MARINE ECOLOGICAL CONSERVATION FOR THE CANADIAN EASTERN ARCTIC

A Systematic Planning Approach for Identifying Priority Areas for Conservation

Technical Report

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SYNOPSIS

The MECCEA study (Marine Ecological Conservation for the Canadian Eastern Arctic) is the first to design a true network of ecologically connected Priority Areas for Conservation in the Canadian Eastern Arctic. The systematic conservation planning approach by MECCEA contributes to ongoing efforts to establish Arctic marine protected areas, by identifying key areas of marine biodiversity. The MECCEA study establishes a baseline against which conservation plans can be periodically reassessed in an adaptive management framework, in the face of rapid climate change effects in the Arctic Ocean.

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This report may be cited as:

Roff, J.C., Giangioppi, M., Gerhartz-Abraham, A., Merritt, W., James, T.D., Keenan, E., and Davidson, E. 2020. Marine Ecological Conservation for the Canadian Eastern Arctic (MECCEA) – a Systematic Planning Approach for Identifying Priority Areas for Conservation. WWF-CANADA. 281 + xxii pages.

ACKNOWLEDGMENTS

This study would not have been possible without a sustained budget. A special thanks to the *Moore Foundation* who funded this project.

Our thanks to all those individuals, groups and organizations who have helped us to retrieve and interpret data, assess conservation features, and/or provided technical advice and support. They include:

Philippe Archambault, Université Laval
Laurent Bertino, Nansen Environmental and Remote Sensing Center
Carla Caverhill, Fisheries and Oceans Canada
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Ian Fleming, Memorial University
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Dominique Robert, Université du Québec à Rimouski
Jason Roberts, Duke University
Boris Solovyev, Russian Academy of Sciences
Garry Stenson, Fisheries and Oceans Canada
Margaret Treble, Fisheries and Oceans Canada
Teresa Tufts, Government of Nunavut Fisheries and Sealing Division
Sara Wong, Acadia University

Thanks to all external participants of the MECCEA expert review workshops.

These meetings were of significant importance to the development of the project and this final technical report.

Ted Cheskey, Nature Canada
Ryan Eagleson, University of Guelph
Jonathan Fisher, Memorial University
Sarah Fortune, University of British Columbia
Tony Gaston, Ottawa University
Cindy Grant, Université Laval
Nicole Hutchinson, Fisheries and Oceans Canada
Nigel Hussey, University of Windsor
Sarah Jamal, Fisheries and Oceans Canada
Martine Landry, Environment and Climate Change Canada
Mark Maftei, High Arctic Gull Research Group
Jeff Maurice, Nunavut Tunngavik Incorporated
Gayle McClelland, Consultant
Francine Mercier, Parks Canada
Jessica Mitchell, Fisheries and Oceans Canada
John Morrison, WWF-USA
Monique Newton, WWF Arctic Programme
Irina Onufrenya, WWF-Russia
Gary Pardy, Fisheries and Oceans Canada
Bethany Schroeder, Fisheries and Oceans Canada
Boris Solovyev, Russian Academy of Sciences
Martin Sommerkorn, WWF Arctic Programme
Garry Stenson, Fisheries and Oceans Canada
Warren Wilson, Consultant
Peter Winsor, WWF Arctic Programme
Sara Wong, Acadia University

Thanks to all external experts who reviewed targets for conservation features.

Karel Allard, Canadian Wildlife Service
Markus Dyck, Government of Nunavut
Steve Ferguson, Fisheries and Oceans Canada
Katie Florko, University of British Columbia
Sarah Fortune, Fisheries and Oceans Canada
Tony Gaston, Canadian Wildlife Service
Cindy Grant, Université Laval
Mark Maftei, High Arctic Gull Research Group
Mark Mallory, Acadia University
Fred Short, University of New Hampshire
Garry Stenson, Fisheries and Oceans Canada
Ian Stirling, University of Alberta
Greg Thiemann, York University
Ron Togunov, University of British Columbia
Cortney Watt, Fisheries and Oceans Canada
Sarah Wong, Acadia University
Brent Young, Fisheries and Oceans Canada
David Yurkowski, Fisheries and Oceans Canada

Thanks to WWF-Canada staff who provided additional contributions and/or support to the project:

Joyce Arabian
Mark Brooks
Doug Chiasson
Paul Crowley
Andrew Dumbrille
Tina Knezevic
Brandon Laforest
Antonella Lombardi
Jessica Park
Colleen Parker
Sarah Ratcliffe
Sarah Saunders
Naomi Seabrooke
Hanchen Shen

Data

Much of the data used in this study was available in publicly accessible databases, but other data were proprietary or not yet publicly available. Further details of data and methodology, not recorded in this report, may be available by request to WWF-Canada.

This study was conducted using data provided by the E.U. Copernicus Marine Service Information and the NASA Goddard Space Flight Center, Ocean Ecology Laboratory, Ocean Biology Processing Group.

MECCEA REPORT SUMMARY

Background and Context

Bordered by three oceans, Canada is truly an oceanic nation, but facing ever-increasing demands on resources and threats to marine biodiversity. The Arctic is of special significance to Canada, containing five of its thirteen marine bioregions, almost half of the Canadian marine environment. The Arctic bioregions are of major importance to migrant species—marine mammals, birds, and fish—that seasonally benefit from its rich resources. The Arctic is among the most rapidly changing regions on Earth, though presently still minimally impacted by humans. To date, Canada has protected 13.8% of its marine and coastal areas. However, we do not presently know whether these areas constitute true networks of protected areas. Nor do these areas approach the International Union for the Conservation of Nature (IUCN)'s target to protect 30% of each marine habitat. WWF-Canada, therefore, directed special attention to advancing the agenda of marine conservation in Canadian Arctic waters.

Overview

The MECCEA study represents the first comprehensive and quantitative spatial planning study for conservation in the Canadian marine Arctic, encompassing four of its five bioregions.

The study used a unique combination of geomorphic, oceanographic, and biological data with information from Indigenous Knowledge sources to define marine Priority Areas for Conservation (PACs).

Efficient use was made of both high-quality in situ oceanographic data and recent remotely sensed data.

Both representative and distinctive areas were mapped, along with key habitats of priority species.

The MECCEA study has followed a systematic conservation planning approach following a series of well-defined steps and concepts that ensured efficient use of all available geophysical and biological data, compared to previous efforts to identify important areas for future conservation in this region.

Conservation features were rigorously selected from well-defined criteria and objectives, based on fundamental study goals.

Seascapes were constructed from available geophysical data for both pelagic and benthic realms, as surrogates for sparse biological data.

The PACs themselves were selected using the most widely used marine spatial planning program—Marxan—and were separated according to quantified minimum, median, and high targets.

Resulting PACs covered between 30 and 47% of the study area and included all selected conservation features. Nearly all of the 513 conservation targets were met for all three PAC scenarios.

MECCEA also indicated the added conservation value of its PACs by evaluating the degree of overlaps with existing and proposed conservation measures, the Draft Nunavut Land Use Plan, and by recording potential synergies with adjacent terrestrial protected areas.

The conservation features represented in each PAC allow a perspective on their individual contributions to an overall strategy of marine conservation. This listing also permits the relative contributions of representative and distinctive features and priority species to be separately defined.

Goals and Conservation Objectives

Through the Marine Ecological Conservation for the Canadian Eastern Arctic (MECCEA) study, WWF-Canada's goals are to:

- identify a network of priority areas for conservation (PACs) in Canada's Arctic marine environment;
- encourage the Government of Canada to institute a sound Arctic marine protected area network as part of its international commitments to marine conservation;
- identify individual sites for marine conservation and work with specific interested parties to advance the establishment of future protected areas; and
- provide input into various marine/coastal planning processes, environmental assessments and fisheries management.

The MECCEA study (Marine Ecological Conservation for the Canadian Eastern Arctic) has three conservation objectives:

- To protect **distinctive**, **unique**, **rare** or **endangered** species and ecological features:
- To protect **representative** examples of each type of identified ecosystem and habitat:
- To ensure that the PACs are integrated into the wider landscape and seascape by patterns of **connectivity**.

These PACs should take into account all described conservation features (CFs) within the study area—four of Canada's five Arctic marine bioregions. A systematic planning study using a comprehensive hierarchical framework, should integrate available data from the species to ecosystem level. The MECCEA analysis is based on information from both conventional scientific and Indigenous Knowledge (IK) sources. WWF-Canada convened two expert workshops to review data sources and conservation objectives, criteria, CFs and targets, and methods of analysis.

Canada's Arctic Marine Bioregions

Distinguishing boundaries between marine bioregions is complex because they can be recognized on the basis of geomorphology or oceanography or biology. As the first level of a hierarchical classification, we documented that the four bioregions of the MECCEA study, which includes the Arctic Basin, Arctic Archipelago, Eastern Arctic, and the Hudson Bay Complex, do in fact differ meaningfully in their characteristics. For example: the Arctic Basin is unique in having a set of canyons not seen in in the other regions; the Hudson Bay Complex is unique in having a very high number of small islands and small coastal inlets. The Arctic Basin and the Arctic Archipelago also differ in seasonal ice cover, temperature, and salinity. The four marine bioregions can also be distinguished biologically in terms of their benthos and fish species assemblages. Our review of all the geomorphic, oceanographic and biological characteristics of the four bioregions, shows that these are appropriate and defensible "ecoregions".

MECCEA's Conservation Features: Representative and Distinctive

Conservation features may be either representative or distinctive. Spatially defining representative areas has become an integral part of marine bioregionalization schemes ensuring inclusion of habitat diversity and metrics of community type. Geomorphic structures—used as surrogates for biological community types—were considered in four categories: bathymetry, offshore features, coastal inlets, and other coastal features, representing the major associated community types. Oceanographic factors, including water masses (defined by temperature and salinity), water column stratification, and bottom current speed, were used to describe seascapes—the marine equivalent of terrestrial landscapes. An epi-pelagic seascape, used as a surrogate for productivity and biodiversity, was constructed from ice cover regimes, water masses, and water column stratification. A benthic realm seascape, used as a surrogate for community biodiversity, was constructed from bathymetry, benthic water masses, and bottom current velocity. Seascapes made efficient use of extensive oceanographic data that would otherwise not have been taken fully into account.

For each taxonomic/ecological group of organisms, data sources were defined. If no data were available, MECCEA described how each group was represented by habitat surrogates. The representation of primary producer communities in Arctic waters was summarized for benthic inter-tidal microphytic and macrophytic algae, and the sympagic community. Annual phytoplankton productivity was modelled from bathymetry, sea surface temperature, cloud cover, total daily PAR (photosynthetically available radiation), and chlorophyll (chlor) a. The dataset for benthos comprised 13,705 entries with 1,023 species and 343 families. Both at the family and the species level there were clear differences in taxonomic assemblages among the four bioregions, and according to depth strata. The fish database contained 39,085 records with 208 species. Again, there were differences in fish assemblages among the bioregions and according to depth strata.

To complete the inventory of CFs, distinctive areas and priority species were also mapped. Areas of high productivity were indexed from chlor a. Seasonal locations of the ice edge zone and polynyas, and other key habitats of high productivity and feeding "hotspots", were also located. Further identification of key habitats (e.g. feeding, and breeding) focused on CFs for priority species. Priority species included polar bear, walrus, narwhal, beluga, bowhead whale, and four species of seals. Key habitats for seabird colonies and their foraging areas, and location of important areas for shorebirds and waterfowl were also identified. Areas of taxonomic richness for benthos and fish were identified, as were locations of deep-sea corals, sea-pens, sponges, anadromous fish, and individual fish species of particular conservation concern. Information from IK sources, providing information on a broad range of species, was also included for analysis.

Setting MECCEA's Conservation Targets

In preparing for Marxan analyses, only data which directly addressed MECCEA conservation objectives were included. In order to avoid multiple-counting of CFs, with consequent biases, a series of logical "decision trees" was implemented, that addressed MECCEA conservation objectives. This ensured that each CF contributed unique and consistent information. All CFs were split by bioregion, increasing replicability in the network. Target setting for CFs was based on three methods. Targets predominantly for representative features were based on size, scaled to the area of the largest feature. Targets predominantly for distinctive features and priority species were based on scoring by external experts of three factors: current conservation status, vulnerability, and rarity/uniqueness. The summed and averaged scores for these factors produced the final target range for each CF. Targets for important bird areas were adapted from categories used by BirdLife International.

Identifying Priority Areas for Marine Conservation: Marxan Analyses

MECCEA used the decision-support tool Marxan to select locations that collectively represent the biodiversity features of the planning region. Analyses of existing and planned protected areas showed significant conservation gaps in the Canadian Eastern Arctic. Marxan accomplished the tasks of identifying options that met predefined conservation targets at the minimum feasible area cost. Marxan scenarios using 513 CFs were generated; all attained nearly 100% of targets. Decisions on the set of PACs depended on the boundary length modifier (BLM) and targets for CFs. The higher BLM value (10) selects fewer PACs, at the expense of larger total area. Scenarios with the minimum targets covered 30%, median targets covered 39%, and high targets covered 47% of the planning region. Despite limited data, MECCEA has devised a robust plan for a coherent set of PACs, which captures all identified CFs and incorporates existing protected areas. Three Marxan scenarios, that included existing protected areas (with the exception of Tuvaijuittuq), were selected for subsequent consideration.

Assessing Connectivity

An important objective for MECCEA was to provide PACs that were connected into the wider seascape as a network. Connectivity is especially significant in the Arctic, where differential habitat productivity and seasonal migrations dominate annual trophodynamics and produce hotspots of animal abundance. We have undertaken an evaluation of many aspects of connectivity among the PACs, including migration corridors for marine mammals and the significance of narrow passages. We also included other aspects of connectivity: summer and winter use areas by marine birds and marine mammals; and connections between ocean and freshwater, and to and from the land. We also recorded genetic differences among "stocks" or populations of several species including polar bear, beluga, bowhead whale, narwhal, and walrus. Dispersal patterns for larvae were modelled, across seasons and depths, based on oceanographic currents. The PACs are predominantly well-connected, with Lancaster Sound a notable hub, but some areas in the Arctic Basin appear to be relatively isolated by oceanographic and biological processes.

Commercial Activities and Inuit Use Areas: Overlap with MECCEA's PACs

To understand the potential interactions among the ecologically-identified PACs (for minimum, median and high targets) and other marine activities (e.g. commercial activities, and Inuit use areas), we collected other spatial data in the study area to overlay with the PAC scenarios. Three key commercial activities occur within the MECCEA bioregions: marine shipping, mining, and fisheries. Overlap between PACs and shipping corridors ranged from 45 to 62%, and overlap with actively fished regions ranged from 63 to 79.%. Between 49 and 70% of Nunavut Inuit use areas (encompassing many activities), as identified in the Nunavut Coastal Resource Inventory, coincide with the PACs. Overlap between the DNLUP (Draft Nunavut Land Use Plan) Special Management Areas and PACs ranged from 80 to 94%, while overlap with the DNLUP Protected Areas ranged from 70 to 77%. Information generated through the MECCEA study should, therefore, help to support and reinforce the need for protecting the PACs, by providing a comprehensive representation of conservation and use priorities.

Key Recommendations

Marine spatial planning should define: potential environmental impacts; protection categories; permitted activities; and management practices for the recommended PACs and the network. This goal is to ensure persistence of the CFs as a whole.

WWF-Canada recommends that:

- The Government of Canada works with Indigenous peoples and other key stakeholders to develop a Marine Protected Area network in the Canadian Arctic, as a major component of Marine Spatial Planning to enable Integrated Oceans Management and Ecosystem Based Management.
- A "toolbox" of marine conservation and management measures be used for Marine Protected Area network implementation, including:
    - Federal, provincial and territorial legislation
    - Indigenous Protected and Conservation Areas (IPCAs); and
    - Other Effective Area-Based Conservation Measures (OEABCMs)
- A stepwise approach to marine conservation be adopted, beginning with a 30% minimum target by 2030, and increasing to 50% by 2050.
- The Ecologically and Biologically Significant Areas (EBSAs) outside PACs should be managed with a high degree of risk aversion to prevent harm to biodiversity.

Management must be recognized in the context of whole-Arctic marine conservation and the rights of Indigenous peoples. Management must also recognize the role of EBSAs and connectivity to adjacent Canadian bioregions and internationally with, for example, WWF's pan-Arctic project, ArcNet: An Arctic Ocean Network of Priority Areas for Conservation. Management plans are required not only for static locations but for the entire network to assess vulnerability and resilience, including adaptive management for climate change.

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CHAPTER 1: INTRODUCTION AND BACKGROUND

WHY MARINE BIODIVERSITY CONSERVATION IS IMPORTANT

In the face of increasing rates of species extinctions, biodiversity conservation is of now of prime concern. The reasons for protecting biological diversity are several and encompass environmental, economic and social benefits (e.g. Beaumont et al., 2007; Díaz et al., 2015). The rationale for protecting biodiversity can be summarized into categories, including intrinsic value, anthropocentric value (e.g. supply of goods and services), and ethical value. An explanation of these terms and concerns is given by Roff and Zacharias (2011) and will not be repeated here. An excellent summary of the benefits of marine protected areas and networks has been published by the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM) Oceans Task Group (2017) (see Text Box 1.1).

The benefits of protected areas in conserving and restoring biodiversity and fisheries are by now so well documented in world-wide studies, that no further review is required here. Where the beneficial effects of marine protected areas have not materialized, this has generally been due either to their establishment in relatively pristine areas where change is not to be expected, or where there was a failure of protection due to lack of monitoring or enforcement of management measures and regulations (e.g. Bergseth et al., 2015).

Biological conservation is not an ideology. It has become a reality and a necessity. We are protecting our planet for ourselves because there is no alternative. We simply do not know the "tipping point" (Gladwell, 2000) of ocean environments and their ecosystems, beyond which they may no longer provide us with the "goods and services" we rely on but take for granted.

SIGNIFICANCE OF THE THREE OCEANS FOR CANADA

Canada is unique among nations in that its provinces and territories border on three oceans – Pacific, Atlantic and Arctic. The significance of these three oceans to Canada is embodied in Canada's Oceans Strategy (2017), wherein the Minister of Fisheries and Oceans Canada at the time (Robert G. Thibault) writes:

> "As a country bordered by three oceans, Canada is truly an oceans nation. Today we see an ever-increasing number of demands on oceans and their resources. While traditional fishing and marine transportation continue to be of prime importance, they are now joined by other uses, such as aquaculture, oil and gas exploration and development, recreational and commercial fishing, and tourism. Canada's oceans also support important features of Canada's social and cultural identity. Managing these demands is critical to the protection of the marine environment and the long-term sustainability of Canada's oceans and their resources."

The significance of the three oceans to Canada is further emphasized in the *Oceans Act* (1996), in several explicit and important statements (see Text Box 1.2).

The aquatic science community of Canada has long recognized the significance of its three oceans and has been active in research into its environment and ecology (e.g. the Canadian research networks CHONe and ArcticNet). A five-year National Plan has been specifically developed to lay the groundwork for marine biodiversity research in Canada (see Zwanenburg et al., 2003). A major contribution to the 2007–2008 International Polar Year concentrated on all three of Canada's Oceans (Carmack et al., 2010), and an important and timely summary of knowledge of biodiversity in Canada's three oceans has been compiled by Archambault et al. (2010).

Text Box 1.1. Benefits of marine protected areas and networks.

According to the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM) Oceans Task Group (2017), individual protected areas can:

- maintain the ecological processes that generate ecosystem services;
- protect marine ecosystem structure, functions and recovery;
- improve ecological resilience through restored structures, increased productivity and increased food web complexity;
- protect specific areas containing important biophysical features and processes;
- protect habitats important for providing refugia (e.g. for endangered or depleted species), breeding and nursery grounds, rearing, and foraging;
- enhance the ability of nearby areas to recover from disturbances, by exporting larvae and adult organisms to those areas;
- support increased size, abundance and diversity of marine species;
- support economic activities that are compatible with MPA objectives such as fishing, aquaculture, transport, recreation, tourism and education;
- provide sites for marine research and monitoring; and
- maintain areas with important spiritual or cultural heritage value.

In addition, according to CCFAM (2017), strategically designed networks of marine protected areas may enhance the benefits of individual protected areas by scaling benefits up to the bioregional level in order to:

- support and set the conservation foundation for coordinated Marine Spatial Planning (MSP), Integrated Oceans Management (IOM) and Ecosystem-Based Management (EBM) of marine resources and activities with federal, provincial, and territorial government agencies, rights-holders and stakeholders;
- provide larger, more abundant, and diverse species throughout the network area;
- help mitigate climate change impacts by preserving and protecting coastal and marine species, ecosystems and habitats that are most critical for carbon storage;
- increase ecosystem resilience;
- protect historical sites and other sites of cultural importance;
- increase quality of life in local communities; and
- provide additional benefits where adjacent national networks of marine protected areas are linked across borders (e.g. Canada/U.S.).

SIGNIFICANCE OF THE ARCTIC OCEAN

In recent years, the Arctic Ocean has assumed a dramatic and growing significance. It is the only truly polar ocean, at the top of the world nearly surrounded by land. It is the northern junction of Pacific and Atlantic waters, with flora and fauna increasingly contributed by both.

Polar regions of the oceans are major heat sinks that contribute to stabilizing climate from extreme heat. The Arctic Ocean is also a major site of CO_2 absorption from the countries of the northern hemisphere (Sommerkorn and Hassol, 2009).

The Arctic is perhaps the most rapidly changing region on Earth, experiencing some of the most dramatic climate and other CO_2-related impacts occurring anywhere on our planet. Massive environmental and ecological changes presently underway in the Arctic have been reported by the Arctic Council's working groups: the Arctic Monitoring and Assessment Programme (e.g. AMAP, 2012), Conservation of Arctic Flora and Fauna (CAFF, 2013; Eamer et al., 2013), Protection of the Arctic Marine Environment (PAME, 2013), as well as other organizations including WWF (Sommerkorn and Hassol, 2009) and the Intergovernmental Panel on Climate Change (IPCC, 2013). The climate-related trends of diminishing sea ice, increasing sea surface temperatures and increased coastal erosion of shorelines are also well documented.

Distributions and ranges of many marine species are also expanding northwards as the Arctic continues to warm (CAFF, 2013).

The Arctic is of great significance to a diversity of migrant species, marine mammals, birds and fish, which could not complete their life cycles without its rich seasonally available resources. However, although the marine Arctic is more species-rich than often imagined and has a high diversity and abundance of seasonal migrant species (Michel et al., 2013), it is relatively poor in endemic species. The exceptions, such as Arctic cod, however, play important roles in regional food webs (Bradstreet et al., 1986). Despite many rapid changes, the Arctic is still presently one of the world's regions rated as most natural and least impacted by humans (Watson et al., 2018; Jones et al., 2018).

Text Box 1.2. Abstract from the *Oceans Act* (1996).

The Oceans Act (1996), emphasizes the significance of the three oceans in several explicit and important statements including that:

- Canada recognizes that the three oceans, the Arctic, the Pacific and the Atlantic, are the common heritage of all Canadians;
- Parliament wishes to reaffirm Canada's role as a world leader in oceans and marine resource management;
- Canada promotes the understanding of oceans, ocean processes, marine resources and marine ecosystems to foster the sustainable development of the oceans and their resources;
- Canada holds that conservation, based on an ecosystem approach, is of fundamental importance to maintaining biological diversity and productivity in the marine environment;
- Canada promotes the wide application of the precautionary approach to the conservation, management and exploitation of marine resources in order to protect these resources and preserve the marine environment;
- Canada promotes the integrated management of oceans and marine resources; and
- The Minister of Fisheries and Oceans, in collaboration with other ministers, boards and agencies of the Government of Canada, with provincial and territorial governments and with affected aboriginal organizations, coastal communities and other persons and bodies, including those bodies established under land claims agreements, is encouraging the development and implementation of a national strategy for the management of estuarine, coastal and marine ecosystems.

ARCTIC MARINE CONSERVATION INITIATIVES

The Arctic Council has called for a *pan-Arctic marine protected area network*, and they have developed a framework to achieve this goal, stating the urgency, associated values, principles, and objectives (PAME, 2015). The PAME and CAFF working groups and the WWF Arctic Programme have also been working to achieve conservation of Arctic marine environments through integrated international studies (e.g. under WWF's ArcNet: an Arctic Ocean network of priority areas for conservation). However, progress and implementation of protected area networks has been slow.

The most comprehensive plans for Arctic marine conservation have been developed in the Russian Arctic, where the internal marine waters, territorial seas and the Exclusive Economic Zone (EEZ) have been analyzed using comprehensive geophysical data and historical biological records (Solovyev et al., 2017; Spiridonov et al., 2017). However, in the Canadian Arctic, despite several existing and recently proposed protected areas and marine regulated areas, to date there has been no comprehensive study designed specifically to propose networks of marine protected areas.

INTERNATIONAL COMMITMENTS TO MARINE CONSERVATION

The international community has repeatedly affirmed its commitment to marine conservation (see e.g. Laffoley, 2008). In 2010, the Strategic Plan for Biodiversity was adopted at the Conference of the Parties for the Convention on Biological Diversity (CBD). This plan includes 20 global biodiversity targets, known as the Aichi Targets, which each party to the convention has agreed to achieve.

Aichi Target 11 (CBD, 2011) explicitly calls for a network of marine protected areas: "By 2020, at least 17% of terrestrial and inland water areas and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscape and seascape."

A broadly accepted definition of a marine protected area has been supplied by The International Union for the Conservation of Nature (IUCN): "A clearly defined geographical space recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Day et al., 2012).

At the IUCN World Conservation Congress, held in Hawaii in September 2016, IUCN member states agreed to a new global target for marine protected areas. It calls for "30% of each marine habitat" to be set aside in "highly protected MPAs and other effective area-based conservation measures" by 2030, with the ultimate aim being "a fully sustainable ocean, at least 30% of which has no extractive activities" (WCC, 2016).

CANADIAN COMMITMENTS TO MARINE CONSERVATION

In its response to international calls for increased marine conservation, Canada has agreed to protect its oceans, in part by establishing networks of marine protected areas, and has committed to protect a minimum of 10% of its marine and coastal waters within designated protected areas, or "other effective means of place-based conservation" by the year 2020. In making this commitment, Canada has adopted the IUCN (Day et al., 2012) and CBD (2018) definitions of marine protected areas and networks. A timeline of Canada's marine protection milestones follows.

