in Cumberland Sound • UBC – bowhead whale foraging behaviour in Cumberland Sound • NCP – contaminants annually in beluga from Pangnirtung	• DFO – aerial survey of Baffin Bay narwhal population • DFO – assessment of movement of Jones Sound narwhals • DFO – continue tagging narwhal in Jones Sound and NOW region through 2017

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