On June 8, 2016, the Minister of Fisheries, Oceans and the Canadian Coast Guard announced the Government of Canada's commitment to put in place a plan to reach its domestic and international marine conservation targets of protecting 5% of Canada's marine and coastal areas by 2017 and 10% by 2020.

On October 28, 2017, the Minister of Fisheries, Oceans and the Canadian Coast Guard and the Minister of Environment and Climate Change announced the achievement of Canada's interim target of 5% protection of marine and coastal areas.

On December 21, 2017, the Minister of Fisheries, Oceans and the Canadian Coast Guard announced the establishment of seven new marine refuges, bringing Canada's total ocean territory that is under protection to 7.75%. By this date, Canada had announced that it had exceeded the interim target set for 2017 and was closer to meeting the international target of protecting 10% of marine and coastal areas by 2020.

On August 1, 2019 Prime Minister Trudeau announced that Canada had surpassed its marine conservation target of 10% protection of marine and coastal areas. This achievement was reached through collaborative efforts with Indigenous peoples, all levels of government and stakeholders. To this date, Canada had established 14 MPAs under the *Oceans Act*, three National Marine Conservation Areas, one marine National Wildlife Area, and 59 marine refuges. Collectively, these areas are now protecting 13.81% of Canada's marine and coastal areas.

On December 13, 2019, the Government of Canada committed to working towards a new target of protecting 25% of Canada's marine areas by 2025, and subsequently 30% by 2030 (Minister of Fisheries, Oceans, and the Canadian Coast Guard Mandate Letter, 2019).

EXISTING CANADIAN MARINE PROTECTED AREAS

Marine protected areas in Canada (see Text Box 1.3 for a note on terminology) have been established under a variety of names and are managed for a variety of primary purposes. Chief among these are:

- Marine Protected Areas (MPAs) used only for areas designated by Fisheries and Oceans Canada (DFO).
- National Marine Conservation Areas (NMCAs) under Parks Canada;
- National Wildlife Areas (NWAs) and Migratory Bird Sanctuaries (MBS, similar to Nesting Bird Sanctuaries, NBS, but on land) under Environment and Climate Change Canada; and
- a series of other provincial and territorial protected areas.

Marine refuges are fisheries closures, put in place under the *Fisheries Act* to protect marine ecosystems and species. They can be created much more quickly than *Oceans Act* MPAs. However, marine refuges may only protect a single species, and many do not restrict potentially harmful activities like mineral or oil and gas extraction.

Text Box 1.3. Marine protected area acronyms.

In order to avoid confusion and inconsistency, a note on terminology and acronyms used in referring to marine protected areas is needed.

The acronym "mpa" is used by Fisheries and Oceans Canada (DFO, 1999), to refer to ANY existing or proposed marine protected area irrespective of jurisdiction. In contrast, "MPA" is used only for areas that have been designated by DFO.

In this report, we use the official acronyms MPA, NMCA, etc. as defined in this chapter, to refer to specific locations and Canadian jurisdictions.

We use the term "protected area" (marine being understood) generically to refer to any marine protected area without reference to jurisdiction. This is equivalent to the use of "mpa" by DFO (1999).

The terms "Priority Conservation Area" (PCA) or "Priority Area for Conservation" (PAC), have been widely used in the conservation literature to indicate areas that have high value. We shall use the term "Priority Area for Conservation" (PAC) to refer to locations identified by the MECCEA study, as explained in Chapter 2.

In combination, these areas contribute to Canada's current tally, as of August 2019, of 13.81% of Canada's marine and coastal areas.

In summary, in Canada we have an inventory of the types of protected areas, their primary purpose and jurisdiction, and the actual levels of protection afforded in various defined zones. However, we have no overall review as to whether the sum totals of these areas can legitimately be considered as coherent "sets of marine protected areas" (*sensu* Ardron, 2008), or whether these areas constitute true *networks* of protected areas. Nor do these areas collectively approach the IUCN target that 30% of each marine habitat be protected. These are important issues for the present study—Marine Ecological Conservation for the Canadian Eastern Arctic (MECCEA).

EXISTING MARINE PROTECTED AREAS IN THE CANADIAN ARCTIC

Despite still being rated as essentially pristine, given projections for climate change, the marine Arctic has become very vulnerable to human disruption. Unfortunately, neither the Aichi Target declarations nor the Canadian government response to them indicate where protection should be afforded within Canada's marine environment. However, there are good reasons for the Canadian marine Arctic bioregions to be prominent on the agenda for protection.

The Arctic Ocean is of special significance to Canada. Of the thirteen marine bioregions recognized by Canada (see Chapter 3 for further consideration), five are Arctic in nature and designation, and one more is at least partially sub-arctic in nature. Thus, almost half of Canada's marine and coastal waters has a firm connection to the Arctic Ocean.

The recent development of conservation measures in the Canadian Arctic has greatly increased the proportion of protected areas there. The announcement of Tallurutiup Imanga NMCA, along with the establishment of three new marine refuges (Hatton Basin, Davis Strait, and Disko Fan), have brought the total coverage of protected areas in the Eastern Arctic marine bioregion (Figure 1.1) to a reported 22.5%. Similarly, the establishment of Tuvaijuittuq MPA has dramatically increased protection in the Arctic Basin marine bioregion (Figure 1.2) from a fraction of a percent, to approximately 38%. Although these numbers are encouraging, some marine bioregions—such as the Arctic Archipelago (Figure 1.3)—still only have moderate spatial protections at 13.8%, while others—such as the Western Arctic and Hudson Bay (Figure 1.4)—are nearly devoid of conservation, at only 0.25% and 0.62%, respectively.

Again, although there has been a dramatic recent increase in marine protected area designation in the Canadian Arctic: the spatial coverage is very uneven among the marine bioregions (Appendix 1); we have no synthesis as to whether these areas could be considered as coherent sets of marine protected areas; or whether they constitute true networks of protected areas. In addition, the range of permitted activities in some of these areas, or their management plans, may not be defined (see Appendix 1).

INDIGENOUS AND LOCAL KNOWLEDGE

Experience world-wide has consistently shown that effective "place-based" marine conservation is only achieved in socio-economic collaboration with local people (e.g. Agardy, 1997; Díaz et al., 2015). This must be especially true in the Canadian Arctic. The marine bioregions within MECCEA's scope spread across five provinces and territories, and the traditional territories of multiple Indigenous peoples (see Appendix 1). Indigenous people within this area have depended on the maintenance of marine resources as a central part of their culture and life. Indigenous-driven protection of important areas has taken place intrinsically since time immemorial through management and sustainable use.

The Government of Canada has a legal obligation and a courtesy to consult with Indigenous peoples. Conservation must also be informed by Indigenous Knowledge (IK) as well as scientific knowledge, through collaboration with Indigenous rightsholders. The MECCEA study draws on information from both sources of knowledge (see Chapters 2 and 6). IK is especially significant in a region where scientific knowledge on wildlife remains relatively low.

WWF-Canada does not have the authority to establish marine protected areas of any kind. The MECCEA project is intended as a tool to inform a process of establishing an Arctic protected areas network to be led by Fisheries and Oceans Canada, and to inform conservation and stewardship planning efforts by local communities. As part of the duty to consult, in establishing a robust protected areas network, DFO's process would necessarily include consultation with Indigenous peoples, inclusion of IK and perspectives, and partnerships with Indigenous organizations.

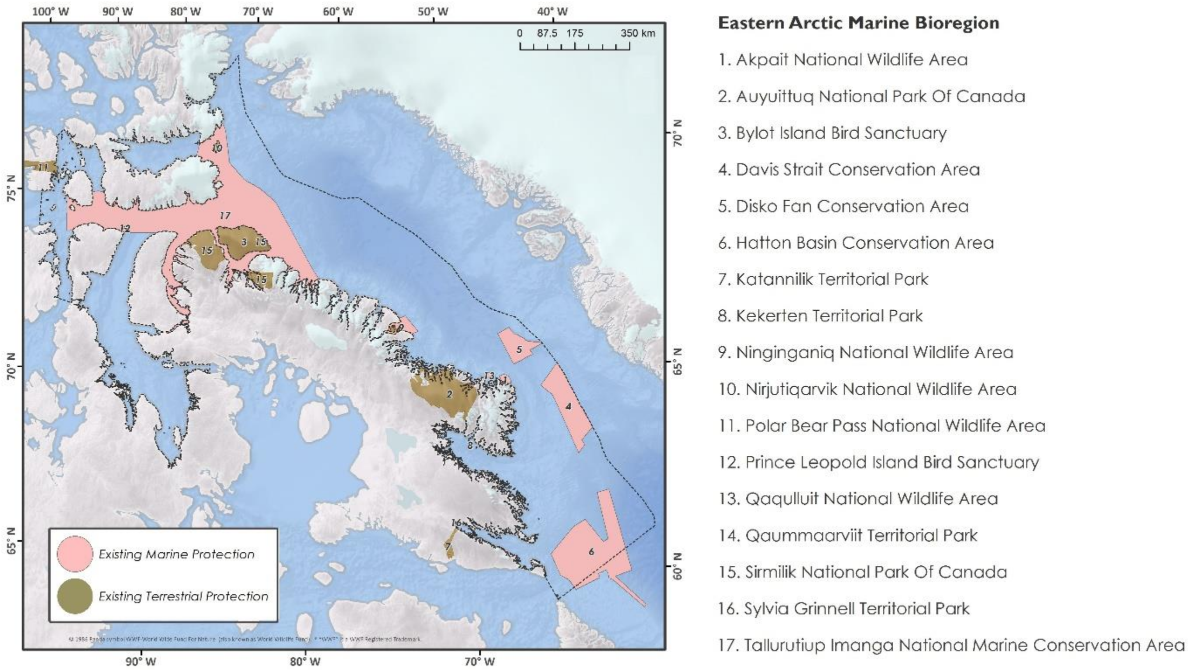

Figure 1.1. Existing marine and terrestrial protected areas in the *Eastern Arctic* marine bioregion.

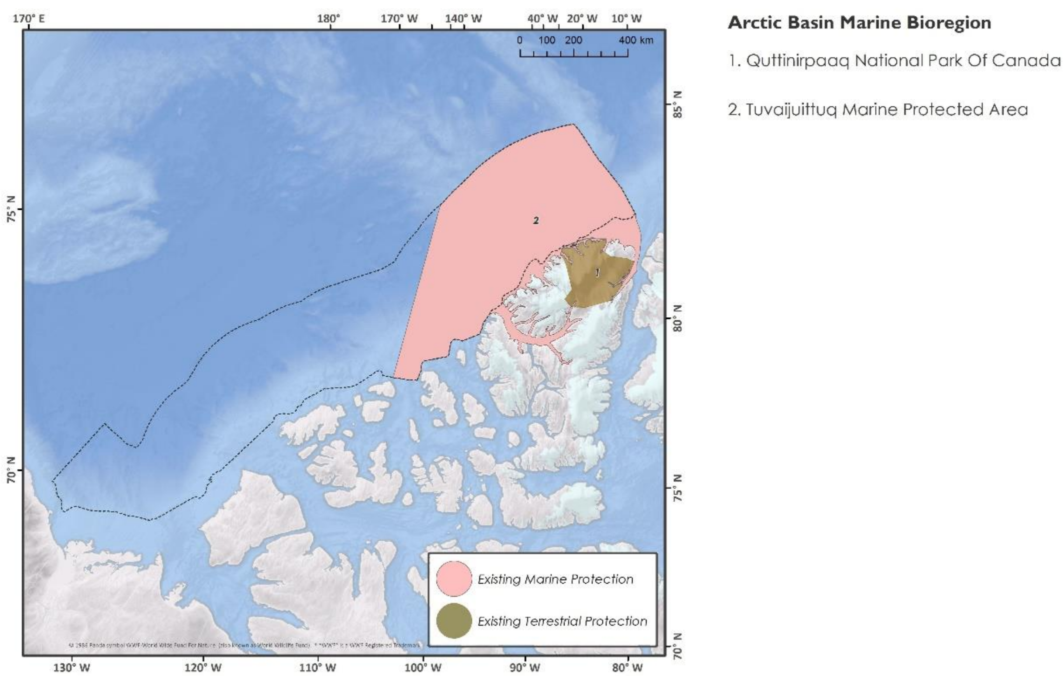

Figure 1.2. Existing marine and terrestrial protected areas in the *Arctic Basin* marine bioregion.

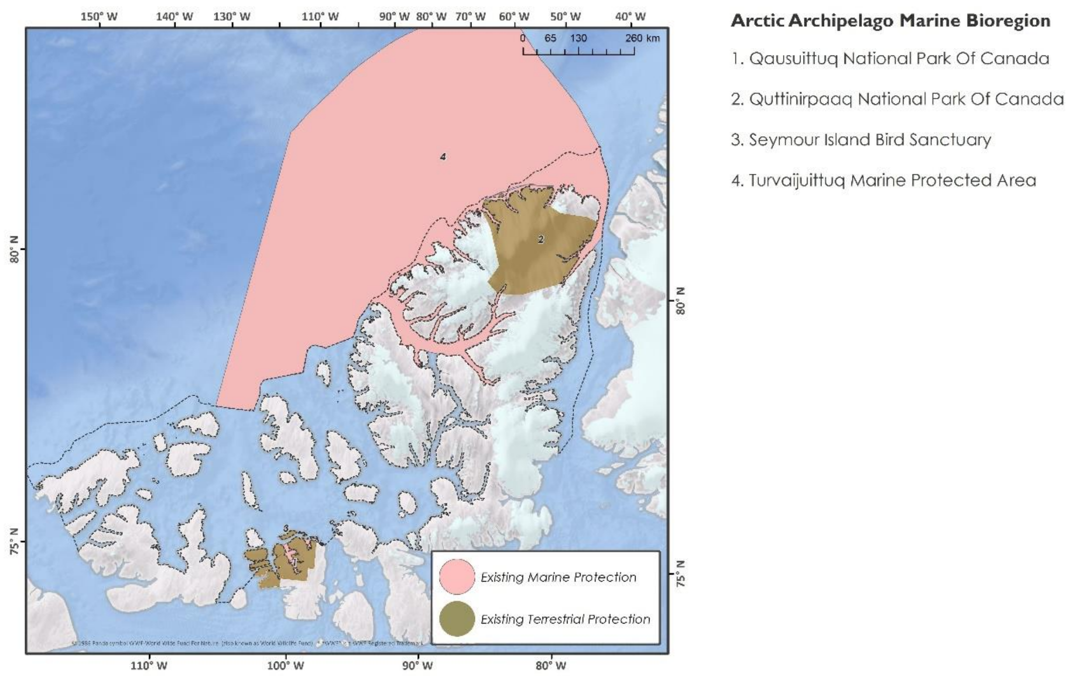

Figure 1.3. Existing marine and terrestrial protected areas in the *Arctic Archipelago* marine bioregion.

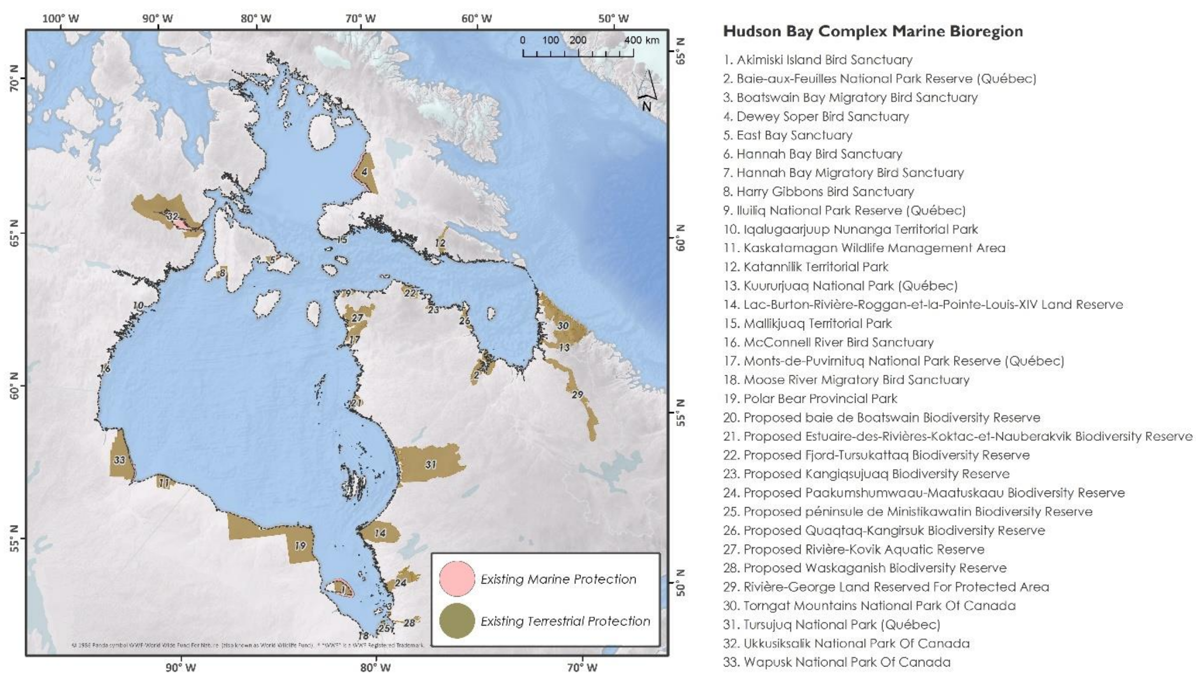

Figure 1.4. Existing marine and terrestrial protected areas in the *Hudson Bay Complex* marine bioregion.

FURTHER IMPORTANT ISSUES

Despite the fact that we have inventories of the various "protected" marine areas in Canada, it is remarkably difficult to satisfactorily sum them in terms of the ecological goals they are intended to fill, because of the varying levels of protection they afford and the varied purposes for which they were established. Even though Canada has declared that it has now met its numerical target of protecting 10% of its marine and coastal waters by 2020, this does not mean that it will satisfy the intent of the provisions of the IUCN Aichi Target 11. Here we examine several issues more closely.

The phrases “areas of particular importance for biodiversity” and “ecologically representative” in Aichi Target 11 can be taken as referring to distinctive and representative areas, respectively (see Roff and Zacharias, 2011)—central themes for the MECCEA project. However, Canadian marine protected areas have generally been established in isolation. We do not know if they are representative of the Canadian marine environment or if they capture the major areas of “particular importance for biodiversity.”

These concepts are explicitly considered in the MECCEA planning process, in Chapters 4, 5 and 6. In Chapter 7, we review the process of setting conservation targets for each identified conservation feature. In Chapter 8, we show how the decision support tool Marxan has been used to define a coherent set of marine protected areas that encompass all representative areas and those distinctive areas of particular importance for biodiversity.

The important question of connectivity among protected areas that would justify them as “integrated into the wider landscape (with connections to the land and freshwaters) and seascape” has been examined in Canada most directly by Roff and Zacharias (2011) and Kenchington et al. (2019). Existing marine protected areas in Canada have not been “integrated into the wider landscape and seascape” nor are they yet defined as a “well-connected systems of protected areas”. This issue is examined and modelled in Chapter 9.

In concluding this chapter, we note that the Canadian Arctic is still a neglected area for marine spatial planning. According to CCFAM (2017) work on marine protected areas network development is advancing and/or staled in five priority marine bioregions: Pacific Northern Shelf, Western Arctic, Newfoundland-Labrador Shelves, Scotian Shelf, and the Estuary and Gulf of St. Lawrence. The four marine bioregions under study by MECCEA (4 of the 5 Canadian Arctic marine bioregions) are not mentioned.

Special attention is therefore directed towards Canadian Arctic waters by WWF-Canada to enhance and advance the agenda of marine conservation; this is the rationale for the present MECCEA study.

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CHAPTER 2: OVERVIEW OF THE MECCEA PROJECT

FOREWORD AND TERMINOLOGY

We use the term Priority Areas for Conservation (PACs, see Text Box 1.3), which is defined in the context of this project as follows:

> **A Priority Area for Conservation (PAC) is an area of the marine environment of documented biodiversity value that should be prioritized for future conservation and management efforts. PACs should be protected and managed using appropriate combinations of federal, provincial and territorial legislation, Indigenous Protected and Conservation Areas (IPCAs), and Other Effective Area-based Conservation Measures (OEABCMs).**

The term “Priority Area for Conservation (PAC)” (also Priority Conservation Area, PCA) has been widely used in the conservation literature to indicate areas that have high biodiversity value. Generally, PACs can be identified in several objective ways. For example, Biological Valuation Maps (BVMs, see Derous et al., 2007) apply the EBSA criteria (Ecologically and Biologically Significant Areas, DFO, 2004) as ecological values to a spatial framework covering an entire study area. This leads to the identification of PACs whose aggregate ecological value is greater than that of the surrounding areas.

The MECCEA PACs are areas of high ecological value, each with a combination of conservation features. Collectively they meet specified targets for all conservation features within a bioregion (see below and Chapter 7). Therefore, they are WWF-Canada priorities for conservation. PACs are identified through Marxan analyses (see below and Chapter 8). Marxan is the most widely used software for systematic marine conservation planning.

Additional terms that will be frequently used in this report are listed in the Glossary.

BACKGROUND

In order to advance the Canadian agenda for marine conservation, in April 2017 WWF-Canada initiated a study to inform the development of an Arctic network of PACs. In doing so, WWF-Canada has undertaken to address the current gap in planning for networks of marine protected areas in the Canadian Arctic. Through this initiative, WWF-Canada is acting to assist and encourage the Federal Government of Canada with respect to conservation of the Canadian Marine Arctic.

At the time of the MECCEA study, the only Arctic marine bioregion for which DFO has commenced planning is in the Western Arctic (Figure 2.1), where they intend to produce a separate draft network design. The MECCEA study encompasses the remaining four Arctic marine bioregions recognized by the Canadian Government (DFO, 2009), namely: the Arctic Basin, Arctic Archipelago, Eastern Arctic and Hudson Bay Complex (Figure 2.1; marine bioregions 5, 7, 8, 9).

Conservation planning in the Canadian Arctic is a complex undertaking. The Arctic as a whole is remote, sparsely populated, physically challenging, and yet rapidly changing. All predictions of rates of climate change have been underestimates as shown, for example, by comparison of present ice conditions with projections of eighteen models from Solomon et al. (2007). Yet despite these rapid changes in the Arctic marine environment, conservation efforts have not been integrated. Rather, like in many other areas, efforts constitute localized initiatives directed at individual species, groups of species (notably birds and marine mammals), or specific regions. As presently described and delineated, Canada’s marine protected areas do not constitute a network (as defined for example by IUCN-WCPA, 2008; see Chapter 9). Nor do they constitute a coherent set of protected areas, e.g. by fulfilling criteria of representativity, replication, connectivity, etc. (Johnson et al., 2014). Unfortunately, the term “ecological coherence” remains to be adequately defined (see Ardron, 2008; OSPAR, 2013). These deficiencies are true of each of Canada's oceans including the Arctic Ocean.

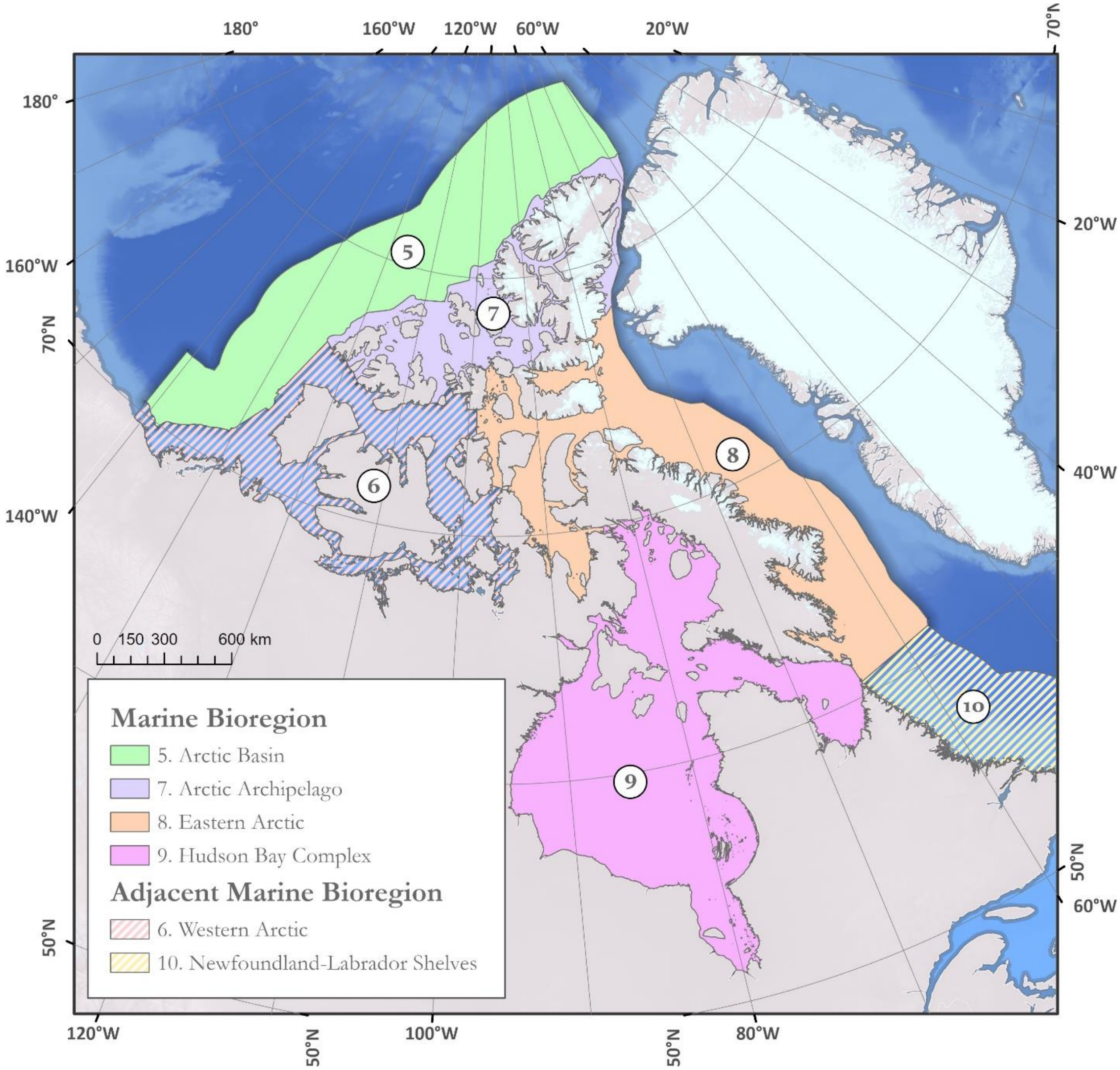

Figure 2.1. Marine Bioregions of Canada, as indicated by DFO (2009). The MECCEA study concerns Arctic Marine Bioregions 5, 7, 8, and 9.

Each of Canada's Arctic marine areas designated as protected (see Appendix 1) has one or more specific described purpose or purposes, and each one is likely to contribute to the conservation of marine biodiversity features beyond the stated purpose(s). However, although Canada can now claim that it has reached or exceeded its goal of protecting 10% of its marine environment (see Chapter 1), this does not complete the ecological task. The interactions and connectivity among these areas, and their complementarities or synergies of purposes are neither known nor documented. Nor is the sum total of their contributions to habitat protection, or their overall role in biodiversity conservation known, either as sets of marine protected areas, or as they may interact with other tools used in policy and management. Furthermore, these protected areas are very unevenly distributed among marine bioregions.

A major reason for the present MECCEA study is to rectify this situation and to produce recommendations for a coherent set or sets of PACs in the Canadian Arctic marine environment.

These PACs will represent all recognized conservation features—recorded and mapped from defined conservation targets—within the four marine bioregions of the study area. Further, these coherent sets of PACs (sensu Ardron, 2008) will be evaluated for the existence of patterns of connectivity among them, such that they can confidently be described as comprising a true network or networks.

This present MECCEA initiative entails a systematic and comprehensive framework that seeks to integrate planning from the species to the ecosystem level, by combining “fine-filter” and “coarse-filter” approaches (see below). Such an approach should also prove invaluable for regional planning in a changing environment (e.g. Tingley et al., 2014).

In particular, in the MECCEA project, WWF-Canada has developed networks of PACs that drew upon the best available information, to identify areas of high conservation value. In addition, the study identifies regions of overlap between areas of high conservation value and commercial activities and between areas of local use by Inuit. WWF-Canada has drawn on experts from government, academia, and Arctic organizations to collect and analyze the best available data from scientific, socio-economic, and IK sources. This has enabled the identification and mapping of representative and distinctive areas, key habitats of priority species, and various types of seascapes (i.e. marine landscapes; see below).

In this systematic planning study for marine biodiversity conservation, we have endeavoured to make as few arbitrary decisions as possible. We also document what we have done, how we have done it, and why the decisions taken were made. Given this record of our study, any future decisions made by the Government of Canada to legally implement any marine conservation decisions can be weighed and evaluated against what we present here.

The MECCEA study will also contribute towards international efforts to support the development of an Arctic Ocean network of PACs (i.e. ArcNet) presently being undertaken by the WWF Arctic Programme at the international level (see below).

GOALS AND CONSERVATION OBJECTIVES OF MECCEA AND THE PLANNING PROCESS

The goals and conservation objectives of MECCEA are summarised in Text Box 2.1 (as defined following an expert review workshop—see below), and they will be recalled and applied throughout this report. Conservation planning for MECCEA has proceeded in a series of well-defined steps that are summarized in Text Box 2.2 and Figure 2.2. The full process of conservation planning is described in the following chapters.

CONSERVATION FEATURES, STRUCTURES AND PROCESSES

Systematic planning for marine conservation involves the recognition and protection of as many components of biodiversity as possible. Conservation features are selected from the array of regional biodiversity components for which we have information.

A general classification of biodiversity components, across the ecological hierarchy from genes to ecosystems, has been described by Zacharias and Roff (2000) for marine ecosystems. Such a “checklist” is a straightforward organization of biodiversity components, which allows us to select what features could be included in a marine conservation study, depending upon available data. In this view, the components of biodiversity are recognized as either *structures* or *processes*. Such a hierarchy provides a useful framework for several environmental, cultural, socio-economic, and management purposes (see e.g. Roff and Zacharias, 2011).

However, we usually have little data available on processes themselves, rather these are inferred from changes over time of various structural components. It is generally some inventory of structural components of biodiversity that we can enumerate and spatially map. Where conservation features cannot be contained in defined static locations (e.g. migration corridors of marine mammals), another higher level of conservation, such as EBSAs (DFO, 2004; DFO, 2011), is required for management in a seasonally or spatially adaptive manner.

Text Box 2.1. MECCEA Project Goals and Conservation Objectives.

MECCEA's goals and conservation objectives were finalized following the first WWF-Canada Expert Review Workshop (see acknowledgments).

Goals

- To identify a network of priority areas for conservation (PACs) in Canada's Arctic marine environment.
- To encourage the Government of Canada to institute a sound Arctic marine protected area network as part of its international commitments to marine conservation.
- To identify individual sites for marine conservation and work with specific interested parties to advance the establishment of future protected areas.
- To provide input into various marine/coastal planning processes, environmental assessments and fisheries management. There is rarely sufficient information on the distributions of marine community types to allow them to be used directly for comprehensive planning in marine conservation.

Conservation Objectives

The MECCEA project's overall conservation objectives are:

1. to protect **distinctive**, **unique**, **rare** or **endangered** species and ecological features in each of the four Arctic marine bioregions, including:
   a. key habitats of Arctic priority species (O1A);
   b. ecologically sensitive areas (O1B);
   c. areas of high productivity and high species diversity/concentrations (O1C).
2. to protect **representative** examples of each type of identified ecosystem and habitat, in each of the four Arctic marine bioregions (O2); and
3. to ensure that the PACs are integrated into the wider landscape and seascape by patterns of **connectivity** (O3).

A HIERARCHICAL APPROACH TO MARINE CONSERVATION

Ideally, all approaches to marine conservation would be considered and combined in an integrated hierarchy of spatial planning.

Any non-arbitrary selection of marine areas as candidates for enhanced conservation or protection, must specify some basis for that selection. Selection may be based on expert opinion, available scientific data, and local Indigenous knowledge. In practice, some combination of these kinds of information will usually be required. Information generally falls into two categories: one based on individual species (often preferentially on priority species such as megafauna like larger fishes and marine mammals) and associated distinctive areas; and the other based on recognition of representative areas. These different approaches are often referred to as "fine-filter" and "coarse-filter", respectively. Further principles from an international advisory group to the Global Open Oceans and Deep Seabed report (UNESCO, 2009) were also followed by MECCEA in its planning process (Text Box 2.3).

One spatially explicit hierarchical approach to marine conservation has been advanced by Last et al. (2010) but applied only to the classification of benthic communities. We have adopted this type of approach for the MECCEA study, but we have applied it to both pelagic and benthic environments and included representative and distinctive areas, seascapes, and priority species (Table 2.1, Roff and Solovyev, submitted).

Text Box 2.2. The process of conservation planning in MECCEA.

- Establish a working group of WWF-Canada staff, consultants and volunteer experts.
- Identify goals, objectives, and timelines for the study.
- Determine the types of data available in the following categories:
  - Biological in situ data;
  - Geophysical in situ data;
  - Remote sensing data;
  - Data from indigenous knowledge sources; and
  - Socio-economic data.
- From the available data on biodiversity structures and processes, produce a list of all features within each of the four bioregions that warrant conservation in order to meet the conservation objectives overall. When spatially mapped, collectively, these are the *conservation features* (CFs) of the study.
- Define the process and quantitative rules to decide what proportion of each of the conservation features should be protected. These constitute the *conservation targets*.
- Define geographically and map: distinctive and representative areas, and associated seascapes and priority species.
- Use the decision support tool Marxan to analyze the data and produce maps of an efficient and coherent set of *Priority Areas for Conservation* (PACs). These maps incorporate spatially explicit distributions of all conservation features, as close to their designated target values as possible.
- Using the output from Marxan, examine the pathways of connectivity among the PACs, both in terms of passive dispersal and active migrations, to define networks of PACs.
- Examine the relationships among the proposed networks of PACs and existing Arctic protected areas (under all Canadian federal jurisdictions) to determine whether the existing areas have been efficiently sited for conservation purposes.
- Examine the relationships among the proposed networks of PACs and human uses to identify potential conflicts or synergies.
- Produce management considerations and recommendations.

The modified MECCEA framework presented in Table 2.1—essentially a bioregionalization scheme—is not now strictly hierarchical, since its lower levels may not be contained entirely or exclusively within the layer above. Nevertheless, this framework does indicate at which levels of the hierarchy data should be considered, the approximate range in scale, which features we have reconstructed from surrogates of available environmental data, and how data are inter-related. Missing information can be identified and the level of confidence in planning recommendations can be assessed.

In approaching conservation in this way—in terms of conserving representative and distinctive habitats, seascapes and priority species—recognition of an environmental spatial hierarchy is indispensable. It also ensures that a comprehensive and inclusive set of PACs can be proposed as comprising a truly coherent set of marine protected areas.

Whatever approach is adopted, a prime requirement is to map and spatially define the natural biogeographical and geophysical patterns of marine distributions. This means that if the goal is to preserve as many species as possible, a practical approach would be to preserve as many recognizably different habitat types as possible, as explicit in the WCC (2016) call for increased marine conservation. A hierarchical classification of habitat types that makes use of available geophysical and oceanographic features is therefore clearly practical and effective.

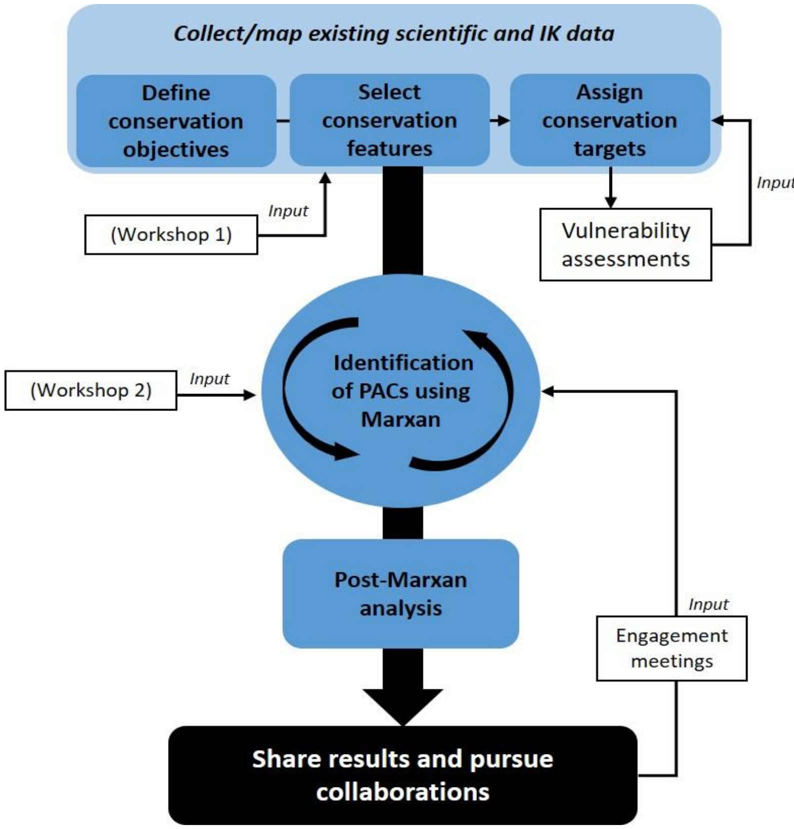

Figure 2.2. The MECCEA systematic planning process, showing the central importance of MARXAN. IK = Indigenous Knowledge; PAC = Priority Area for Conservation

Text Box 2.3. Principles for marine biogeographic classification systems.

The following principles were agreed by an international advisory group to the Global Open Oceans and Deep Seabed report, GOODS (UNESCO, 2009) and are followed by MECCEA in the planning process.

1. As pelagic systems are three-dimensional and dynamic, and benthic systems have a more stable, two-dimensional foundation, benthic and pelagic environments should be considered separately;
2. Classification should not be based upon the unique characteristics of distinctive areas or upon individual focal species. Therefore, the "diagnostic species" concept should be avoided as it is counter to the goal of identifying representative areas that reflect patterns in total biodiversity;
3. Classification should reflect taxonomic identity, which is not addressed by systems that focus on biomes. As species composition is considered important, the terrestrial biome concept is not appropriate;
4. Generally recognizable communities of species should be emphasized and do not require the presence of either a single or diagnostic species, or abrupt changes in composition between units. As such, rigid multi-taxa discontinuities should not be expected as the processes affecting distributional histories may differ;
5. The influences of ecological structures and processes in defining habitats and their arrays of species should be recognized; and
6. Classification should be hierarchical with a nested structure based upon appropriate scales of features.

Table 2.1. A spatial planning framework (bioregionalization scheme) for the MECCEA study adapted from concepts and classifications of Roff and Taylor (2000) and Last et al. (2010), showing examples of conservation features.

Level	Name	Scale	Representative Areas/Seascapes		Distinctive Areas/Priority Species	
			Description	Examples	Description	Examples
1	Province	>1,000 km	Largest oceanic areas of biogeographically-defined character	Arctic Ocean	Distribution range of priority species	Bowhead whale pan-Arctic distribution range
2	Marine Bioregion	100–1,000s km	Defined by a suite of oceanographic, topographic, and/or biological features	Arctic Basin, Arctic Archipelago, Eastern Arctic, Hudson Bay Complex	Distribution range of sub-species/population of focal species	Eastern Canada/West Greenland population of Bowhead whale
3	Region	10–100s km	Broad scale bathymetry	Euphotic zone, continental shelf, slope, abyssal plain	Distinctive areas defined by geography/bathymetry, and seasonal habitats of populations of priority species	Wintering grounds of the Eastern Canada/West Greenland population of Bowhead whales
4	Geomorphic features	10–100s km	Areas defined from topography and geomorphology	Offshore geomorphic features e.g. banks, basins Coastal geomorphic features (bays, estuaries, headlands)	Areas defined from topography and advective processes	Canyons
5A	Geophys.-defined primary habitats	10–100s km	Representative habitat types defined by oceanographic and geophysical data	Sympagic seascapes defined by ice characteristics Pelagic seascapes defined from water masses, stratification, depth, etc. Benthic seascapes defined from water masses, depth, substrate, etc.	Distinctive habitat types, defined by oceanographic and geophysical data	Polynyas, marginal ice zone High primary production from models High chlor a Upwelling, gyres

Level	Name	Scale	Representative Areas/Seascapes		Distinctive Areas/Priority Species	
			Description	Examples	Description	Examples
5B	Biologically-defined primary biotopes	10s km	Representative habitat types defined by biological communities, groups of species, or processes	Areas defined by fish communities (i)	Distinctive habitat types defined by biological communities, groups of species, or processes	Areas of high fish species richness
6	Secondary biotope	<10 km	Representative biotopes and their associated community types	Representative benthic communities defined by species assemblages and substrate type (ii)	Distinctive biotopes and their associated focal species Foundation species or communities	Key habitats for some priority species, e.g. haul out sites, rookeries Deep sea corals, sea pens, siliceous sponges
7	Biological Facies	m to km	Biological indicator species of specific habitats	(iii)		*Zostera marina*
8	Micro-communities	mm to m	Species assemblages dependant on a species of the biological facies e.g. epiphytic community	(iii)		(iii)

(i) Not available for MECCEA. Fish data used to define bioregions and depth intervals only.
(ii) Not available for MECCEA. Benthos data used to define bioregions and depth intervals only.
(iii) Not available for MECCEA.

The advantages of hierarchical habitat classification have become widely appreciated (e.g. Urban et al., 1987). For conservation purposes, the objective is to establish a system within which all natural communities and habitats can be recognized. The hierarchy itself should discriminate first among the broadest spatial and ecological units, while at the lower levels of the hierarchy, habitat and community types are progressively more closely related. In this way, our hierarchy is an analogue of the taxonomic "Natural System of Classification".

AVAILABILITY OF DATA

Despite the remoteness of the MECCEA study regions, there exists a surprising quantity of data for some regions of the Canadian Arctic. The features captured in the data can sometimes be considered as conservation features themselves, or in other cases can be combined to create conservation features as surrogates of representative habitat types, i.e. seascapes. For example, many records exist of ocean currents, circulation patterns, CTD (conductivity, temperature and depth) records, and there are recent compilations of geomorphic features. Canadian data from several federal agencies exists for marine mammals, seabirds, fish, and benthic species of invertebrates.

However, many of the data are scattered in time and space and are far from uniformly distributed. Because of the uneven coverage of data among the four marine bioregions, we elected to undertake analyses for the marine bioregions individually and combined. The available geophysical and biological data for the Canadian Arctic marine bioregions have never previously been systematically applied to the task of planning for marine conservation. The MECCEA study represents the first attempt to do this.

A major consideration is the timeframe over which data were reported. Observations for biological and geophysical data were collected over decades, but in our study they were pooled as if contemporaneous and current. In the face of a very rapidly changing Arctic environment, we admit that this may unavoidably introduce some aliasing of data elements and temporal biases.

RESILIENCE

In the MECCEA study, we considered incorporating some assessment of resilience into our sets of PACs and the ensuing network. Components of resilience could be considered to include conservation features such as:

- areas of high plankton biomass as indexed by chlorophyll (chlor) a;
- areas of high production as modelled by rates of primary production;
- location, size and inter-annual variability and persistence of polynyas; and
- areas heavily utilized by several groups of species at higher trophic levels e.g. "hotspots" as indexed by Arctic Trails (Yurkowski et al., 2019) or other data compilations.

Although we included several such features that may be considered as resilient, we do not consider the subject of resilience itself as a major feature of the MECCEA study. However, see Chapter 11 for management considerations that address resilience.

INDIGENOUS KNOWLEDGE

Numerous Indigenous peoples inhabit the shores of the Arctic marine bioregions included in the scope of this study. Inuit live in the four regions of Inuit Nunangat: Nunavut, Inuvialuit Settlement Region, Nunavik, and Nunatsiavut. The scope of the study also includes the people who live around the Hudson Bay coastline: Cree, Dene, Metis, and non-Indigenous communities in Quebec, Ontario, and Manitoba (Figure 2.3).

The MECCEA analysis is based on information from both conventional scientific data and Indigenous Knowledge (IK) sources. This includes information relating to conservation features used in the Marxan analysis (e.g. information relating to species and habitats) and information used to develop maps of local uses in the study region to create overlay maps for the post-Marxan analysis (e.g. information relating to hunting areas, campsites, cultural sites, etc.).

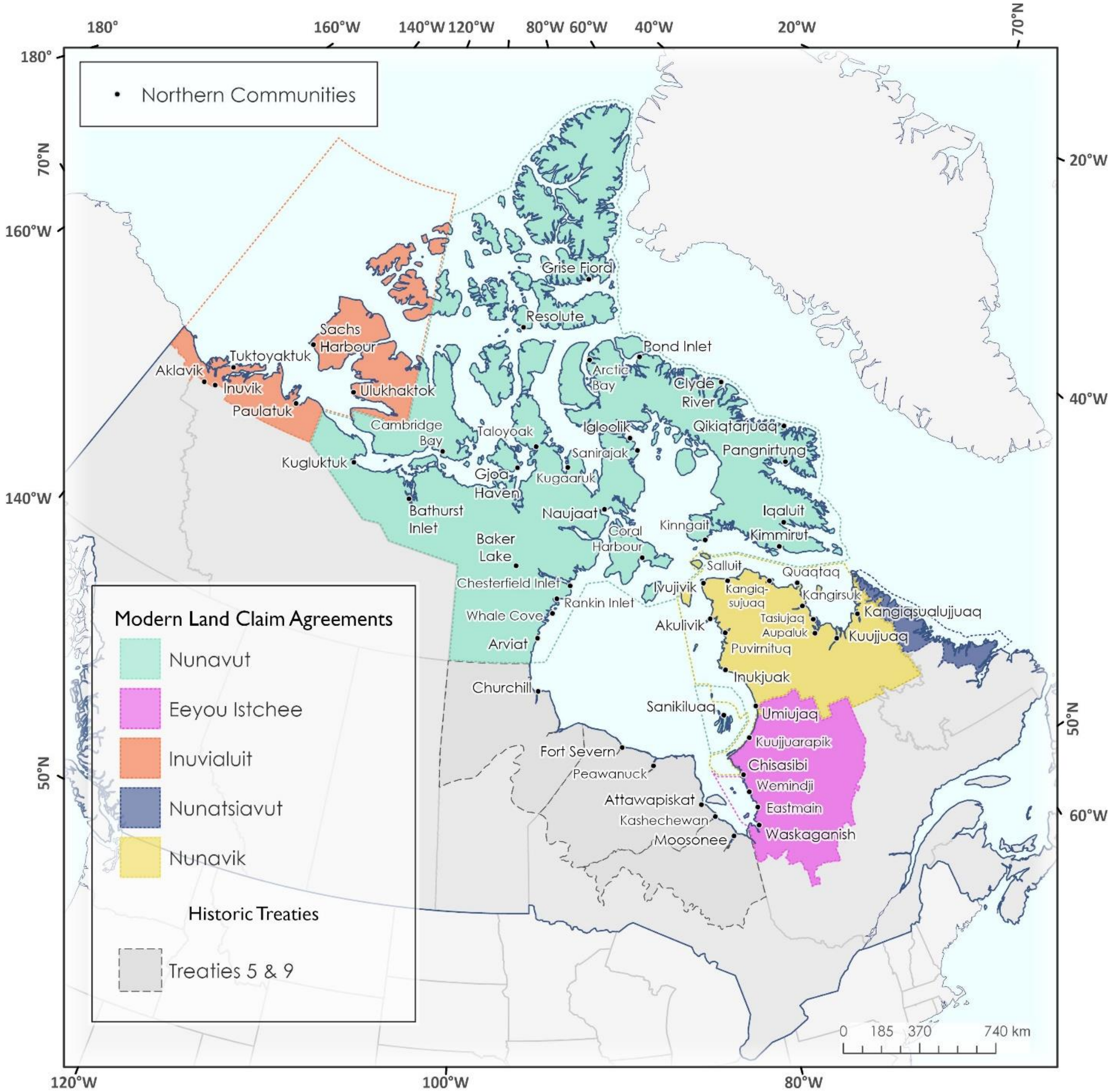

Figure 2.3. Indigenous peoples who live around the four Marine Bioregions of the MECCEA study area.

In the Marxan analysis phase (Chapter 8), information from IK sources was the basis for several of the conservation feature layers, mainly for marine mammal features. In the post-Marxan analysis phase, local use information was used to develop overlay maps with the Marxan scenarios (see Chapter 10). As well, submissions to the draft Nunavut Land Use Plan from Nunavut communities, which map or describe special management and protected areas, have been compared with the Marxan scenarios as part of the post-Marxan phase to identify areas of overlap and potential synergies for conservation. These submissions were drafted by community representatives based on local knowledge.

The primary source of information for both IK and local uses information is the Nunavut Coastal Resources Inventory (NCRI) (Government of Nunavut, 2008). The NCRI is a Government of

Nunavut project that is establishing an inventory of local marine and coastal resources and activities in each Nunavut community, through interviews and participatory mapping with local holders of IK (more commonly referred to as Inuit Qaujimajatuqangit by Inuit).

Although other resources for ecological information from IK sources have also been developed within the study area (for example, the Inuit Land Use and Occupancy Study and the Nunavut Atlas), the spatial data from these studies were not available for use by MECCEA. As a result, there is more information from IK sources for the Nunavut Settlement Area within the MECCEA study than for elsewhere. However, future analyses incorporating additional information from other sources and regions could be completed in the future if data become available.

EXPERT REVIEW AND KNOWLEDGE SHARING

As part of the MECCEA study process, WWF-Canada convened two expert workshops in Ottawa between February 2018 and February 2019 (Figure 2.2). The purpose of the first workshop was to discuss proposed conservation objectives, criteria, conservation features, and targets needed to carry out a Marxan analysis. The second workshop focussed on testing and validating the Marxan analysis to get feedback from experts and to consider factors not currently included in the analyses, such as commercial activities (i.e. fisheries and marine transportation) and local use areas. The expert reviews also noted any data we may have omitted, or to which we had access but elected to omit from the MECCEA report. In this latter case we gave reasons why such data were not included.

Following the second expert review, WWF-Canada re-ran Marxan analyses to produce the final scenarios incorporating the input and recommendations received during the workshops. The final network of PACs has been presented and discussed with key federal, provincial, and territorial agencies, and with Indigenous organizations and Arctic communities.

RELATIONSHIP BETWEEN MECCEA AND ARCNET

The Canadian Arctic marine bioregions are connected to the rest of the Arctic in many ways (e.g. oceanography, climate, species, and people). The MECCEA project is thus connected into a broader Pan-Arctic marine system. Therefore, the results stemming from MECCEA are contributing to the development of a pan-Arctic scale marine protected area network, by providing a national and regional data set and through sharing expertise.

The pan-Arctic project, ArcNet, is an initiative led by the WWF Arctic Programme with a management team composed of WWF staff in five of the Arctic States (Canada, United States, Russia, Norway, and Denmark/Greenland). The geographic scope of ArcNet is the southern boundaries of the Arctic Large Marine Ecosystems (LMEs) excluding the Aleutians, Faroe Plateau LME, Norwegian Sea LME, Aleutian Islands LME, and West Bering Sea LME.

The main goal of ArcNet is to identify and map an ecologically representative and well-connected pan-Arctic network of marine areas that will be managed for the conservation and protection of biodiversity and will support the resilience of ecological processes and associated ecosystem services and cultural values.

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CHAPTER 3: MARINE BIOREGIONS OF THE CANADIAN ARCTIC

PRIMARY SEPARATION OF THE MARINE ENVIRONMENT

The primary determinant of differences among marine communities is between the pelagic and the benthic realms. Their differences in taxonomy and adaptations of biota exceed those of any community changes in latitude or depth, and any differences among provinces or marine bioregions (see Roff and Zacharias, 2011). This separation could, therefore, legitimately be considered as the first level of a global conservation hierarchy.

Nevertheless, we used combinations of the geophysical features of the pelagic and benthic realms, to describe seascapes at Level 5 of our hierarchy (see Table 2.1). This provides a more efficient use of available data, at a level below that of marine bioregions.

BOREAL POLAR PROVINCE AND ARCTIC MARINE CLASSIFICATION SYSTEMS

The global marine environment has been spatially classified by several authors and organizations, using different data and criteria. Major recent classifications include: Longhurst (2007), Sherman and Alexander (1986), PAME (Protection of the Arctic Marine Environment, 2015), Spalding et al. (2007), UNESCO (2009), the CEC (Tri-National Commission for Environmental Cooperation) in Wilkinson et al. (2009), and DFO (2009). These classifications are briefly reviewed here.

The Arctic Ocean itself is Level 1 of our hierarchical classification (Table 2.1). It is significantly enclosed by land and is considered to be part of a greater Boreal Polar Province (BPP), which includes the Chukchi, East Siberian, Laptev, Kara and Beaufort Seas, along with Hudson Bay, the Canadian Archipelago, and the northern part of the Barents Sea (Longhurst, 2007).

The geographic boundary between the Arctic Ocean and the Pacific Ocean is generally recognized as the Bering Strait, although oceanographic features, characteristic of the Arctic, extend through the Bering Strait well into the Pacific Ocean, bounded by the Aleutian chain of islands. The boundary between the Arctic and Atlantic Oceans is more diffuse and variably defined.

Within this broadly delimited polar province, the various marine bioregions (also variously termed LMEs—Large Marine Ecosystems or Ecoregions—have been defined by several groups and authors, including DFO (2009) and Government of Canada (2011) who defined the present Canadian marine bioregion boundaries.

The five major biogeographic units defined by Government of Canada (2011) for the Arctic (Figure 2.1) are: the Arctic Basin, the Arctic Archipelago, the Western Arctic (which includes the Beaufort Sea and the Queen Maud Gulf), the Hudson Bay Complex (which includes Foxe Basin, Hudson Bay, and James Bay), and the Eastern Arctic (which includes Lancaster Sound, Baffin Bay and Davis Strait). Other classifications of the Arctic Ocean, which include Canadian waters, are similar in their boundary designation but warrant comparison.

A comprehensive classification of the Arctic marine environment has been advanced by PAME (2015), a working group of the Arctic Council. This classification subdivided the Arctic region into 18 LMEs, with five included in the Canadian Exclusive Economic Zone (EEZ). The criteria, common to all the globally recognized LMEs (Sherman and Alexander, 1986), include: bathymetry, oceanography, indices of productivity, and trophic linkages. The PAME report differentiates the Beaufort Sea, the Hudson Bay Complex, the Canadian Eastern Arctic plus western Greenland region, and the Canadian high Arctic plus west Greenland area. Thus, it does not distinguish the Canadian Archipelago and the Canadian Arctic Basin as separate marine bioregions.

The classification of Arctic ecoregions by Spalding et al. (2007) is similar to that of PAME (2015). It recognizes the Beaufort Sea and the Hudson Bay Complex. However, here Lancaster Sound is separated from the DFO Eastern Arctic as its own ecoregion. The boundary between the Northern Labrador ecoregion and Baffin Bay/Davis Strait is located further north than in the DFO scheme. Also, the Arctic Archipelago is recognized but this ecoregion extends further into the High Arctic and includes most of the Canadian part of the Arctic Basin.

The CEC report on Marine Ecoregions of North America (Wilkinson et al., 2009) again shows similarities to other systems of classification. Hudson Bay complex, the Arctic Archipelago, and the Arctic Basin are again recognized as separate ecoregions; however, the Eastern Arctic is combined with DFO region 10—Newfoundland and Labrador (see Figure 2.1).

The marine ecoregions defined by DFO in 2004 (Powles et al., 2004), are essentially the same as those of DFO (2009), except that Lancaster Sound is separately recognized, and the boundary between the Eastern Arctic and Labrador–Newfoundland is different.

Surprisingly, in its "Ecosystem status and trends report: Arctic Marine Ecozones", DFO (2010) does not distinguish between the five major marine bioregions identified in DFO (2009) and Government of Canada (2011). Rather it combines the Arctic Basin with the Arctic Archipelago **and** the Eastern Arctic, while retaining the Hudson Bay Complex and Beaufort Sea marine bioregions.

Other marine classification systems developed since the mid-1980's have focused specifically on Canadian ecosystems and involved a variety of government and non-government bodies including Parks Canada and WWF-Canada. These initiatives all involved variants of the above biogeographic boundaries; they are summarised in DFO (2009) and are not considered further here.

In summary, after examining all these biogeographical classification schemes, the DFO (2009) and Government of Canada (2011) classification scheme has been accepted as the basis of our MECCEA study, and it constitutes Level 2 of the hierarchy presented in Table 2.1 and is described in further detail below.

ARCTIC MARINE BIOREGION BOUNDARIES

A particular problem in trying to distinguish boundaries between marine bioregions is that they can be recognized on the basis of geomorphology **or** oceanography **or** biology. Ideally, all three sets of features would geographically coincide. However, geomorphic features are static on time scales relevant to conservation actions, and oceanographic and biological features are dynamic on short (but not identical) time scales, so this ideal is not achievable.

In terms of boundaries between the four marine bioregions, the most readily justified is the Hudson Bay Complex. It extends furthest south and is almost landlocked to the north of Foxe Basin at Fury and Hecla Strait. Its boundary with the Eastern Arctic in Hudson Strait is set by the apparent limit of penetration of Atlantic water. The temperature-salinity (T-S) characteristics show that it is clearly Arctic (Pett and Roff, 1982) and indicate that Atlantic water does not penetrate directly. The presence of *Calanus hyperboreus* and *Calanus glacialis*, and absence of *Calanus finmarchicus* in Hudson Bay, also testifies to its Arctic character and the lack of Atlantic water (Grainger, 1963). Although the separation of the Hudson Bay Complex from Atlantic influence is by no means complete (Straneo and Saucier, 2008), the boundary between Hudson Bay and the Eastern Arctic is acceptable both oceanographically and biologically.

The separation of the Eastern Arctic and Labrador regions at Cape Chidley (the land boundary between Labrador and Quebec) by DFO is also accepted by PAME (2015). However, the separation between these regions (Baffin Bay plus Davis Strait, versus Northern Labrador) is placed further north at Cape Dyer by Spalding et al. (2007). This is perhaps a more natural (and less geopolitical) division based on bathymetry, because it excludes the deeper waters of the Northern Labrador Sea.

In contrast to the other marine bioregions, the Arctic Archipelago consists of more land (~53.2%) than water, and this region of islands forms the central mass of the Last Ice Area (see below). Its boundary with the Arctic Basin is set by the 200 m isobath – a reasonable separation recognized by biological oceanographers worldwide (also see Chapter 5). The poleward boundary of the Arctic Basin is set geopolitically by the Canadian EEZ. The western limits of the Eastern Arctic and the Arctic Archipelago are set by the international boundary with Greenland.

Finally, according to PAME (2015) and DFO (2009), the eastern boundary of the Beaufort Sea, where it borders the Arctic Archipelago and the Eastern Arctic marine bioregions, is across the eastern Viscount Melville Sound and Franklin Strait (north and south of Prince of Wales Island). This boundary represents the region with the heaviest ice conditions separating migratory marine mammals between Atlantic and Pacific populations. This gives the boundary a meaningful role in designating spatial conservation networks.

IS FURTHER SUB-DIVISION OF THE MARINE BIOREGIONS JUSTIFIED?

There have been suggestions (see above) that Lancaster Sound (including Parry Channel and McClintock Channel) should be considered as a separate marine bioregion from the rest of the Eastern Arctic. The main reason is because of its high apparent biological productivity at higher trophic levels. However, an examination of the water masses of the upper 200 m during ice-free periods reveals that their T-S plots (Figure 3.1) substantially overlap, but with Baffin Bay reaching higher temperatures. Thus, on physical oceanographic grounds, this separation is not warranted. Water masses are further examined in Chapter 4.

It has also been suggested that Foxe Basin, and perhaps James Bay, should be considered as separate marine bioregions from Hudson Bay (thus sub-dividing the Hudson Bay "complex"). Again, although there is greater dilution of salinity in both James Bay and Hudson Bay itself, the T-S characteristics converge to similar "origins" (Figure 3.2). Thus, on physical oceanographic grounds, no further sub-division of the marine bioregion seems justified.

DFO DESCRIPTIONS AND CRITERIA FOR THE FIVE ARCTIC MARINE BIOREGIONS

Beyond the statement of criteria for recognizing the separate Arctic marine bioregions (bathymetry, influence of freshwater inflows, and distribution of multi-year ice) and acknowledgement that they are based on an older classification system for Parks Canada (Harper et al., 1983), the DFO reports (e.g. DFO, 2009) do not give full comparative descriptions of the five Arctic marine bioregions. This is important information to document since these marine bioregions constitute the first level of a national hierarchy of classification for conservation purposes, and we should be assured that they do in fact differ in geophysical, biological and other characteristics.

The DFO (2009) report of the five Arctic marine bioregions and the DFO (2010) Marine Ecosystem Status and Trends Report (of its three recognized Arctic regions) both contain regional descriptions, from oceanography to human uses and economic prospects, but there is no overall comparison of features among the regions. Indeed, Figure 1 of Government of Canada (2011), which shows the marine bioregions, has a caveat in a footnote that states, "Geographic boundaries for bioregions have not been determined. Bioregion lines are only for illustrative purposes." A more extensive analysis of the geophysical and biological characteristics and a further review of the boundaries among these marine bioregions is therefore warranted—as suggested by DFO (2009).

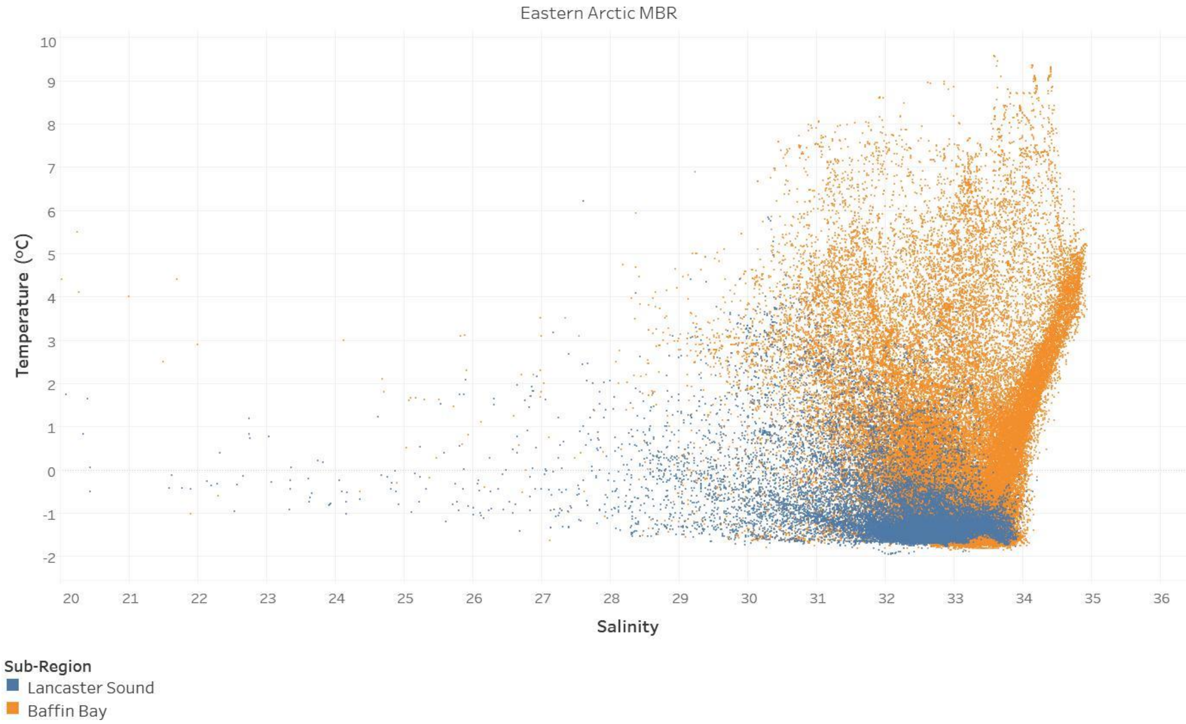

Figure 3.1. Temperature salinity (T-S) relationship of water masses in the Eastern Arctic bioregion, showing differences between Lancaster Sound and Baffin Bay waters.

CHARACTERISTICS OF THE FOUR MECCEA ARCTIC MARINE BIOREGIONS

Given that the five Canadian Arctic marine bioregions are de facto recognized as separate by DFO, it is important to document that the four marine bioregions comprising the MECCEA study area do in fact differ significantly in their geophysical and biological characteristics. Sources for the following data are reviewed in Chapters 4 and 5 of this report.

Before undertaking the Marxan analyses and to supplement published information, MECCEA undertook a review of selected geomorphic, oceanographic and biological features of the four marine bioregions and the boundaries between them. A comparison of the physical and oceanographic characteristics discussed below is provided in Table 3.1.

First, it is clear that the Hudson Bay Complex is by far the largest of the marine bioregions followed by the Arctic Basin and the Eastern Arctic, being of similar surface area. The Arctic Archipelago is by far the smallest area. In terms of depth, the Arctic Basin is deepest, and the Hudson Bay Complex and Arctic Archipelago are the shallowest. The hypsographic curves of the regions (Figure 3.3) show these differences in graphic form.

Ice cover is also significantly different among the areas as would be expected based on the range of latitudes from 51.170°N in the south of James Bay to 86.310°N in the north of the Arctic Basin. These differences naturally are also reflected in the average seasonal levels of chlor a.

Surface salinities are lowest in Hudson Bay, where massive freshwater runoff from the huge drainage basin dilutes the salt content. In combination with the highest surface temperatures of any of the marine bioregions (primarily a simple consequence of lower latitude), the Hudson Bay Complex also exhibits the highest degree of vertical water column stratification. Maximum bottom water salinity is observed in the Eastern Arctic as a consequence of the dominance here of water of Atlantic origin. The 5th and 95th percentile values of temperature and salinity (Table 3.1) indicate differences better than the absolute range of observed values.

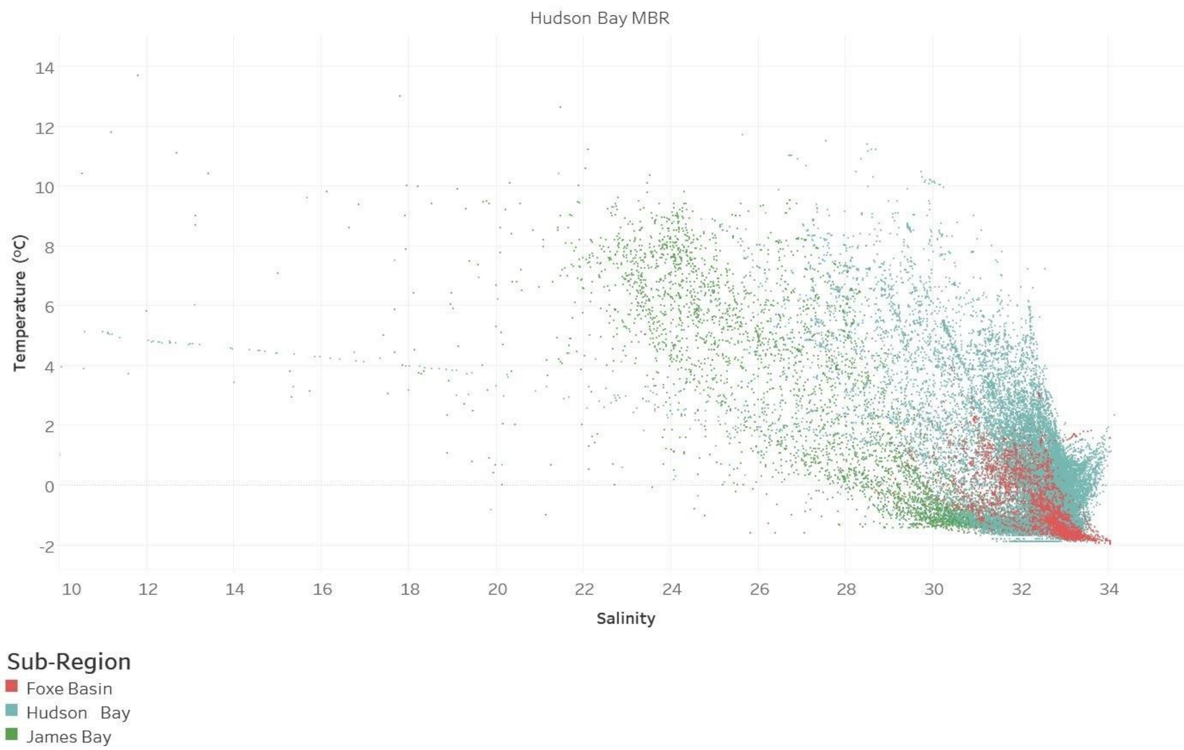

Figure 3.2. Temperature salinity (T-S) relationships of water masses in the Hudson Bay Complex, showing differences among Foxe Basin, Hudson Bay and James Bay waters.

Differences among the four marine bioregions also extend to their geomorphic features, summarised in Table 3.2. The Arctic Basin is unique in having a set of canyons not seen in the other regions. The Hudson Bay Complex is unique in having a very high number of small islands (i.e. <1 km^2) and small coastal inlets. In summary, it can be seen that these four marine bioregions do indeed differ in their geophysical and geomorphic features.

Biological differences (in fish and zoobenthos taxonomic assemblages) also support the separation among the marine bioregions; these are considered further in Chapter 5 of this report.

MECCEA MARINE BIOREGIONS - MAPPING DISCREPANCIES

During the process of mapping in the four Canadian Arctic marine bioregions, some spatial discrepancies were noted. The original shapefiles of the four Arctic marine bioregions were obtained from DFO. However, the edges of the polygons that ought to mark the boundaries between waterbodies and landmass, misaligned with the actual coastlines by up to several kilometers. WWF-Canada has informed DFO of these discrepancies, and the revised maps of the four MECCEA marine bioregions were made available to DFO.

In order to represent coastal habitats within this project, we have relied on spatial data contained within the CanVec Series Hydrographic Features Dataset (Natural Resources Canada, 2017). These data are produced at a high spatial resolution of 1:50,000. Given the higher precision of these data relative to that used by the DFO's marine bioregions, minor discrepancies inevitably emerge in the location of the coastline used by these two datasets. To ensure conformity, all data representing coastal features were clipped within a set distance of the DFO marine bioregion coastline. While still generally correct, it should be noted that this process resulted in a minor loss of accuracy in the CanVec data.

Table 3.1. Selected physical characteristics of the four MECCEA Arctic marine bioregions.

Feature	Arctic Basin	Arctic Archipelago	Hudson Bay Complex	Eastern Arctic
Surface Area (km^2)	752,053	269,946	1,243,022	784,873
Depth Mean/Max (m)	1,780/3,758	220/865	113/930	675/2,782
Area Permanently Ice-covered (%)	89	57	0	0
Area Seasonally Ice-covered (%)	11	43	100	99
Area Permanently Ice-free (%)	0	0	0	1
Sea Surface Temp. Min/Max/Mean (°C)	-1.77/5.58/-0.54	-1.78/4.08/-0.58	-2.02/12.5/0.45	-1.92/6.88/0.28
95th Percentile Temp. (°C)	0.465	0.66	5.28	3.79
5th Percentile Temp. (°C)	-1.59	-1.57	-1.24	-1.5
Salinity Min/Max/Mean (PSU)†	15.03/34.99/33.42	23.74/35.29/32.68	18.92/34.7/31.66	24.14/34.96/33.39
95th Percentile Salinity (PSU)	34.95	34.79	33.27	34.77
5th Percentile Salinity (PSU)	30.02	29.84	27.77	31.23
Stratification Value Min/Max/Mean§	0.42/44.28/4.44	0.58/24/9.06	0.09/28/8.06	0.55/18/4.51
Tidal Range Min/Max/Mean (m)	0.06/0.26/0.12	0.04/2.56/0.4	0.05/5.03/1.35	0.36/4.07/1.41
Chlor a Mean/Max (mg/m^3)	0.32/62.44	0.75/62.25	1.16/99.9	0.55/88.51

†Practical Salinity Units

§$(\Delta\sigma_t/\Delta d)$x100—see Chapter 4.

Table 3.2. Prevalence of geomorphologic features in the four Arctic marine bioregions (in km² and % of bioregion area unless otherwise indicated).

Geomorphic Feature	Arctic Basin	Arctic Archipelago	Eastern Arctic	Hudson Bay Complex
Shelf	160,548 (21.3%)	263,222 (97.9%)	431,796 (55.2%)	1,238,296 (99.5%)
Shelf Valley	45,434 (6.04%)	150,125 (55.9%)	159,572 (20.4%)	243,737 (19.6%)
Basin	253,578 (33.7%)	54,098 (20.1%)	298,443 (38.1%)	197,924 (15.9%)
Glacial Trough	40,810 (5.43%)	145,628 (54.2%)	132,196 (16.9%)	195,817 (15.7%)
Sill	1,298 (0.17%)	14 (0.005%)	1,242 (0.16%)	none
Abyss	426,149 (56.7%)	none	83,527 (10.7%)	none
Gully / Canyon	83,392 (11.1%)	none	1,362 (0.17%)	none
Escarpment	1,356 (0.18%)	none	890 (0.11%)	none
Rise	126,194 (16.8%)	none	13,548 (1.73%)	none
Slope	164,872 (21.9%)	none	259,584 (33.2%)	none
Terrace	21,067 (2.8%)	none	4,971 (0.64%)	none
Bank	none	179 (0.07%)	3,877 (0.5%)	none
Fan	52877 (7.03%)	none	none	none
Plateau	106702 (14.2%)	none	none	none
Ridge	478 (0.06%)	none	none	none
Trough	none	none	104370 (13.3%)	none
1st Order Coastal Inlets (count)†				
>1200 km²	none	4	12	4
121–1200 km²	none	36	43	33
32–121 km²)	none	31	55	51
<32 km²)	none	261	676	1275
Polynya/Leads (count)	none	3,085 (12)	106,729 (231)	3,8615 (139)
Small Islands†† (count)	none	53 (405)	1,067 (8,427)	491 (22540)
Coastal Wetlands	none	151	1,075	18,649
Shoreline (% of Total)				
Cliff	none	13.4	39.8	4.7
Sandy intertidal	none	3.7	4.3	7.32
Other intertidal	none	69.5	33.4	74.3

†First order coastal inlets are those with no associated secondary inlets (see Chapter 4).
††Small islands were defined as those less than 1 km².

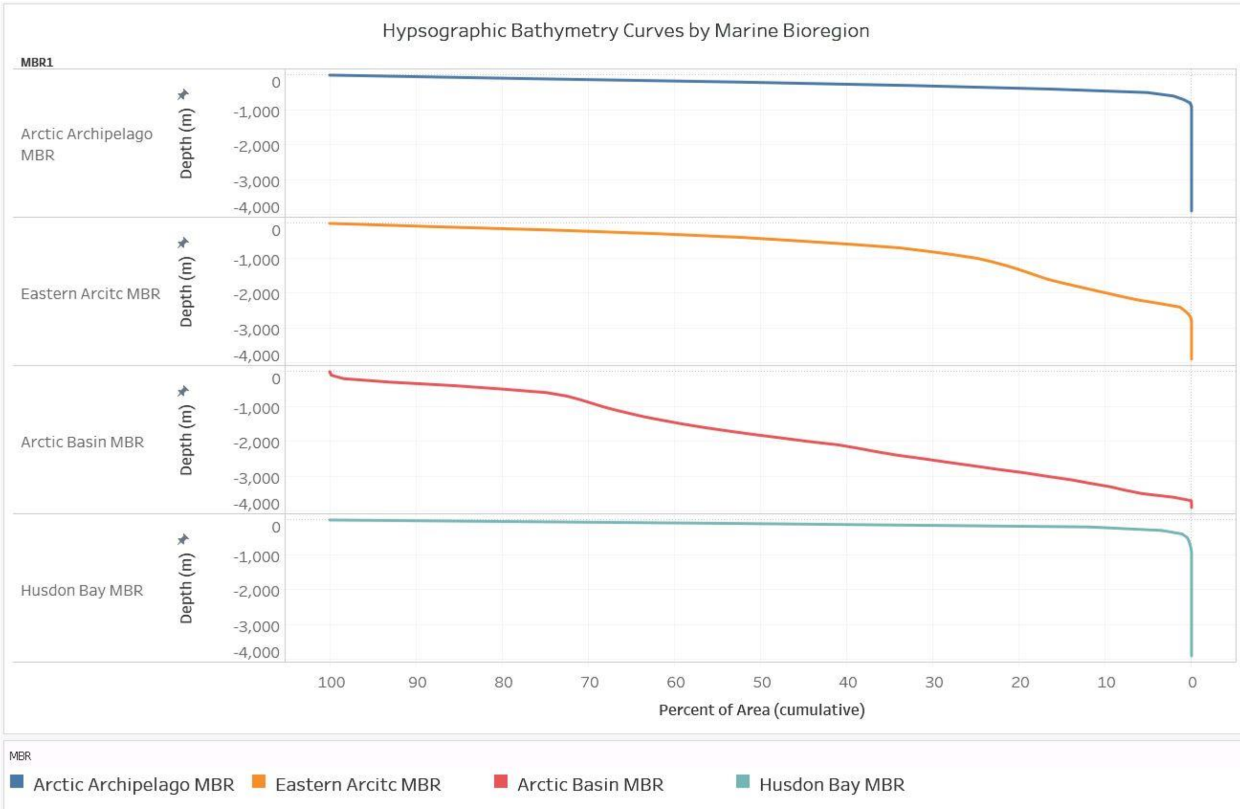

Figure 3.3. Hypsographic bathymetric curves for the four MECCEA bioregions.

DFO EBSAS IN THE ARCTIC MARINE BIOREGIONS

In addition to the suite of existing protected areas in the five Arctic marine bioregions legislated or regulated by federal Canadian agencies, DFO has also identified EBSAs (Ecologically and Biologically Significant Areas) in these regions (DFO, 2004), and their number has increased to 61 in the intervening years (DFO, 2011; DFO, 2015; Kenchington et al., 2011; Paulic et al., 2014). Arctic EBSAs include those in the Arctic marine bioregions as a whole, in northern Foxe Basin, in the Western and Eastern Arctic, and in the Hudson Bay Complex. The currently recognized EBSAs cover a wide proportion of the Arctic marine bioregions.

These EBSAs have been identified in recognition of various features considered of vital ecological importance to the functioning and resilience of marine ecosystems. The most significant features recognized are: high productivity crucial to food webs, primarily from the WWF RACER study (Christie and Sommerkorn, 2012); ice features and the biological communities dependant upon them; benthic features especially for deep-sea coral, sea pens and sponges; marine mammal migration routes; summer and winter habitats and key habitats for life stages; walrus haul out sites; and seabird colony foraging radii. Some of these Arctic EBSAs have global significance, e.g. Lancaster Sound, the North Water polynya, and the future last multi-year ice pack—the Last Ice Area (LIA) of the Arctic Archipelago and the Arctic Basin (see below). DFO (2011) readily acknowledges that the currently recognized Arctic EBSAs are subject to several uncertainties generally related to data reliability. Knowledge is far from complete and subject to revision particularly in the face of climate change.

A major purpose of noting the existence and locations of these EBSAs in the various Arctic marine bioregions is that we can compare the locations of the MECCEA PACs with those of the DFO EBSAs and check for correspondence and similarity of purpose. If there is such agreement reached by two independent analyses—expert judgement for EBSAs (i.e. Delphic) versus quantitative analysis for PACs (e.g. Marxan)—we should have greater confidence in the reasons for the establishment of conservation areas in these regions. The important and potentially synergistic relationships between the much smaller and static PACs, and the much larger, more variable and flexible management options for EBSAs are considered in Chapters 9 and 11.

THE LAST ICE AREA

Projections of climate change indicate the total disappearance of summer sea ice in the Canadian Arctic by the year 2040, with the exception of one area called the Last Ice Area (Figure 3.4). This region covers the whole of the Arctic Archipelago, much of the Arctic Basin, the edge of the Beaufort Sea and a northern part of the Eastern Arctic (Huard and Tremblay, 2013). In due course it may become a refuge for concentrations of Arctic wildlife dependent on the remaining sea ice for survival, including bowhead whales, seals, narwhals, and polar bears.

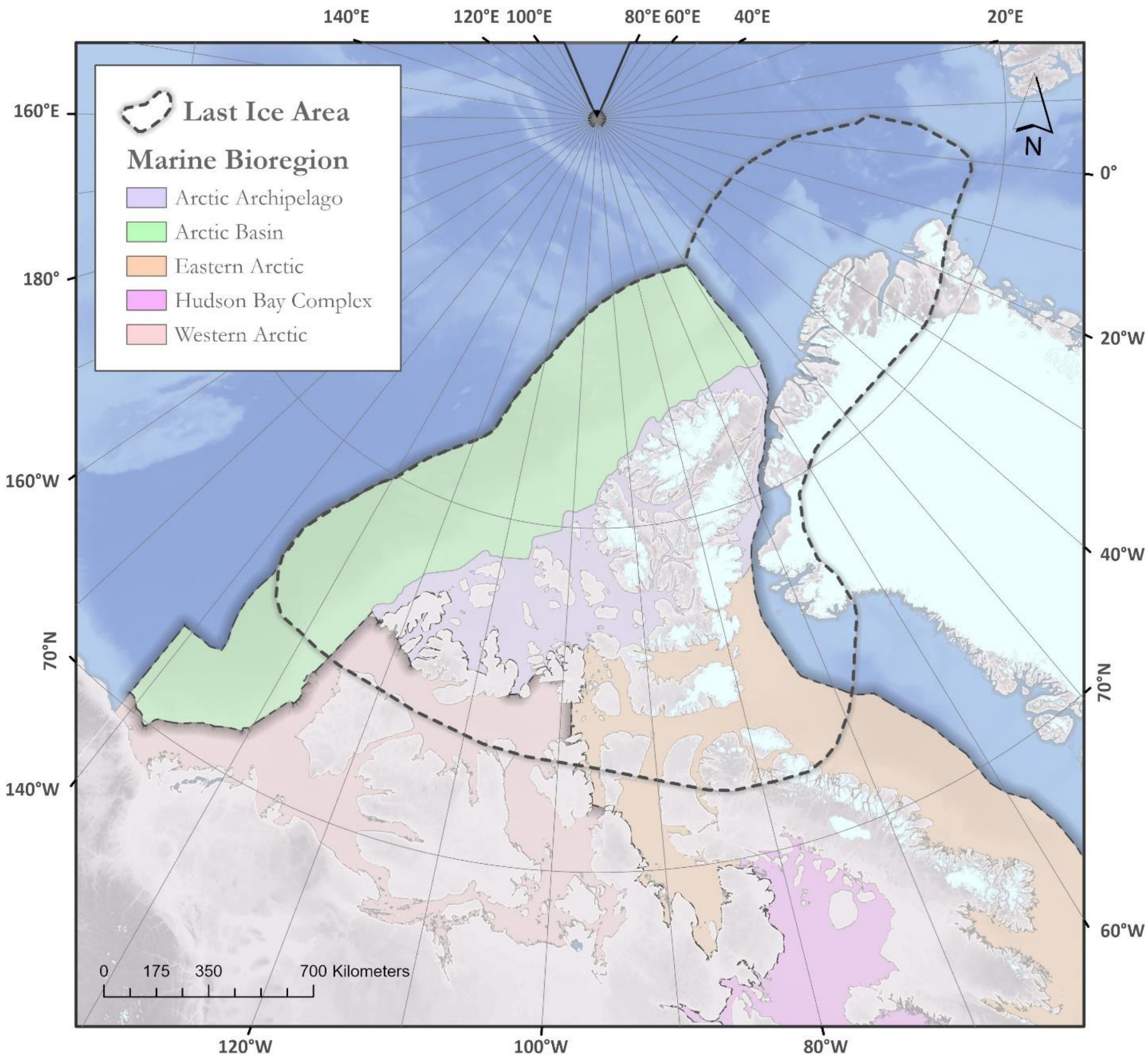

Figure 3.4. Geographic location of the Last Ice Area (LIA), showing its overlap with the Arctic marine bioregions.

However, even this area may be ice-free by the year 2070. Estimates suggest that the rate of loss of both annual and perennial sea ice has been increasing each decade of observation, with most recent estimates as high as 12.8% (±2.3%) loss per decade between 1979 and 2018 (Vaughan et al., 2013; Meredith et al., 2019).

DFO, Parks Canada, and Environment and Climate Change Canada (ECCC) are working with Indigenous, northern and international partners to explore the best ways to collaboratively protect and manage this area and to establish protected areas in this portion of Canada's High Arctic (e.g. the recently established Tuvaijuittuq MPA). The present MECCEA study forms an important adjunct to these national Canadian initiatives.

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CHAPTER 4: REPRESENTATIVE AREAS—GEOMORPHOLOGY, OCEANOGRAPHY, SEASCAPES

INTRODUCTION

The practice of spatially defining representative areas (e.g. Day and Roff, 2000; Roff and Taylor, 2000) has now become an integral part of overall marine bioregionalization schemes (e.g. Table 2.1). It has become a central tenet in marine conservation planning as a means to ensure that a final proposed network of protected areas adequately represents the whole diversity of habitats in a marine bioregion. The essential arguments for mapping representative areas are summarized in Text Box 4.1. In this study, representative areas, as exemplars of every kind of identifiable habitat within a region, will be selected by defined protocols (see Chapter 7) for inclusion in a Marxan analysis (see Chapter 8).

Text Box 4.1. Significance of representative areas in bioregionalization mapping and conservation.

- There is rarely sufficient information on the distributions of marine community types to allow them to be used directly for comprehensive planning in marine conservation.
- Marine biological communities are strongly associated with oceanographic and geophysical characteristics of the marine environment. This association allows these characteristics to be used as descriptors of habitat types, which in turn act as surrogates of the array of community types in both the pelagic and benthic realms.
- Knowledge of the spatial distribution of oceanographic and geophysical characteristics is generally available at spatial scales suitable for conservation planning.

Oceanographic and geophysical characteristics can be combined hierarchically and additively to progressively define marine habitat types that represent the array of biological community types (see e.g. Roff and Taylor, 2000; and Table 2.1).

- We can be confident that the resulting hierarchies and seascapes do indeed capture the array of representative biological communities (but see Roff and Zacharias 2011 for caveats) even though we may not be able to precisely define their species memberships.
- Collectively, representative areas include a greater species diversity than is contained in a set of distinctive areas or the habitats of focal species.
- A major significance of oceanographic and geophysical variables is that they can be used to recalibrate habitat types in regions of a rapidly changing environment and as more data become available. These are critically important attributes for environmental planning and therefore are of major importance in the marine Arctic.

Representative areas can be described by any single geophysical variable or biological community type, or by any combination of geophysical variables or parameters. However, a representative area is not identical to a conservation feature. Thus, temperature ranges can describe representative areas, each inhabited by a set of physiologically adapted species. Temperature itself though is not a conservation feature, i.e. it is not a component of biodiversity that warrants conservation in sui juris.

Conservation features include all individual species (including priority species) and their attributes, and all metrics of community type such as taxonomic richness however defined. In addition, a geophysical structure that acts as a surrogate for a well-defined biological community type (e.g. sea ice cover), can also be considered a conservation feature (see Table 4.1 for examples).

Table 4.1. Variables and parameters considered as conservation features (or not) by MECCEA and their use in seascapes.

Variable/Parameter Used to Describe Representative Areas	Considered by MECCEA as a Conservation Feature?	Used in Seascapes? Epi-pelagic (P) Benthic (B)
Temperature (T)	No	No
Salinity (S)	No	No
T-S combined in water masses	No	P & B
Stratification	No	P
Bathymetry	No	B
Sea Ice Cover†	Yes	P
Bottom current velocity	No	B

†Sea Ice Cover can be considered a conservation feature in its own right because its seasonal distribution and development uniquely define the characteristics of the sympagic community.

Furthermore, geophysical variables in certain combinations can also describe types of well-defined habitats (see e.g. Kostylev et al., 2001; Zacharias and Roff, 2001). These in turn are surrogates for defined community types in both pelagic and benthic realms (Roff and Zacharias, 2011). Such combinations of variables/parameters are called seascapes; they define the various types of representative areas and should also be regarded as conservation features. The actual seascapes of MECCEA are considered later in this chapter.

GEOMORPHOLOGY

One key component of any bioregionalization scheme is the geomorphology of the seafloor (see Table 2.1). The important attributes of the seafloor that influence its biodiversity include topography (as geomorphic features), rugosity, substrate type, and local current speed. For MECCEA, geomorphology was considered as conservation features in four categories: bathymetry, offshore geomorphic features, coastal inlets, and other coastal features.

Bathymetry—a measure of water depth in categories—is universally recognized as a biologically significant determinant of both fish and benthic invertebrate community type (see Chapter 5). Offshore geomorphic features are the landscapes of the underwater world. Coastal inlets comprise the array of bays and estuaries, which we treat together at the scale of this study. The category of other coastal features is an attempt to define regions of the shoreline and immediate coastal regions in terms of their substrates and aquatic properties.

Each of these categories forms an independent layer of representative features for the Marxan analysis (see Table 2.1). Narrow marine passages (channels) are considered separately as distinctive features in the post-Marxan analysis in Chapter 9.

Bathymetry

Bathymetric data for the four Arctic marine bioregions was taken from the International Bathymetric Chart of the Arctic Ocean (IBCAO) version 3.0 (Jakobsson et al., 2012). This is a digital database containing all available bathymetric data north of 64°N. In order to provide coverage for portions of the study area south of 64°N, additional bathymetric data were supplemented from the General Bathymetric Chart of the Oceans (GEBCO, 2014). Data were merged into the depth intervals 0–50, 50–200, 200–1,000 and >1,000 m that correspond to coastal photic zone, continental shelf, continental slope, and abyssal regions, respectively (Text Box 4.2, and Figure 4.1).

Although bathymetry forms a separate conceptual layer in our MECCEA bioregionalization scheme (Level 3, Table 2.1), it is used here only as a descriptor and contributor to the benthic seascape (see later in this chapter). This deferred use is to avoid the "double-counting" of bathymetry in the Marxan analyses.

Text Box 4.2. Geomorphic definitions.

Note that each of these geomorphic features may be associated with either distinctive areas **or** with sets of representative habitats. See Harris et al. (2014).

Bank (Continental shelf) An elevation of the continental shelf seafloor that can be physically recognised and circumscribed, where the water depth is significantly less than the surrounding water. A bank is generally sub-circular, elliptical or cone-shaped, without major indentations. It has rather regular contour spacing and rises to a single sub-marine plateau usually some 20–50 m in depth.

Basin (Continental shelf) A depression of the seafloor on the continental shelf that can be recognised and circumscribed, where the water is significantly deeper than the surrounding water. Generally sub-circular or elliptical in shape, with rather regular bowl-shaped contours descending to a single maximum depth.

Depths

0–50 m	Approximation of the photic zone in coastal waters of the continental shelf.
0–200 m	Depth range of the continental shelf.
200–1,000 m	Depth range of the continental slope.
>1,000 m	Abyssal regions.

Canyon (Gully) Steep-sided, V-shaped valleys with heads at or near the continental shelf edge at around 200 m. They become deeper and generally broader across the continental slope and may have tributaries.

Cliff Landform that rises directly and vertically from the sea to significant height. In the Arctic they are important sites for bird colonies.

Escarpment Elongated generally linear, steep slope in non-shelf areas.

Fan Smooth, fan-like sediment deposits sloping away from the deeper ends of a canyon.

Glacial Trough Formed by glacial scour. Of irregular shape and depth, they are typically U-shaped with relatively steep sides and may be branching. Basins on the shelf may coincide with some part of a glacial trough.

Inlet For MECCEA purposes, estuaries and bays are combined in a single category. **Estuary** A long indentation of the land, where a river with significant land drainage meets the sea and where seawater is significantly diluted with freshwater. **Bay** A concave indentation of the land whose opening to the sea is narrower than its width. Flanked by headlands whose inter-tidal region is comprised of mobile substrates such as sand or silt.

Intertidal Zone Marine coastal region lying between extreme high water and extreme low water levels.

Plateau Flat, or nearly flat area of considerable extent, dropping off abruptly on one or more sides.

Rise A smooth sloping seabed that abuts continental margins, with evenly spaced depth contours.

Ridge A short mountain range rising from the ocean seafloor that does not reach the water's surface and thus is not an island or seamount. They are independent features that rise to at least 1,000 m above the seafloor and are characteristically elongated.

Shelf Valley A valley incised into the continental shelf, >10 km in length and >10 m in depth.

Sill A sea floor barrier of relatively shallow depth, that restricts water movements between basins.

Terrace Isolated, relatively flat, or gently inclined area bounded by a steeper ascending slope on one side and steeper descending slope on the opposite side.

Wetland Refers to any land that is permanently or temporarily submerged in or permeated with water; includes freshwater and saltwater marshes in coastal regions.

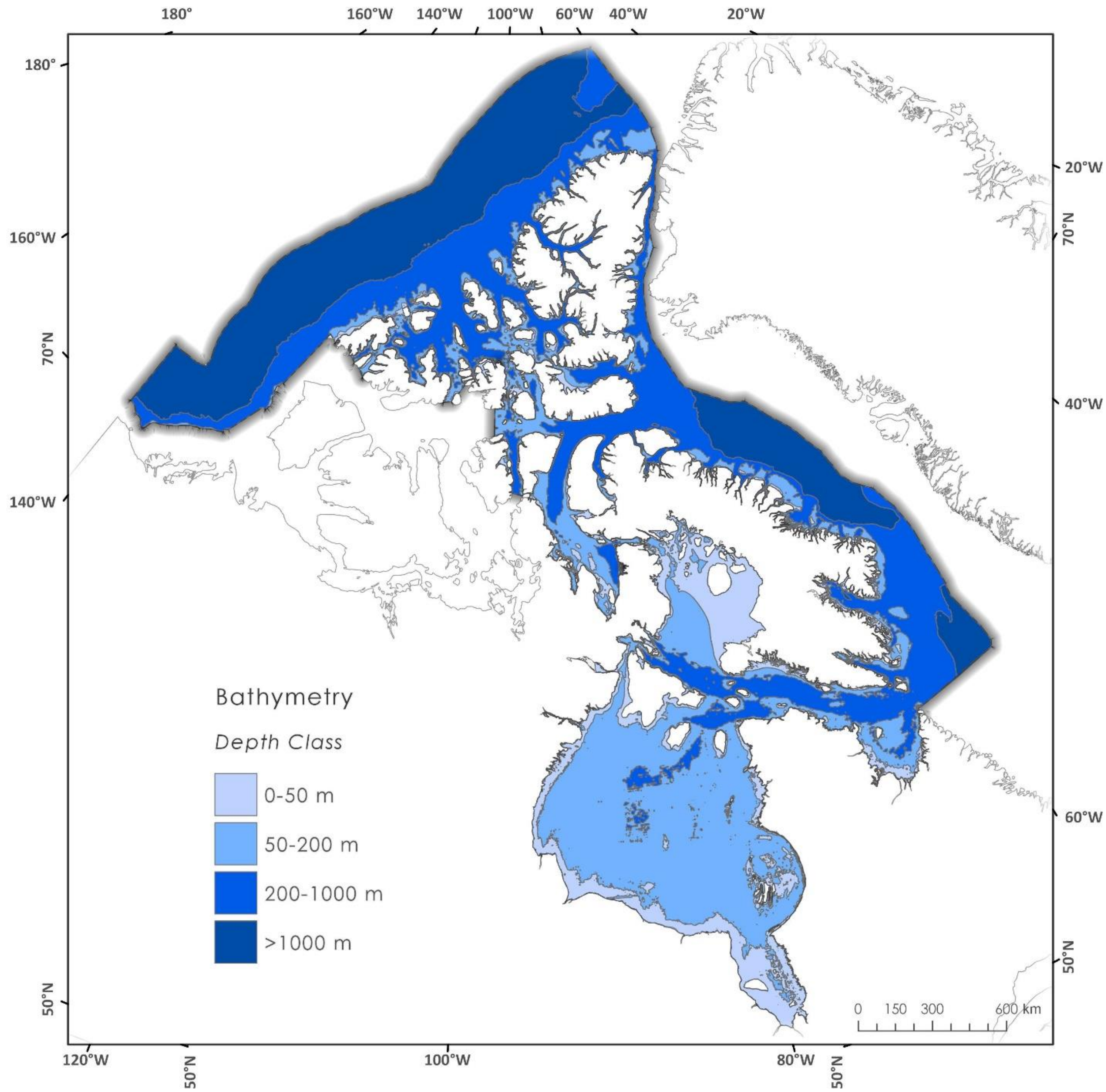

Figure 4.1. Bathymetric depth intervals mapped for the four MECCEA bioregions.

Offshore Geomorphic Features

The offshore geomorphic features comprise a category of topographic characteristics that form an independent level of our classification framework (Level 4, Table 2.1). Each of these geomorphic features (Figure 4.2) contains different sets of habitat types. For example, banks have areas of gravel, coarse sand and silt substrates, each representing a separate habitat to different types of marine benthic communities (see e.g. Kostylev et al., 2001). Geomorphic features therefore represent a level above that of the primary biotopes in the ecological hierarchy.

In order to represent geomorphic features, a modified version of the Blue Habitats dataset of the global seafloor geomorphic features map (Harris et al., 2014) was produced for the four MECCEA marine bioregions. The only additional class of geomorphic feature that was used was for underwater banks, which were manually digitized from bathymetric contours.

To create a single spatial data layer of geomorphic features for the Arctic seafloor, ten features were selected from the Blue Habitats dataset, which required some modification. The goal was two-fold: first, to modify the boundaries of each geomorphic feature class so as to produce a non-overlapping map of all features (i.e. the features were spatially mutually exclusive) and second, to combine the classes to form a single comprehensively exhaustive layer for the four marine bioregions.

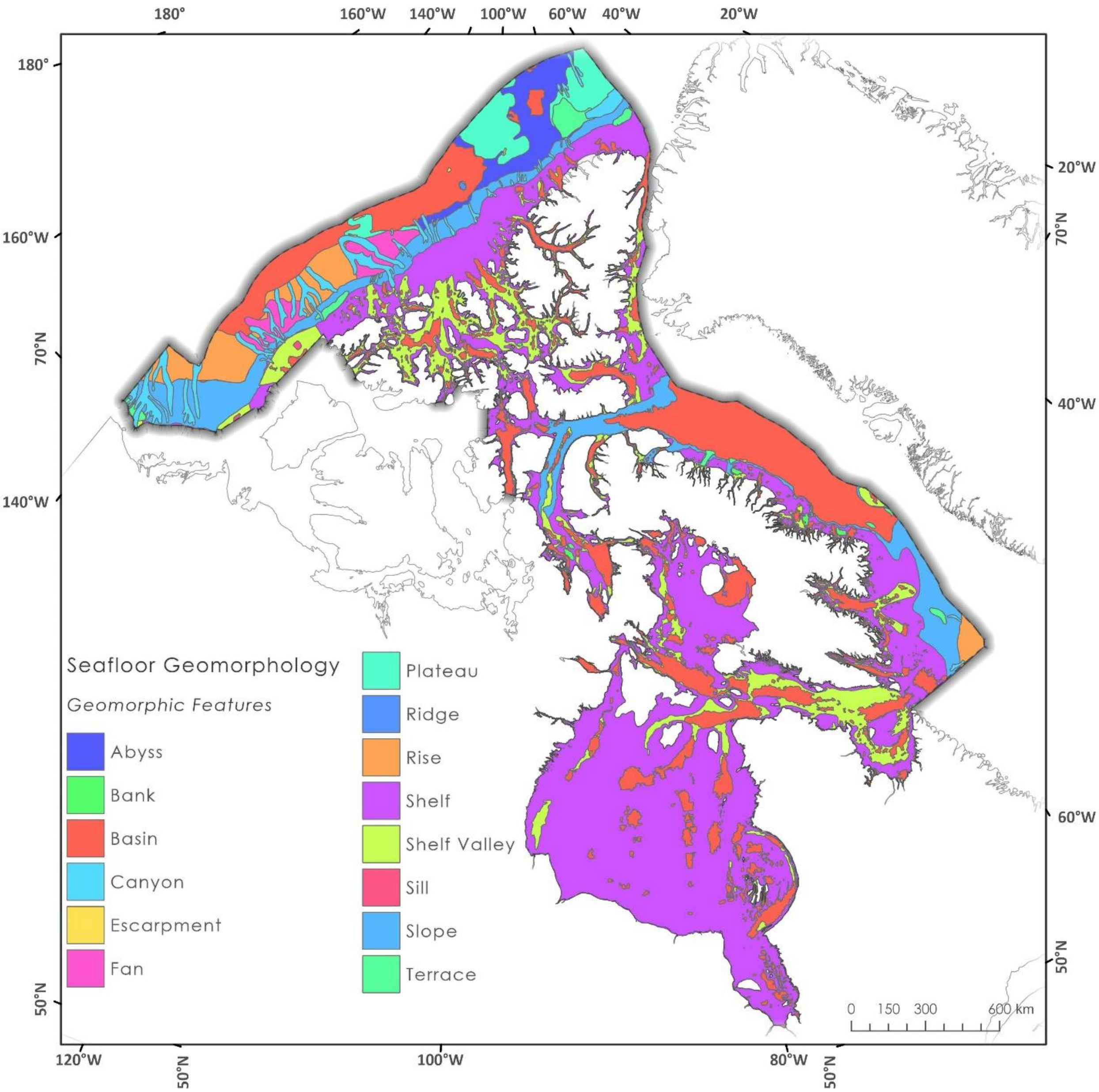

Figure 4.2. Offshore geomorphic features mapped for the four MECCEA bioregions. Definitions of these features are given in Text Box 4.1. The sequence of overlapping features established is described in the text and in Table 4.2.

To achieve this, a sequence was established (Table 4.2) that gave priority, in terms of spatial coverage, to those geomorphic classes representing more discrete features (e.g. canyons) relative to those representing broader features (e.g. basins). Further ordering was based on ecological importance in terms of perceived rugosity. This gave precedence to features of greater topographic complexity, which should in turn indicate features of more diverse habitat assemblages.

Table 4.2. Off-shore geomorphic features recognized and mapped from Harris et al. (2014). For definitions of each of these features see that publication and Text Box 4.1 herein. This sequence is derived from the way in which Blue Habitats data are mapped and the need to establish a non-overlapping map of the features.

Sequence Level	Geomorphic Feature Classes
1	Sills
2	Ridges
3	Escarpments
4	Canyons
5	Terraces
6	Fans
7	Rises & plateaus
8	Basins
9	Banks
10	Shelf valleys
11	Shelf, slope, abyssal

A further feature—glacial troughs—was subsequently removed because of significant overlap with basin features and because of uncertainty of their age and hence biological significance. Note, however, that ice scours represent an important feature of disturbance and recolonization in the Canadian Arctic (Conlan and Kvitek, 2005).

Coastal Inlets

Coastal inlets can be categorized into bays and estuaries. Bays are of various sub-circular shapes, often retaining almost full-strength salinity for most of their area. Estuaries are generally more elongate, and salinity is progressively diluted towards a freshwater source. Coastal bays and estuaries have very different geomorphological, geological, oceanographic and ecological features (Greenlaw et al., 2011).

Coastal inlets were recognized, manually digitized and mapped from the Open Street Map coastline shapefiles (OpenStreetMap, 2016). It was not possible to reliably distinguish between bays and estuaries since morphological features overlapped. A total of some 3,000 inlets ranging in area from less than 1 km^2 to over 1,200 km^2 was recognized (Figure 4.3).

Inlets were then classified into four classes based on combinations of size and complexity of shape. Complexity was recognized as the difference between inlets of simple shape (first order with no associated secondary inlets), versus those with associated inner secondary inlets (second order). This resulted in a classification of inlets as:

- Class 1: First order inlets <32 km^2. The threshold of 32 km^2 was selected to approximate the 40 km^2 size threshold identified by O'Connor (2001) below which bays contain more species of pelagic fish per unit of area relative to larger bays.
- Class 2: First and second order inlets between 32-121 km^2.
- Class 3: First and second order inlets between 121-1,200 km^2.
- Class 4: First and second order inlets >1,200 km^2 (1.5 SD away from the mean inlet size for the whole study area). This class comprises the largest inlets such as Frobisher Bay and Cumberland Sound.

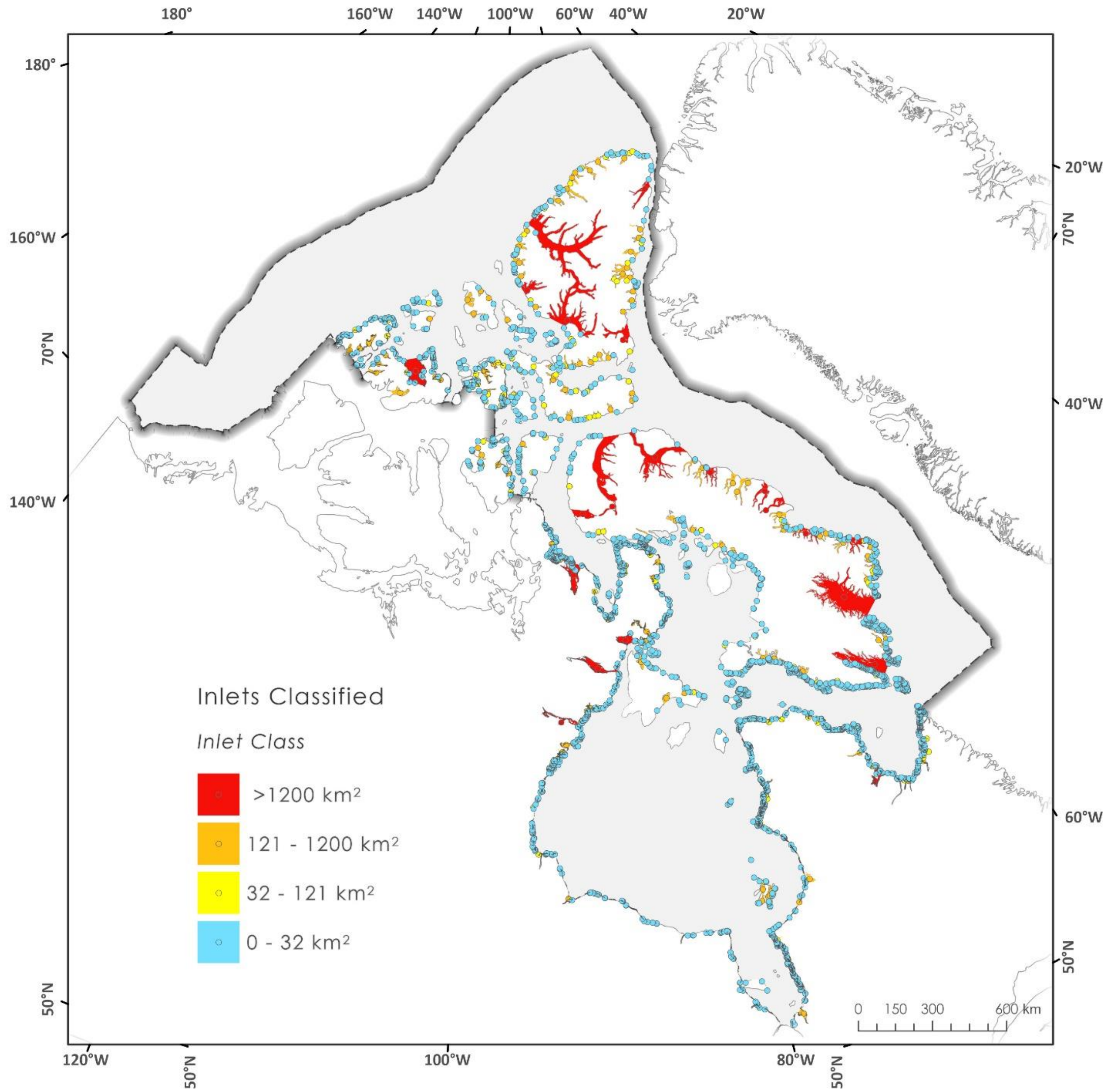

Figure 4.3. Distribution and classification of four size classes of coastal Inlets. Note that, at this scale, inlets do not distinguish between estuaries and bays.

The first three categories can be considered as classes of representative areas, while the fourth class can be thought of as potentially distinctive areas.

Other Coastal Features

The characteristics of the coastline have long been recognized as major determinants of the type of local biological community. At the extremes, on exposed rocky shores a characteristic epifauna and epiflora of macrophytic algae and invertebrates develops, whereas on sheltered muddy shores burrowing infauna and surficial microphytic algae predominate (Bertnes et al., 2001). Over wide geographic regions, a strong statistical relationship exists between shoreline community richness and geophysical features (Zacharias and Roff, 2001).

In order to capture this variation in coastal habitat, a classification scheme was developed for the MECCEA study region. This classification made use of Natural Resources Canada's (NRCan) authoritative data product CanVec (NRCan, 2017), which contains a detailed spatial representation of geographic features throughout Canada. Using this data product, coastal regions were classified into intertidal zones (sandy and other non-sandy), and coastal wetlands (Figures 4.4 and 4.5, respectively). Additionally, a spatial representation of sea-side cliffs was derived from NRCan's digital elevation model data product known as CDEM (Government of Canada, 2015). Using the elevation information available for coastal regions, areas of high slope (>45 degrees) were extracted as areas of potential cliff habitat (Figure 4.6). Once complete, all components of the coastal representation were clipped to an inland extent of approximately 20 km on shore to account for sea-land connections of key Arctic marine species and habitats.

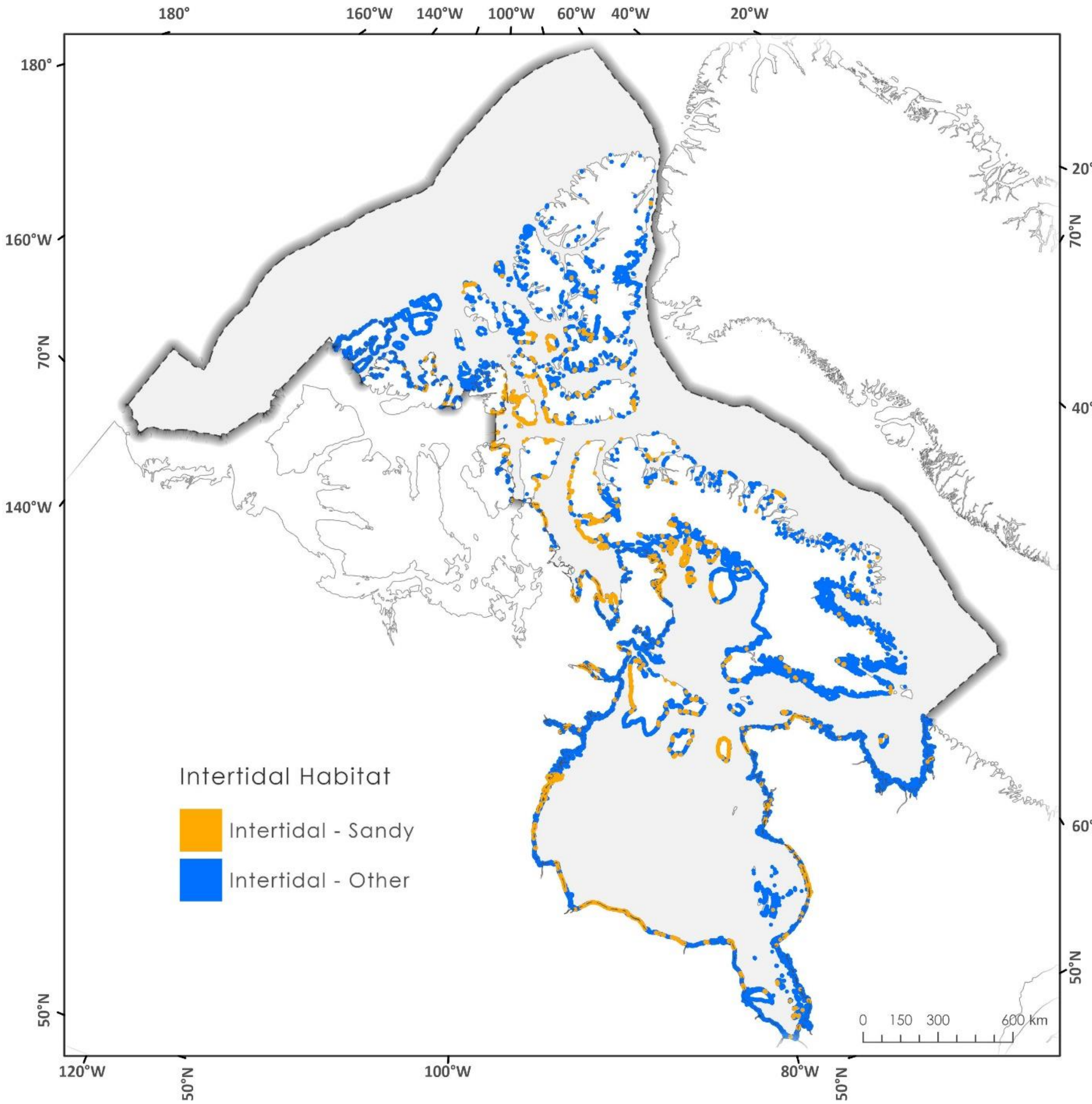

Figure 4.4. Distribution of sandy intertidal zones and other intertidal zones in the four MECCEA bioregions.

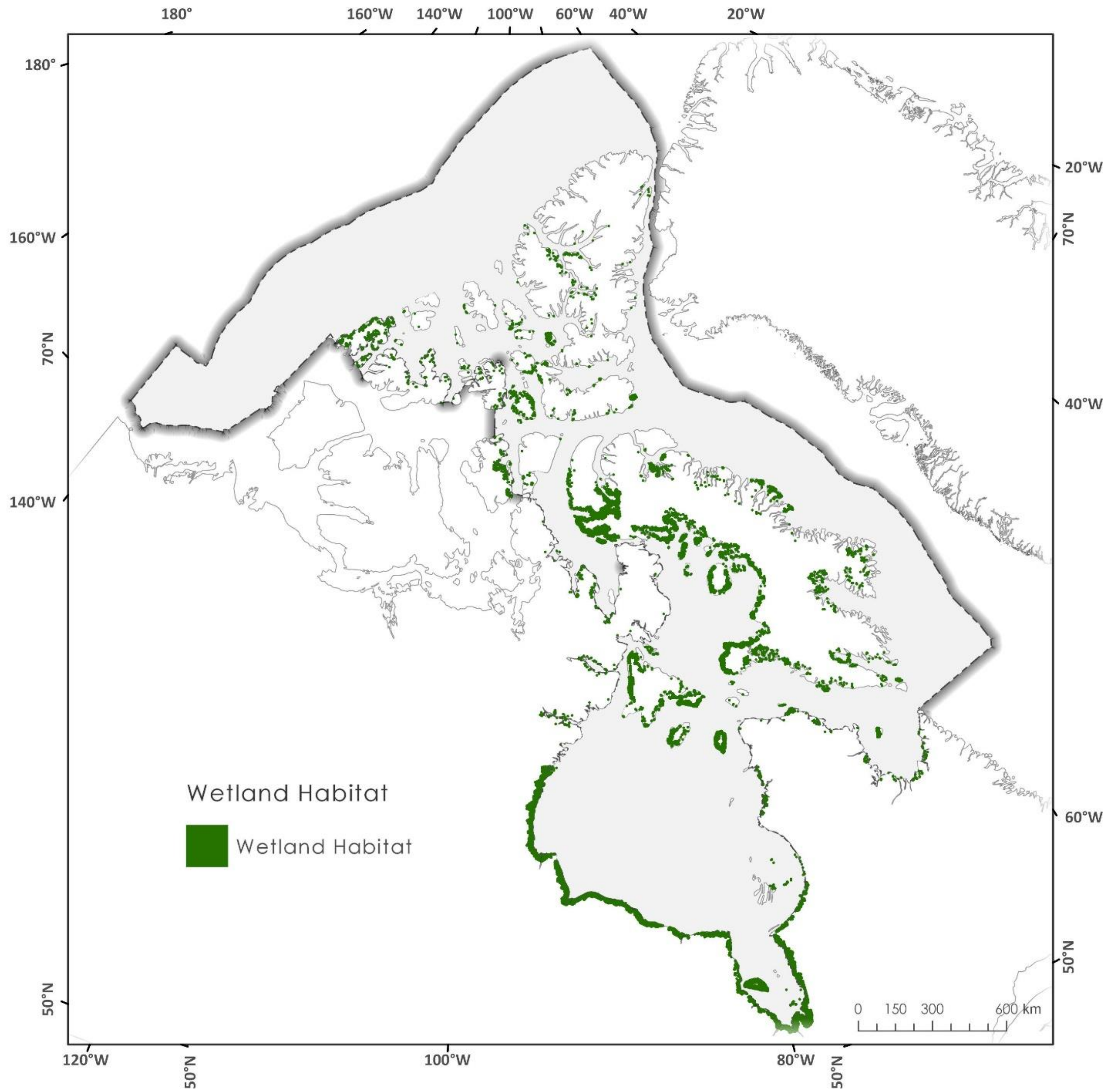

Figure 4.5. Distribution of coastal wetlands in the four MECCEA bioregions.

Substrate Types

There have been several studies on Arctic marine sediments, including several within our study marine bioregions (e.g. Maclean, 2001), but only on a local scale. More comprehensive recent work such as that by Stein (2008) still does not permit any kind of regional mapping of sediment types. The general impression of the Canadian Arctic is that sediments deeper than 200 m are typically dominated by mud, that banks may contain significant deposits of glacial tills, and that areas shallower than 30m are annually heavily disturbed (Ned King, Geological Survey of Canada, personal communication).

However, despite the significance of substrate type for characterization of benthic communities, there is insufficient information to proceed with any useful mapping for our conservation purposes. Canada's Arctic Marine Atlas (2018) says it nicely, "Even preliminary seabed surveys are lacking over wide areas of the Canadian marine Arctic. … Marine ecology is …. influenced strongly by seabed sediments, but information on Arctic sediments is very sparse."

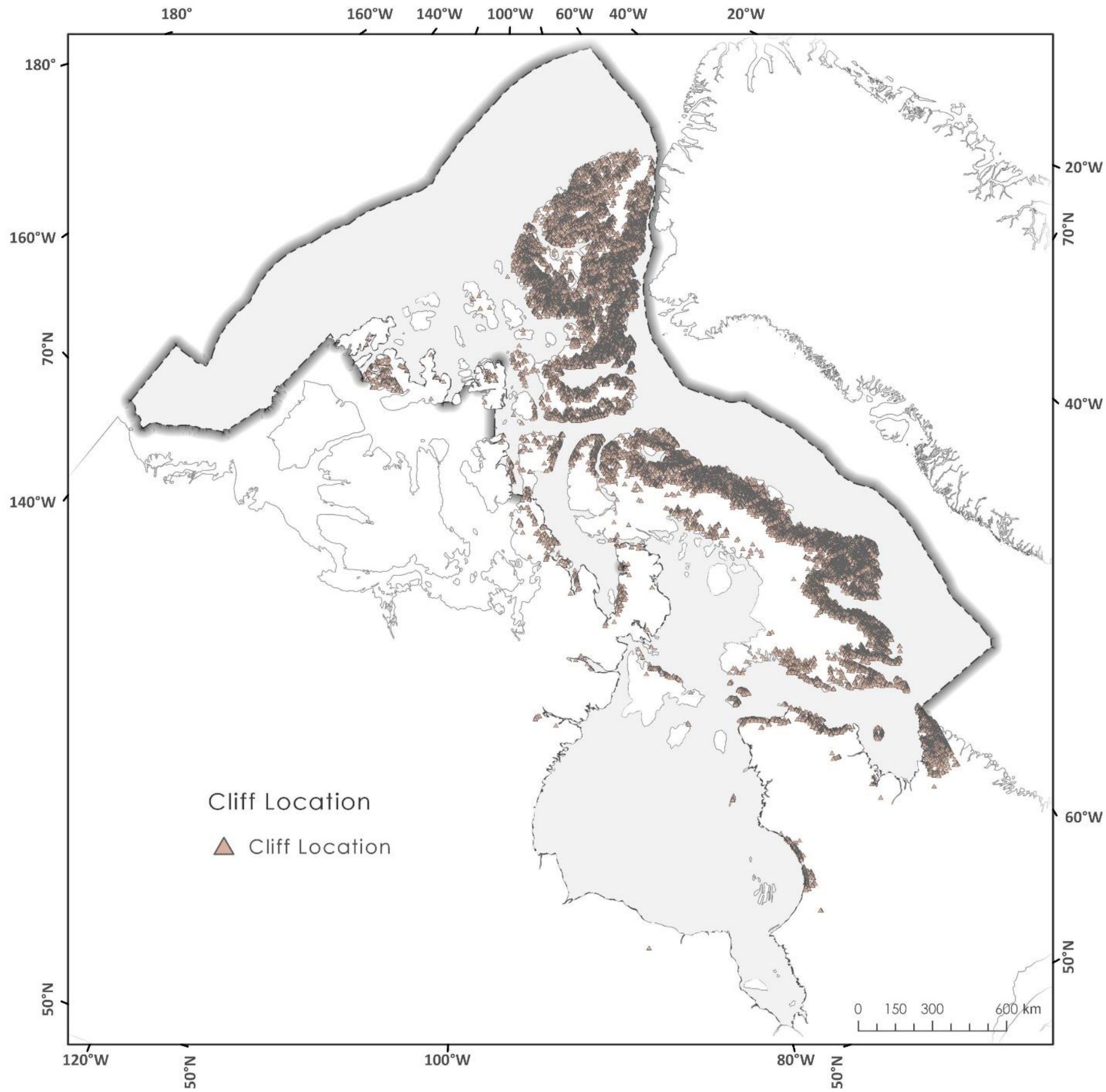

Figure 4.6. Distribution of cliffs in the four MECCEA bioregions.

Rugosity

Rugosity is a measure of spatial complexity that describes vertical changes as a function of horizontal distance from a reference source. It, therefore, represents the undulations of the sea floor. Consequently, rugosity is a measure of the array of small-scale habitat types and a surrogate for the number of different local habitat types for sessile benthic organisms, and/or shelter for mobile organisms (Roff and Zacharias, 2011). Areas of higher rugosity are expected to harbour a higher diversity of organisms. Such an association between benthic rugosity and species diversity has, in fact, long been documented (see e.g. Risk, 1972).

The effects of rugosity on species diversity are most significant at scales of centimeters to meters. Unfortunately, calculations of rugosity for the MECCEA marine bioregions could only be done at the resolution of the available bathymetric data—approximately 500 m. At this scale, any depiction of rugosity merges with the scale of geomorphic features themselves. Therefore, rugosity was not a feature in our representative areas investigation.

OCEANOGRAPHIC DATA

Sea Ice Cover

Our aim was to characterize sea ice extent/concentration using satellite imagery in the following categories: permanent cover (i.e. multi-year ice), inter-annually variable ice cover, seasonally open every year, open all year. The data for this analysis were obtained from the Canadian Ice Service (CIS) 30-year Climatic Ice Atlases, for the period 1981–2010. The Atlas provides several data sets for all Canadian waters (see Government of Canada 2010, Table 4.3).

Table 4.3. Data sets available from the Canadian Ice Service (CIS) 30-year Climatic Ice Atlases (Environment and Climate Change Canada, 2017). Data are made available once a month in the winter and bi-weekly during melt season, or on a weekly basis depending on the dataset. Data for MECCEA were from the period 1981–2010.

Ice Dataset	Description
Median Ice Concentration (10^{ths})	Statistical "normal" ice concentration for the given date in 6 categories: less than 1/10, 1-3/10, 4-6/10, 7-8/10, 9-9+/10, and 10/10.
Median Old Ice Concentration (10^{ths})	Statistical "normal" old ice concentration for the given date in 6 categories: less than 1/10, 1-3/10, 4-6/10, 7-8/10, 9-9+/10, and 10/10.
Frequency of Sea Ice Presence (%)	Percentage of time sea ice is present at concentration of 1-10/10 in 8 categories: 0, 1-15, 16-33, 24-50, 51-66, 67-84, 85-99, and 100%.
Frequency of Old Ice Presence (%)	Percentage of time old ice is present at concentration of 1-10/10 in 8 categories: 0, 1-15, 16-33, 24-50, 51-66, 67-84, 85-99, and 100%.
Frequency of >4/10 Old Ice Presence (%)	Percentage of time old ice is present in concentrations of >4/10 in 8 categories: 0, 1-15, 16-33, 24-50, 51-66, 67-84, 85-99, and 100%.
Median Ice Concentration (10^{ths}, when ice is present)	Statistical "normal" ice concentration on the given date when ice is present in 6 categories: less than 1/10, 1-3/10, 4-6/10, 7-8/10, 9-9+/10 and 10/10. Like Median ice concentration but not considering ice-free periods. Interpreted with *Frequency of sea ice presence* (%) reports that at point A at time T there is an X% chance there will be ice and, when there is, it is usually of concentration Y.
Median Predominant Ice Type (when ice is present)	Statistical "normal" ice type on the given date when ice is present in 8 categories: open/bergy ice, new ice, grey ice, grey-white ice, thin first year ice, medium first year ice, thick first year ice and old ice. Interpreted with *Frequency of sea ice presence* (%) reports that at point A at time T there is an X% chance there will be ice and, when there is, it ss usually type Y.
Dates of Freeze-up and Break-up	Extent of ice on a bi-weekly basis during the freeze-up and break-up periods.

The sea ice categories were extracted from several CIS data products. The *Median Ice Concentration* dataset was used to identify permanent ice areas, seasonally open areas, and permanently open areas. A combination of the *Frequency of Sea Ice Presence* and *Median Ice Concentration when ice is present* datasets were used for the category of inter-annually variable ice cover.

Permanent ice cover was identified where weekly median ice concentrations remained above 9/10ths throughout the year (where 0/10ths is 0% and 10/10ths is 100% ice cover). Similarly, permanently open areas were identified where weekly median ice concentrations remained below 3/10ths throughout the year. Seasonally open areas were identified anywhere ice cover fell between these two extremes. Areas where the frequency of ice presence fell around 50% (34-66%) were identified as having high inter-annual variability between being permanently ice covered or seasonally open (see Figure 4.7). However, subsequently for the seascapes (see below), only three categories of ice cover were included: permanently open (where ice cover never went above 3/10ths); permanent ice (where ice cover never went below 9/10ths); and seasonally open—everywhere else. Further information on sea ice analysis is available from WWF-Canada on request.

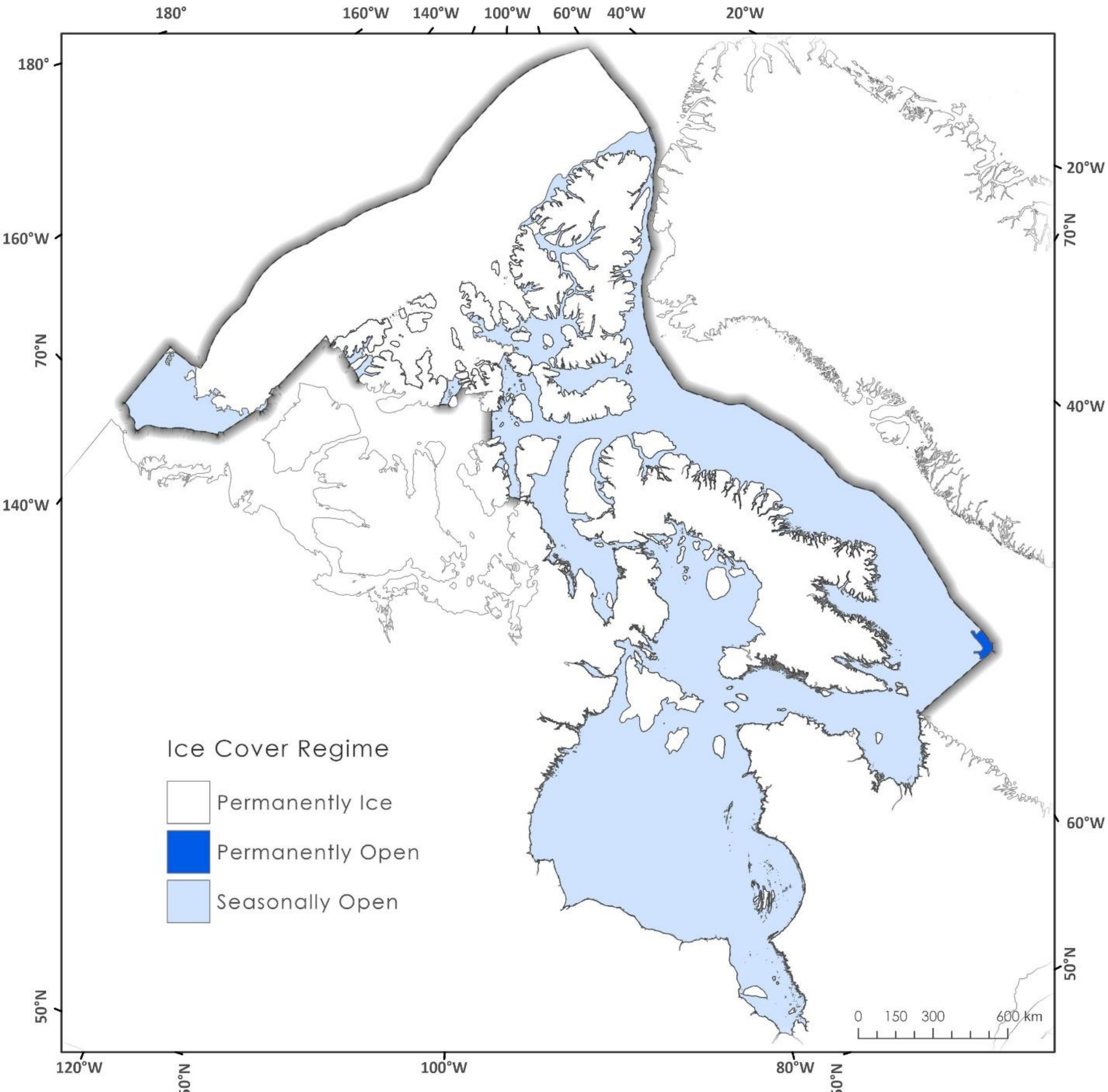

Figure 4.7. Frequency and concentration of seasonal ice cover in the four MECCEA bioregions (and including the Beaufort Sea). Ice cover further north into the Arctic Basin is not shown, but is taken as consisting of permanent ice (see Figure 4.8).

Polynyas and Shore Ice Leads

Polynyas and shore ice leads are considered under distinctive areas in Chapter 6.

Temperature and Salinity

Original conductivity, temperature, depth (CTD) data were obtained from the World Ocean Database (WOD13) (NOAA, 2013). This database includes CTD records contributed by 49 institutions and organizations from Canada and other countries. Records were filtered to include only the four MECCEA marine bioregions and depth, density, temperature and salinity. The final record numbers for each marine bioregion ranged from ~1,000 to ~13,000 for a total of some 25,000 records for all four marine bioregions combined.

The CTD data were examined to establish maximum surface and maximum bottom temperatures, and minimum surface salinity and maximum bottom salinity for each marine bioregion (see Table 3.1). Temperature and salinity profile data were then used to define epi-pelagic and benthic water masses, and to calculate the distribution of the stratification index $\Delta\sigma_t/\Delta d$ (see below).

Unsurprisingly, maximum surface temperature, which was derived from satellite imagery (see Figure 4.8) is reached in southern Hudson Bay and James Bay. Maximum bottom temperature is found in the southern extreme of the Eastern Arctic, where the highest bottom salinities are also located, reflecting the characteristic bottom waters from the Atlantic. Maximum surface temperature and minimum surface salinities (Figures 4.8 and Figure 4.9, respectively) are also found in Hudson Bay reflecting the extreme freshwater runoff from its enormous watershed.

Temperature and salinity are both significant factors that determine the distributions of marine organisms; however, as individual variables they are not conservation features. Rather, in combination with depth, they are used to construct seascapes (see below).

Water Masses

There are several reasons why the identification of water masses is ecologically significant. They are related to physiological tolerances of organisms and to the distribution of fish communities (Roff and Zacharias, 2011; Kees Zwanenburg, unpublished data and personal communication). They can also indicate the origins of planktonic and meroplanktonic organisms, thus aiding in the tracking of organism dispersal.

Water masses in the Arctic are highly complex. Freezing in winter results in local increases in salinity, while melting ice and freshwater runoff in the summer months significantly reduce salinity. These transformations mean that water masses, as characterized by T-S combinations, are not nearly as discrete as at lower latitudes (e.g. Colin and Dunbar, 1964).

In the Canadian Arctic, water masses are well-defined at depths greater than 1,000 m, but on the slope and shelf they become progressively mixed, and their origins become obscured. More sophisticated techniques than temperature and salinity alone are thus required to trace water masses here. A fuller analysis of Arctic water masses, their origins and movements lies beyond the scope of the MECCEA study. However, water movements as a component of connectivity are considered in Chapter 9.

In order to include water mass variations as a contributor to seascapes, we separated combinations of temperature and salinity into ecologically and environmentally reasonable divisions. Epi-pelagic water masses were calculated for the depth interval from surface to 30 m, and benthic water masses were calculated from records closest to the bottom. For both epi-pelagic and benthic water masses, temperature was divided into three intervals: <0°C, 0 to +2°C, and >+2°C. For benthic water masses, salinity was divided into: >34.7 (indicating water of Atlantic origin), 34.7–31.8, and <31.8 PSU (Practical Salinity Units), resulting in three sub-equal classes. For the epi-pelagic realm, there were no records >34.7 PSU, one class from 31.8–34.7 was recognized, and two classes <31.8 were equally divided.

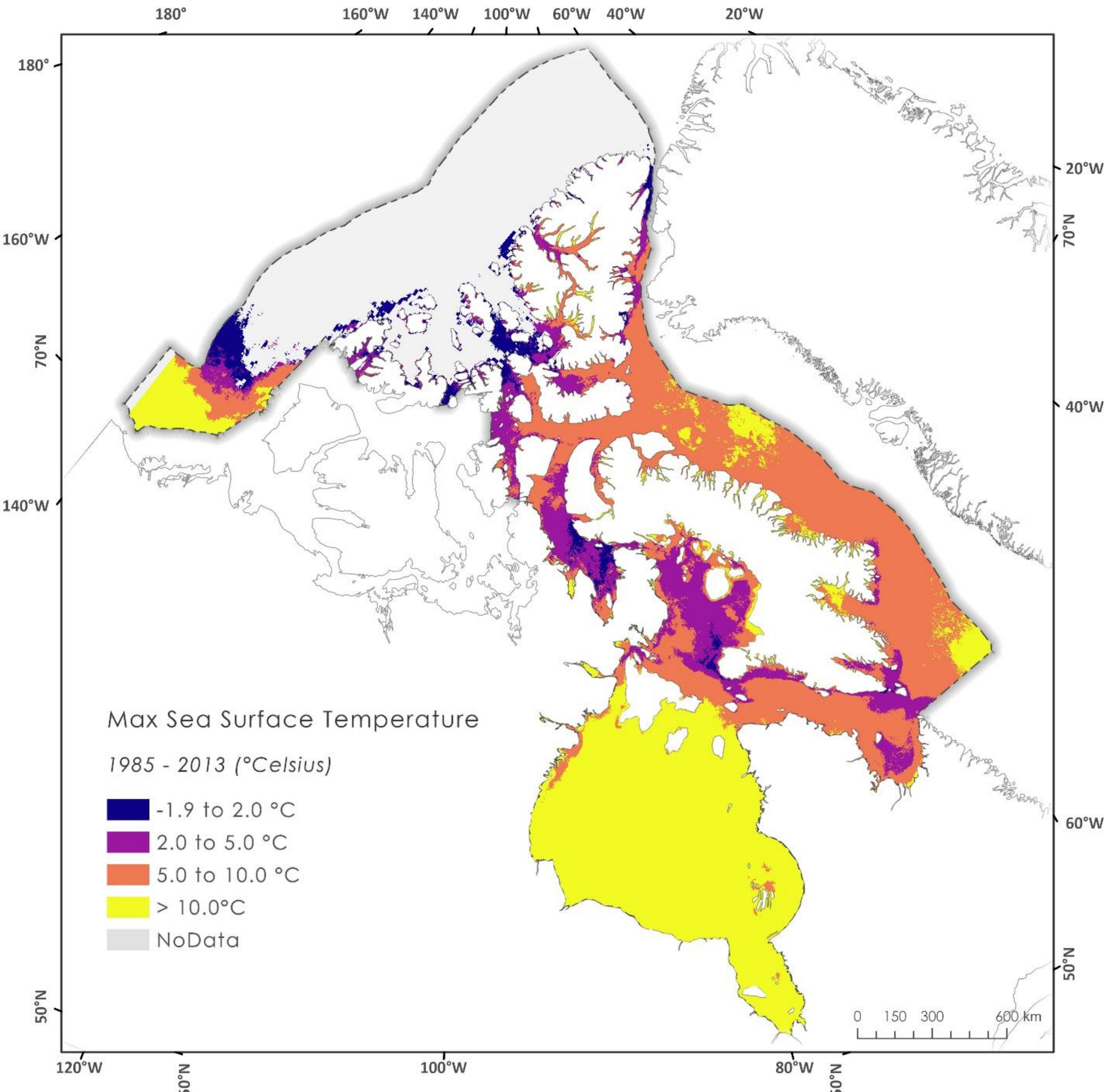

Figure 4.8. Satellite derived maximum sea surface temperature ranges from observations taken in the four MECCEA bioregions (Fisheries and Oceans Canada database, published on St. Lawrence Global Observatory's- SLGO portal. [https://slgo.ca]. Accessed (2017-11-14]).

The resulting water mass T-S combinations for pelagic and benthic realms (Figure 4.10 and Figure 4.11, respectively), thus each have nine combinations of variables in a 3x3 matrix. These two water mass distributions were used in combination with other variables to produce descriptive seascapes which are described in more detail below.

Stratification $\Delta\sigma_t / \Delta d$

Stratification occurs when a water column develops a less dense upper layer during thermal seasonal heating, following the input of surficial freshwater, or due to a combination of both effects. Stratification due to seasonal heating typically dominates at mid-latitudes, but the addition of freshwater becomes significant in coastal waters and at high latitudes with ice cover. Regional patterns of stratification lead to dramatic changes in phytoplankton community composition and control of the seasonal cycle of primary production (see Tett and Wallis, 1978; Tett et al., 1986; Pingree, 1978).

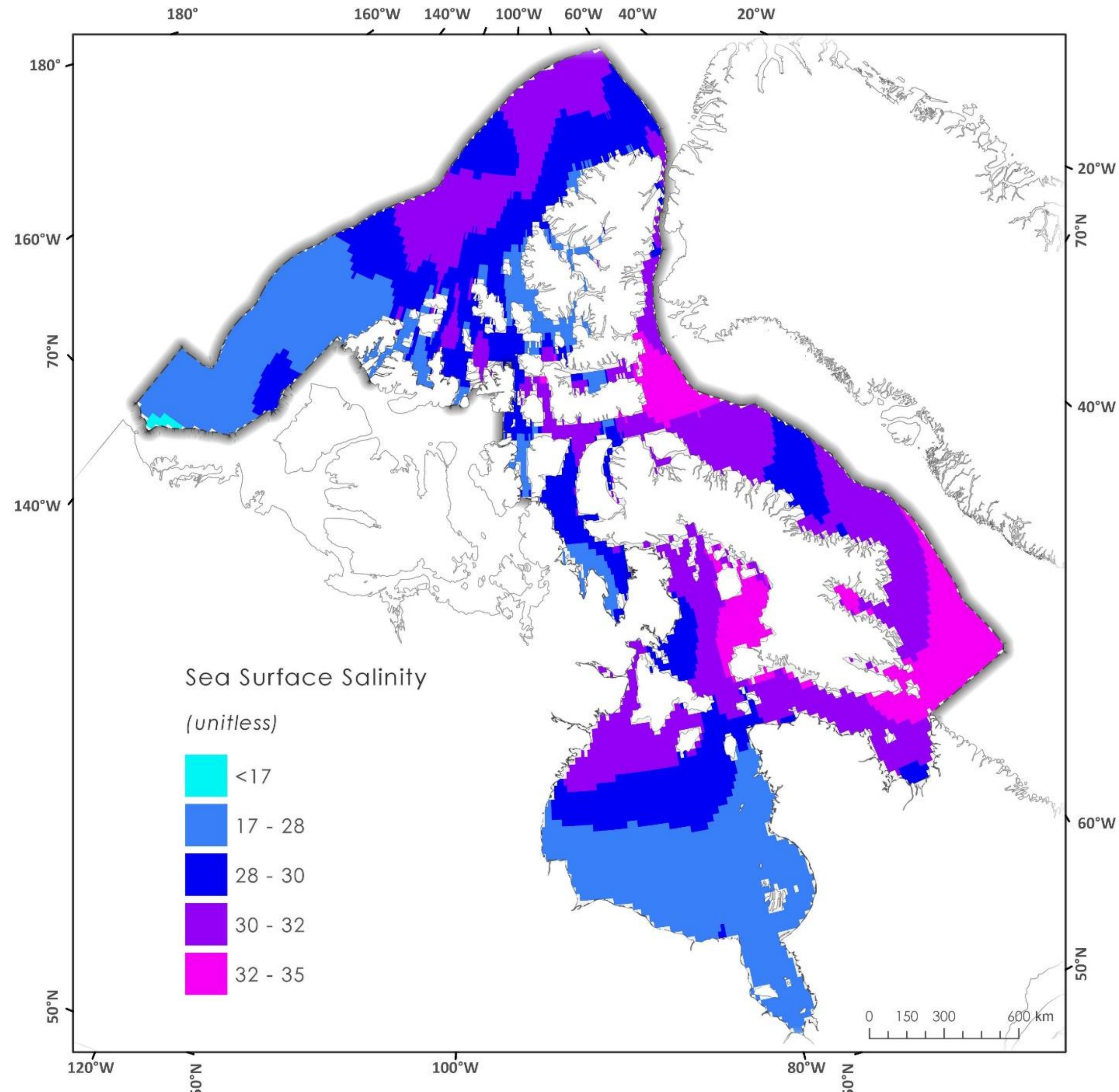

Figure 4.9. Minimum surface salinity ranges from observations taken in the four MECCEA bioregions.

Where changes in salinity can be ignored, seasonal stratification is well described by the stratification parameter (H/U^3; where H is water depth and U is tidal velocity). However, where surface salinity reduction is important, as in Arctic waters, it is more appropriate to use the actual change in density ($\Delta\sigma_t$) with change in depth (Δd) to reflect the combined effects of both temperature and salinity. Values of σ_t during the ice-free period were calculated following formulations in Fofonoff and Millard (1983) using an automated version of the Seawater Density Calculator (Tomczak, 2000). The change in density over the upper 30 m of the upper water column was then calculated as ($\Delta\sigma_t/\Delta d$)x100 (the increase by a factor of 100 is simply to move decimal places).

In the Canadian Arctic, the upper pycnocline develops at depths of 15 to 50 m (Anderson and Roff, 1980). A depth of 30 m was chosen as an approximate average across all marine bioregions. Calculated values of stratification were then separated into three equal quantiles to distinguish between: strongly stratified, moderately stratified and weakly stratified regions (see Figure 4.12). These regions should approximately correspond to differences in the type of annual planktonic nutrient and primary productivity regimes. Although 3 categories were used here for simplicity, note that Tett et al. (1986) separated stratification and production regimes in the North Sea into five rather than three categories.

The choice of 30 m as the reference pycnocline may introduce error at either end of the range of stratification calculation. A pycnocline depth of less than 30 m is more common in areas of high freshwater runoff, and a value closer to 50 m is more common where freshwater additions are much less. However, a more detailed comparison of stratification for 30 and 50 m depths shows they are quite similar (Figure 4.13).

Bottom Current Speed

The data to represent near seafloor currents came from two primary sources. First, residual ocean currents were obtained from the Arctic Monitoring and Forecasting Centre's V4 nominal system model AMFC (Xie et al., 2017). From this model, maximum zonal (u) and meridional (v) vectors were obtained and combined to represent the average residual bottom currents based on all data for the period of 1992-2017.

However, the AMFC model does not consider tidal currents—which are a dominant factor in the current regime of shallow areas. Data on tidal current speed were obtained from the WebTide v0.7.1 application for the Artic domain (Dunphy et al., 2005). Data from this model are represented as 5 separate tidal components (K1, M2, N2, O1, and S2), which were combined to represent the maximum possible tidal current occurring over the water column when all elements align.

Once velocity data were obtained for both residual and tidal currents, these elements were combined via vector addition (i.e. $\sqrt{((residual^{UV})^2+(tidal^{UV})^2)}$) to obtain a representation of bottom current speed (m/s) across the Canadian Arctic. Because precise validation of such model output is a challenge, values were reclassified into 3 quantiles to represent regions with relatively high, medium, and low bottom currents (Figure 4.14). The significance of bottom current speed as a determinant of benthic community type has been reviewed by Wildish and Kristmanson (1997).

SEASCAPES

The term "seascape" is now in common usage in marine conservation. For example, this approach has been used previously to define seascapes for New England and Maritime Canada (CLF - WWF, 2006). Seascapes can be considered as the marine equivalent of terrestrial landscapes, an ecological and environmental unit intermediate between ecosystem and habitat (see e.g. Zacharias and Roff, 2000). Here, the term seascape refers to the replicates of different geophysically-defined, high-level primary biotopes, or habitat types, which act as surrogates for different communities of marine organisms.

Examples from all over the world have repeatedly shown very strong relationships between community type (as species composition) and geophysical variables of the habitat. A moment's reflection will remind us that all textbooks on marine ecology are predicated on this principle. The factors: water depth, water masses (or individually temperature and salinity), stratification, substrate type, and current speed are repeatedly exhibited as correlates of community type (see examples in Roff and Zacharias, 2011).

The general philosophy in trying to define representative areas is to use variables that: (i) are available for the whole study area; (ii) best act as descriptors of habitat types and will differentiate among them; and (iii) vary significantly in space and time. Seascapes are important for the MECCEA study for two main reasons. In addition to geomorphic features, they are the only way we have to describe habitat types at a level below that of marine bioregions. Also, they make efficient use of available geophysical and oceanographic data that would otherwise not be used.

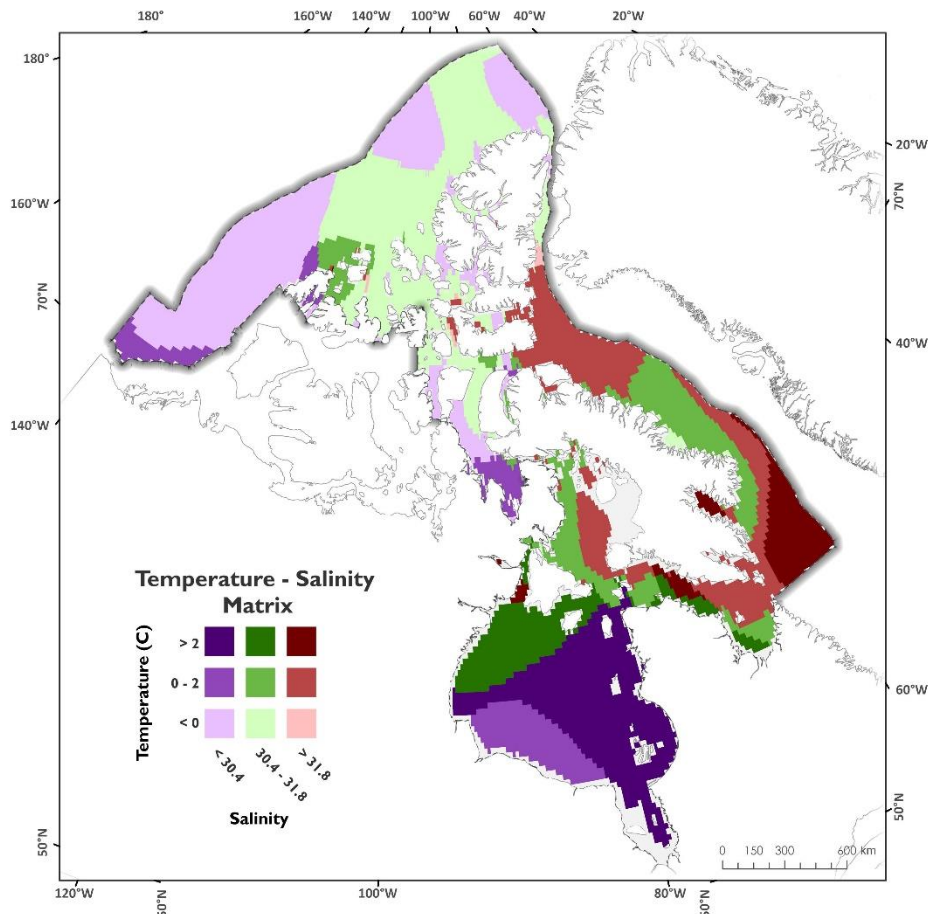

Figure 4.10. Epi-pelagic water masses as temperature-salinity classes, in nine combinations of values from observations taken between 0 and 30 m depth.

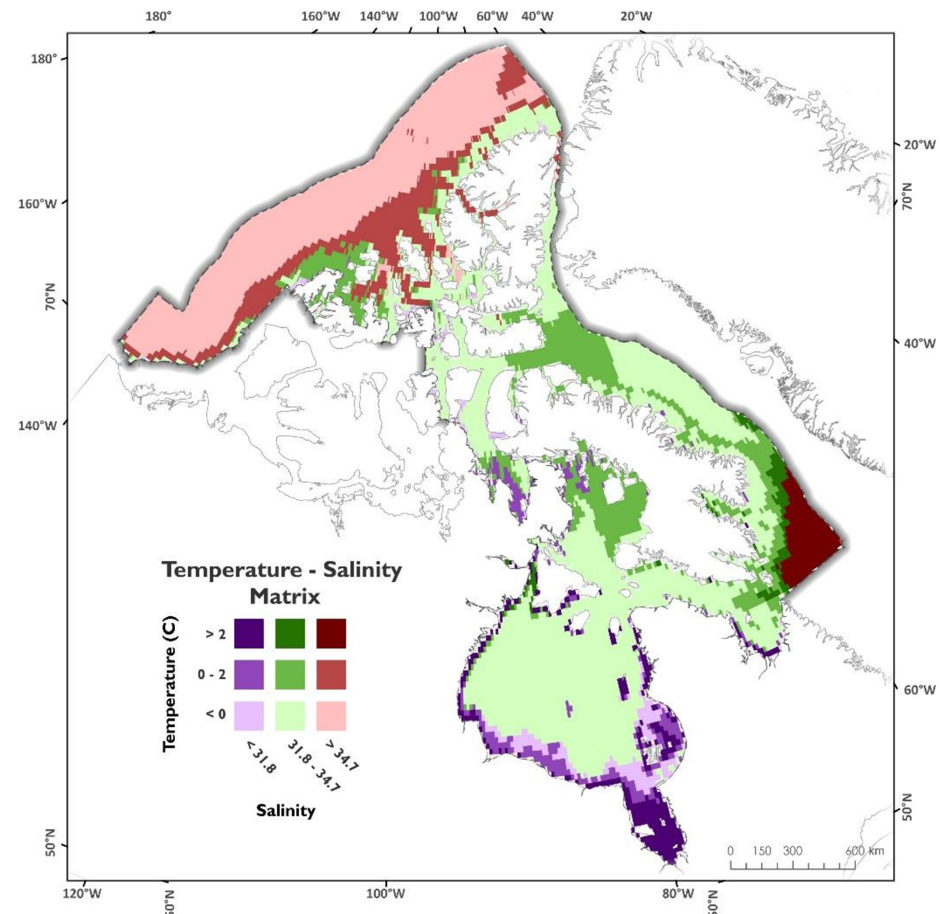

Figure 4.11. Benthic water masses as temperature-salinity classes, in nine combinations of values from observations taken closest to bottom.

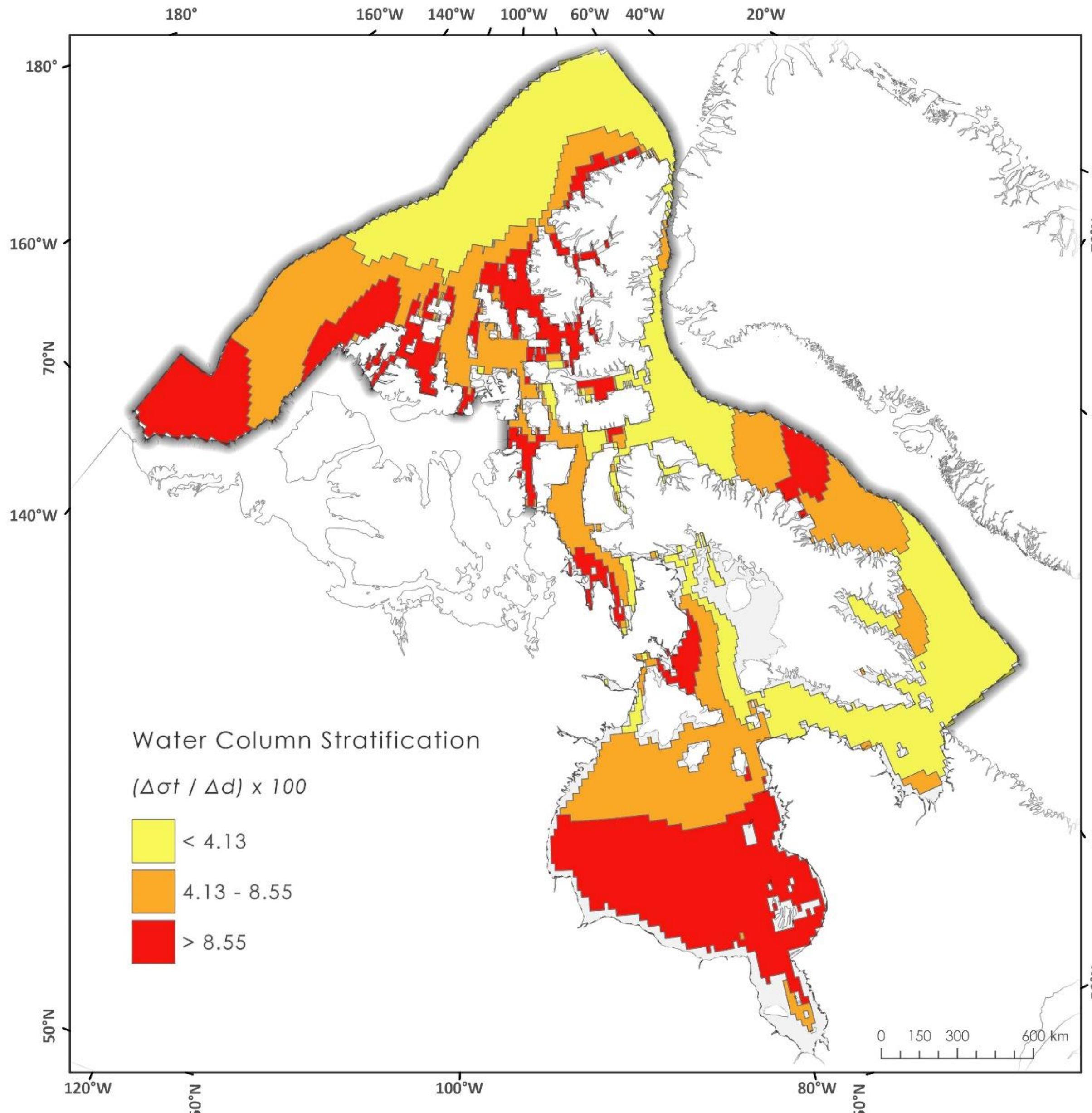

Figure 4.12. Intensity of water column stratification—as *($\Delta\sigma_t$ /Δd) x 100*—between surface and 30 m depth, in three classes.

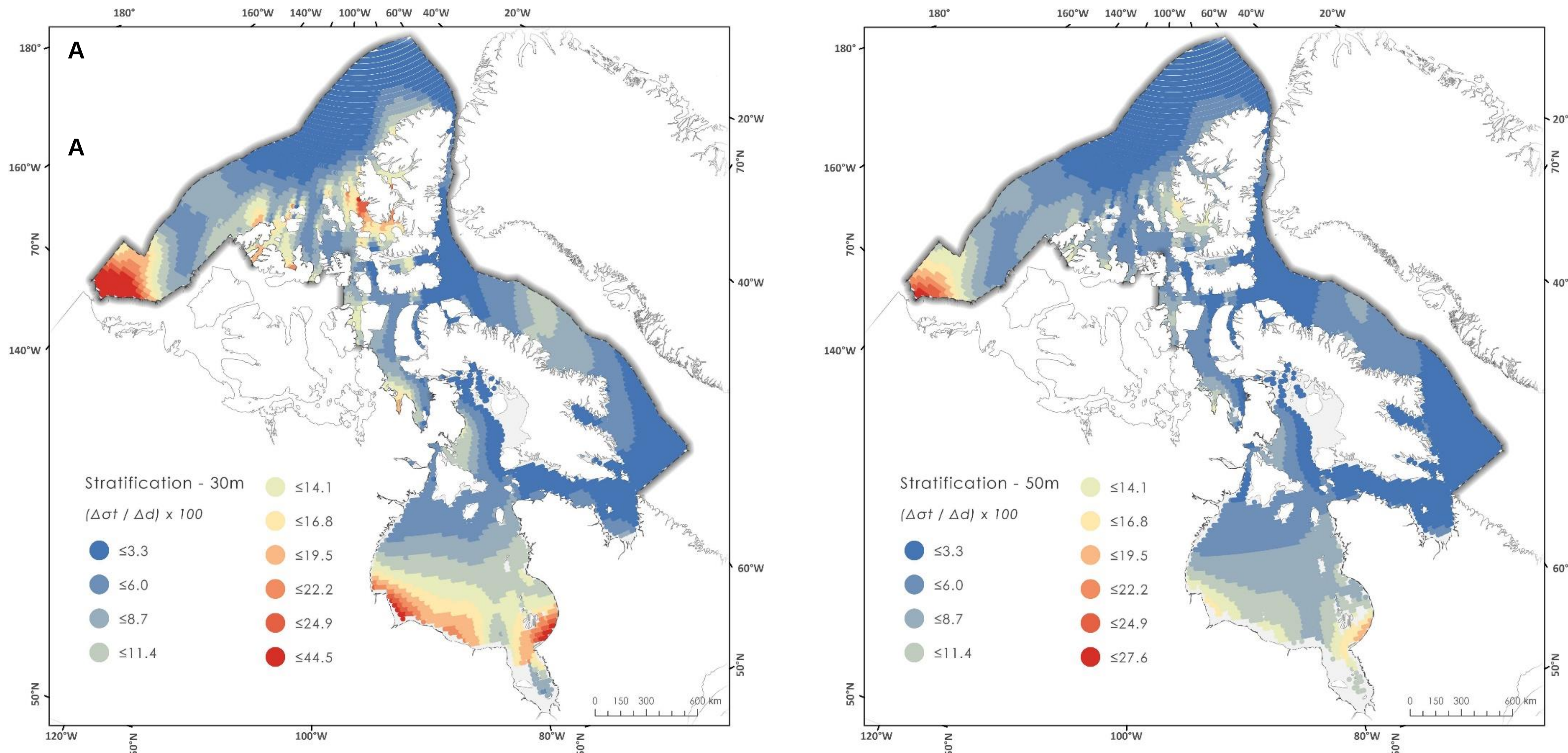

Figure 4.13. A comparison of $(\Delta\sigma_t/\Delta d)$ x 100 values for 30 m (A) and 50 m (B) depths, at increased intervals, showing the two calculated indices are broadly comparable in distributions.

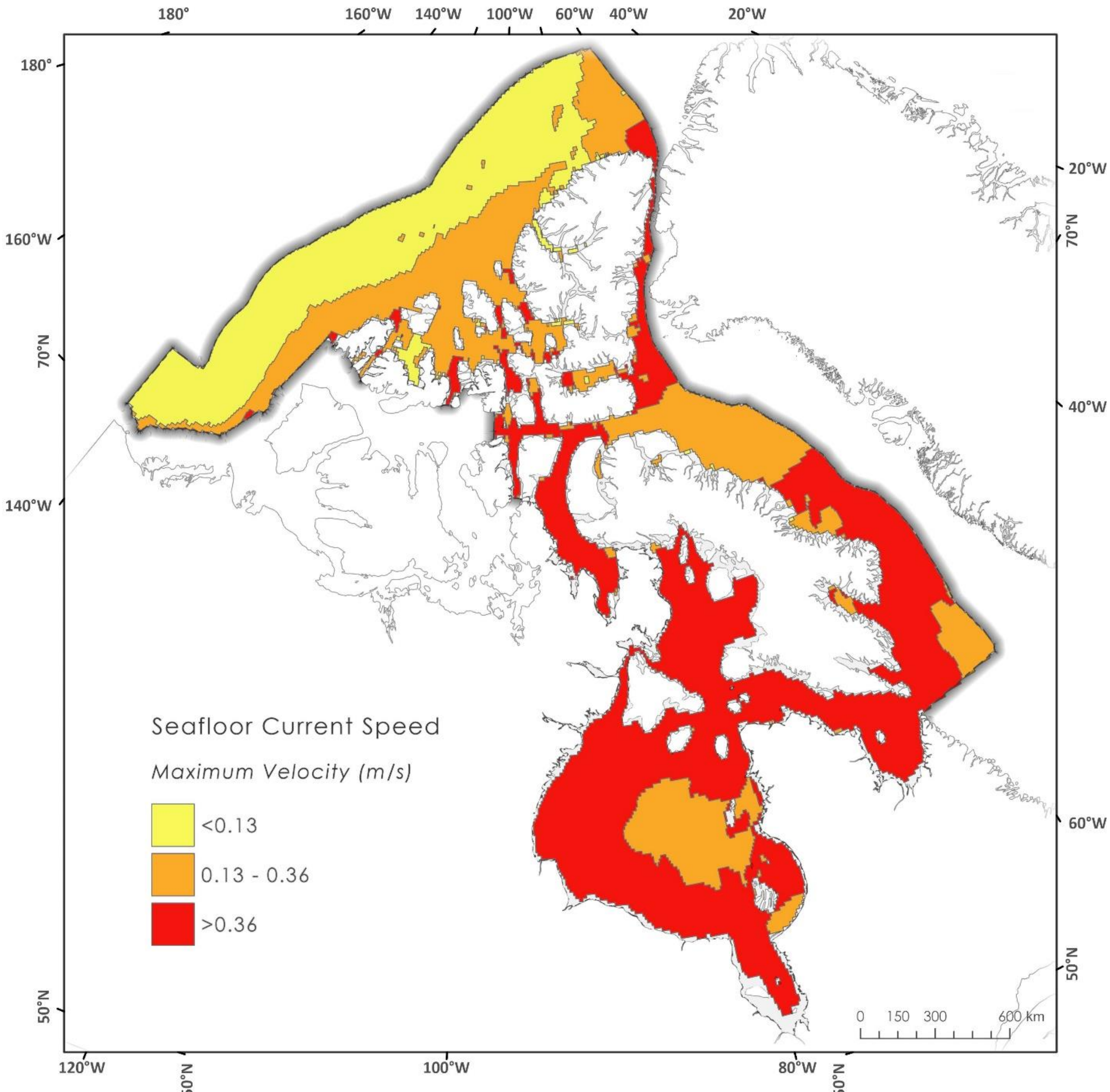

Figure 4.14. Vector addition of maximum residual plus current velocities (m/s) in the four MECCEA bioregions.

Selection of Variables and Parameters

The variables and parameters available to construct seascapes, from in situ observation or from remote sensing, are listed in Table 4.1 and Table 4.4. Geomorphic features are considered in a separate category of their own (at Level 4 of the framework), where they could be legitimately considered a representative seascape type. Features relating directly to productivity were also reserved and considered separately as independent variables, either as distinctive (areas of high chlor a, polynyas and shore leads) or as representative (annual primary productivity regime).

The primary question now is: how to use the remaining data to best construct seascapes as surrogates of community types in the pelagic and benthic realms. The most useful descriptions are simply in terms of some combination of surrogates for productivity, biodiversity and geophysical 'structure'.

Table 4.4. Selection and use of data in representative area seascapes.

Variable or Parameter	How Used
Sea ice annual regime	Pelagic Seascape
Temperature in depth intervals	Combined in water masses
Salinity in depth intervals	Combined in water masses
T-S water masses (from CTD)	Pelagic and Benthic Seascapes
Seasonal stratification, as $(\Delta\sigma_t/\Delta d)$ x 100	Pelagic Seascape
Near-bottom current speed	Benthic Seascapes
Geomorphic features	Removed—used as independent representative
Bathymetry	Benthic Seascapes
Surface chlor a	Removed as independent distinctive
Annual rate of primary production	Removed—used as independent representative
Polynyas and shore leads	Removed as independent distinctive

Epi-pelagic Seascapes

An epi-pelagic seascape (Figure 4.15), which can be considered as a surrogate for productivity, biodiversity and structure, was constructed using used data from:

1. Ice cover in three categories (permanently open, permanent ice, and seasonally open)
2. Epi-pelagic water masses, averaged from near-surface to 30 m depth for the seasonally open water period only (whether water is actually open or not). Intervals for temperature in three categories: <0.0, 0.0–2.0, >2.0°C. Intervals for salinity also in three categories: <30.4, 30.4–31.8, >31.8 PSU.
3. Water column stratification (0–30 m) in three categories.

Epi-pelagic seascapes refer to the water column of 0–30 m; comparison of distributions to a depth stratum of 0–50 m showed little difference. Considered in conjunction with data on chlorophyll levels and modelled rates of primary production, the pelagic realm is now relatively well spatially described.

Benthic Seascapes

A benthic realm seascape (Figure 4.16), which can be considered as a surrogate for biodiversity and structure was constructed using data from:

1. Bathymetry in four depth classes (0–50, 50–200, 200–1,000, and >1,000 m).
2. Benthic water masses, for available observations closest to bottom. Intervals for temperature in three categories: <0.0, 0.0–2.0, >2.0°C. Intervals for salinity also in three categories: <31.8, 31.8–34.7, >34.7 PSU.
3. Current velocities from residual and tidal currents combined (see above).

Considered in conjunction with the seascapes derived from geomorphic data, the benthic realm is now relatively well described.

Seascape Interpretation and Other Options

Even though we do not know the species composition of the component seascapes, in many cases we can specify the general community type. For example, ice-free Atlantic-type water of low stratification in the southern Eastern Arctic will show an early season phytoplankton bloom of diatoms. Shelf depth waters of low salinity and higher temperature will exhibit benthic estuarine type communities of burrowing bivalves and polychaetes.

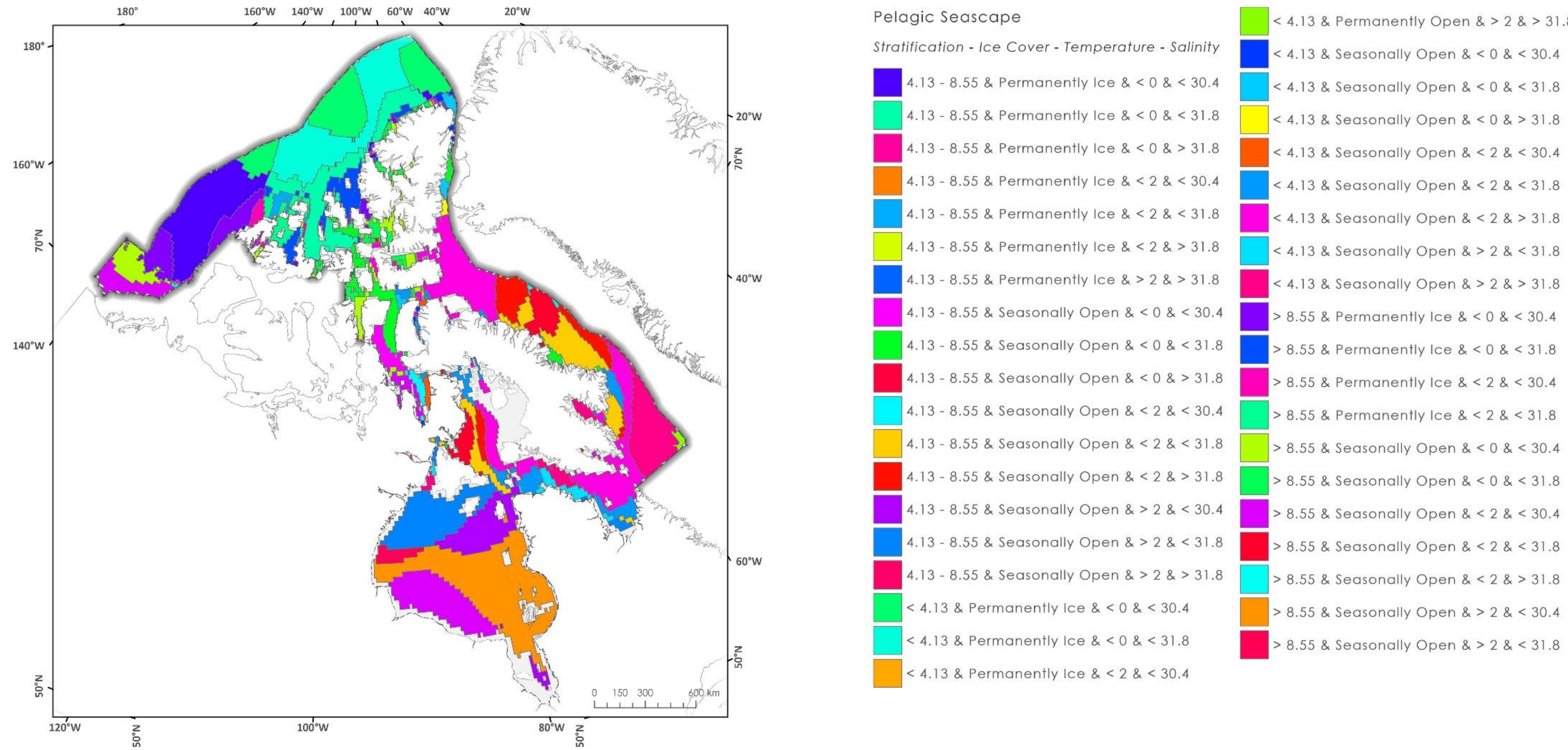

Figure 4.15. Final pelagic seascapes from combinations of geophysical variables. See text and Table 4.1 for further explanation.

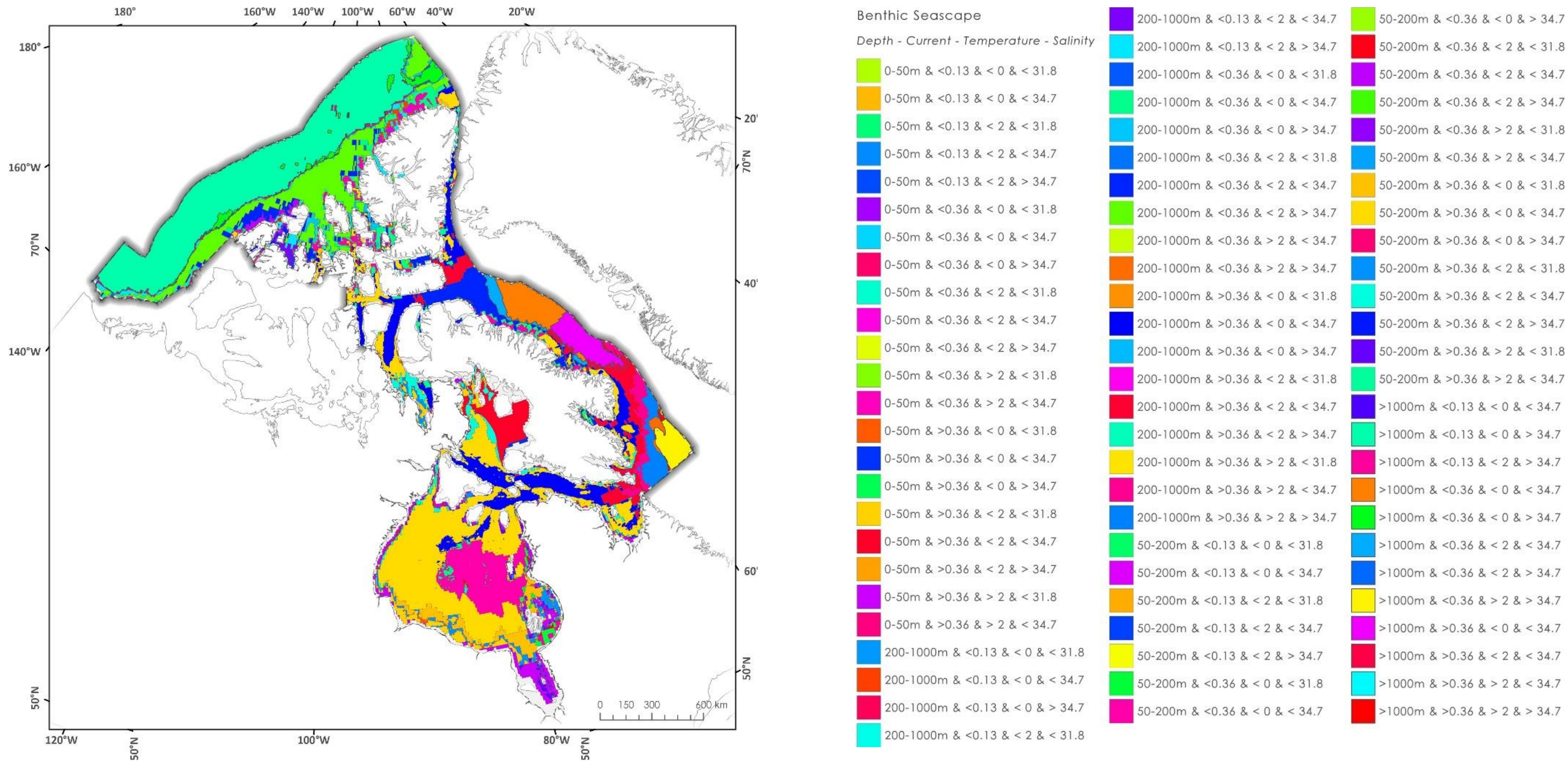

Figure 4.16. Final benthic seascapes from combinations of geophysical variables. See text and Table 4.1 for further explanation.

Seascapes could also be constructed, based on other environmental and physiological concepts. For example, Scope for Growth (see e.g. Southwood, 1988; DFO, 2005) is based on bottom temperature and its relation to growth rate. However, this concept is of limited utility in the Arctic where bottom temperatures generally range between -2 and +2°C. Environmental Stress (= Adversity), as a function of current velocity (e.g. Wildish and Kristmanson, 1997), is already incorporated in our benthic seascape. These separate ideas are therefore not recommended for the Canadian Arctic.

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CHAPTER 5: REPRESENTATIVE AREAS—BIOLOGY

INTRODUCTION

The subject of representative areas is continued here in terms of biological characteristics. Distinctive areas in terms of biological characteristics and priority species forms the subject of Chapter 6.

At this point it may appear rather artificial to separate some features into representative versus distinctive ones. But this is the essential difference between features that are continuous in their distributions, and therefore, occupy all of the study area in the MECCEA Marxan analyses, and those that are discontinuous in their distributions. As will be seen in Chapter 7, this distinction between continuous and discontinuous leads to important differences in the process of setting conservation targets.

For the sake of completeness, and to be clear how the MECCEA study has used available data, various generally recognized taxonomic/ecological groups of organisms are reviewed here, whether we have direct observations for them or not. For each group, however, we clearly define what can be described, how data were obtained or, if no data are available, which groups of organisms could be represented by a surrogate variable or index.

PRIMARY PRODUCERS

The array of primary producer communities in Arctic waters and how they were assessed or indexed is summarized in Table 5.1. Here, for completeness, we review all these communities of primary producers, but pay greater attention to those communities where there exist (or can be reconstructed) sufficient data and geographic coverage to allow for their use in Marxan analyses.

Table 5.1. Primary producers, assessment, and use in MECCEA planning.

Primary Producer Community	Distinctive or Representative	How Indexed
Phytoplankton Primary Production	Representative	Rate as $mgC/m^2/d$ from model
Sympagic community	Representative	Indexed from ice cover categories
Benthic inter-tidal microphytic community	Representative	Indexed from coastal sandy/mud shore surrogate
Benthic inter-tidal macrophytic algae	Representative	Indexed from coastal rocky shore surrogate
Benthic sub-tidal macrophytic algae	Representative	Indexed from bathymetry as surrogate
Seagrasses (*Zostera marina*)	Distinctive	In situ observations and records
Phytoplankton biomass	Distinctive	Areas of high chlor a, from ocean colour by remote sensing
Polynyas	Distinctive	Known distributions
Ice edge community	Distinctive	See Chapter 6 and 11

Benthic Inter-Tidal Microphytic Algae Community

Unsurprisingly, there is scant information about benthic microphytic algae in the Canadian Arctic, although this community must be widespread (e.g. Ellis and Wilce, 1961). However, the contribution of this community to local annual production can be significant. In temperate waters it can reach 1.5 $gC/m^2/day$ or approaching 500 $gC/m^2/yr$ (Ruardij and Baretta, 1988). Such values are comparable on a square meter basis to rates of phytoplankton production in coastal waters. In order to represent this community of primary producers, we only have the linear range of shorelines occupied by sand/mud habitats and the "other" category of inter-tidal substrates, as presented in Chapter 4.

Benthic Inter-Tidal and Sub-Tidal Macrophytic Algae Community

The overall complement and species richness of Arctic inter-tidal and sub-tidal macrophytic algae may be reasonably well documented. Localized Arctic studies have been conducted in considerable taxonomic detail, including genetic analyses (e.g. Küpper et al., 2016). Though once again, we do not have sufficient information to map representative communities either for inter or sub-tidal macrophytes, nor is sufficient information available as a basis to declare any locations or species as distinctive. A catalogue of species common throughout the Arctic is given by Lee (1990), and it is known that macrophytic algae, especially sub-tidal species, are common even at very high latitudes (e.g. Wiencke and Amsler, 2012).

The same lack of data on systematic distributions would be true of these algal groups for most temperate regions as well. In the MECCEA study we, therefore, apply the distribution of coastal rocky shores as a surrogate for inter-tidal macrophytic algae. The bathymetric 0–50 m depth interval is applied as a surrogate for the distribution of the sub-tidal macrophytic community, although we recognize that some species extend below this level.

Significant northward changes in the distribution of sub-tidal macrophytes are to be expected (e.g. Müller et al., 2009; Krause-Jensen and Duarte, 2014.) as climate change progressively reduces seasonal ice cover allowing greater light penetration and warming. However, some historical evidence on the East Coast of Canada appears contradictory on this point (see Merzouk and Johnson, 2011).

Phytoplankton Community

The phytoplankton community is universally represented in Arctic waters (von Quillfeldt, 2000), and some bioregional surveys have been undertaken, for example, in Hudson Bay (Roff and Legendre, 1986). However, multiple challenges accompany the usefulness of this taxonomic group as conservation features (Cecilie von Quillfeldt, personal communication). The knowledge we have is most often simply a snapshot of seasonal and spatial variability of organisms with generation times of hours to days. Multiple interacting drivers (e.g. light, nutrients, grazing, and spatial patchiness) all affect this variability in generally undocumented ways under field conditions. Methodological biases, difficulties with identification of many hundreds or thousands of species, developing taxonomy, and the need for genetic analysis of smaller species (e.g. picoplankton) add to the problems of using phytoplankton community structure as conservation features. Despite all these variables, phytoplankton taxa have nevertheless been used indicators of water masses (Lovejoy et al., 2011) in broad scale surveys.

Chlorophyll a Levels

Chlor a levels, as a measure of phytoplankton biomass, are considered as distinctive areas in Chapter 6.

Phytoplankton Annual Productivity

There are few in situ measurements of rates of phytoplankton primary production (a lengthy and local operation) in the study marine bioregions. There is also little prospect of future systematic spatial and seasonal in situ measurement of these rates of production. The only practicable way to get such estimates for the four study marine bioregions is by the application of a model using remotely sensed data. Such a model is described and assessed in Platt et al.

(2008), and has been applied to most of the region by the Remote Sensing Unit of the Bedford Institute of Oceanography (BIO).

The input data required for this model include: bathymetry, sea surface temperature, cloud cover, total daily photosynthetically available radiation (PAR), and chlor a. Bathymetry and temperature wer reported in Chapter 4 and chlor a concentration will be considered in Chapter 6. Other model parameters and data are not considered further here, but were provided by BIO according to Platt et al. (2008).

The model output was available within the area bounded by 85°N latitude and 95°W longitude. Much of the Arctic Archipelago and all of the Arctic Basin lie outside the applicable model area, also outside is a small part of the eastern Arctic (lying between the southern end of Prince of Wales Island and the southern end of Somerset Island, past the west coast of Cornwallis Island to the northern end of Bathurst Island and the northern tip of Devon Island).

Results from the model for the years 2012–2016 (as maximal $mgC/m^2/d$) are shown in Figure 5.1. For subsequent use, data were binned into the intervals: 0–500; 500–1,000; 1,000–1,500; 1,500–2,000; and >2,000 $mgC/m^2/d$. Areas outside the model coverage were assumed to have the same value as their nearest neighbour (in all cases <200). It should be noted that, although these calculated values are likely to reflect the broad categories of recent production rates and their geography, there is considerable scope for errors in such estimates (e.g. Kahru et al., 2016). The marine Arctic environment is also changing rapidly towards higher values (Arrigo et al., 2008) and more temperate regimes (Ardyna et al., 2014).

Sea Ice and Sympagic Community

As with the phytoplankton community, the taxonomic composition of the sympagic algal community is highly spatially variable. Poulin et al. (2011) reported 1,027 sympagic taxa in the Arctic Ocean, and even a single collection may contain hundreds of species (Cecilie von Quillfeldt, personal communication). The overall chlor a concentration also varies, spatially and seasonally, affected inter alia by ice conditions and snow cover (see e.g. review by Leeuwe et al., 2018). Although chlor a biomass and rates of production are clearly related to ice and snow cover, values can remain significant even under multi-year ice (Lange et al., 2017). Several studies have estimated the rate of primary production of this community (e.g. Gosselin et al., 1997), which may be as important as rates of phytoplankton production (Gradinger, 2009).

For the purposes of the MECCEA study, we have simply indexed the significance of the sympagic community in terms of the ice regime itself (see Chapter 4).

In summary, “permanently covered” was defined as areas that maintained ice concentration greater than 9/10 coverage throughout the year (with lower sympagic production). “Permanently open” was defined as areas that had ice concentrations no greater than 3/10 throughout the year (with negligible sympagic contributions), and the remainder—"seasonally developing” ice cover—with highest biomass and production (see Chapter 4).

ZOOPLANKTON COMMUNITY

As with the phytoplankton, data for zooplankton are geographically scattered, but most taxa of holo-zooplankton encountered in the MECCEA study marine bioregions are widespread (L. Fortier personal communication). However, the Arctic Archipelago is essentially unsampled. The most notable data lie in the distribution of *Calanus finmarchicus*, which is essentially absent from the Hudson Bay Complex (see Chapter 3), reflecting its identification as a separate marine bioregion and the lack of direct influence of Atlantic water.

Although there are frequently clear differences in the community composition of zooplankton, reflecting origins of water masses and inshore-offshore effects (see e.g. Tremblay and Roff, 1983; Darnis et al., 2008), such patterns are variable and require widespread synoptic data.

Such analyses, even if available, would not materially help in conservation planning at a scale below that of marine bioregions.

The meroplanktonic community will be of more concern in connection with the process of connectivity among PACs in Chapter 9.

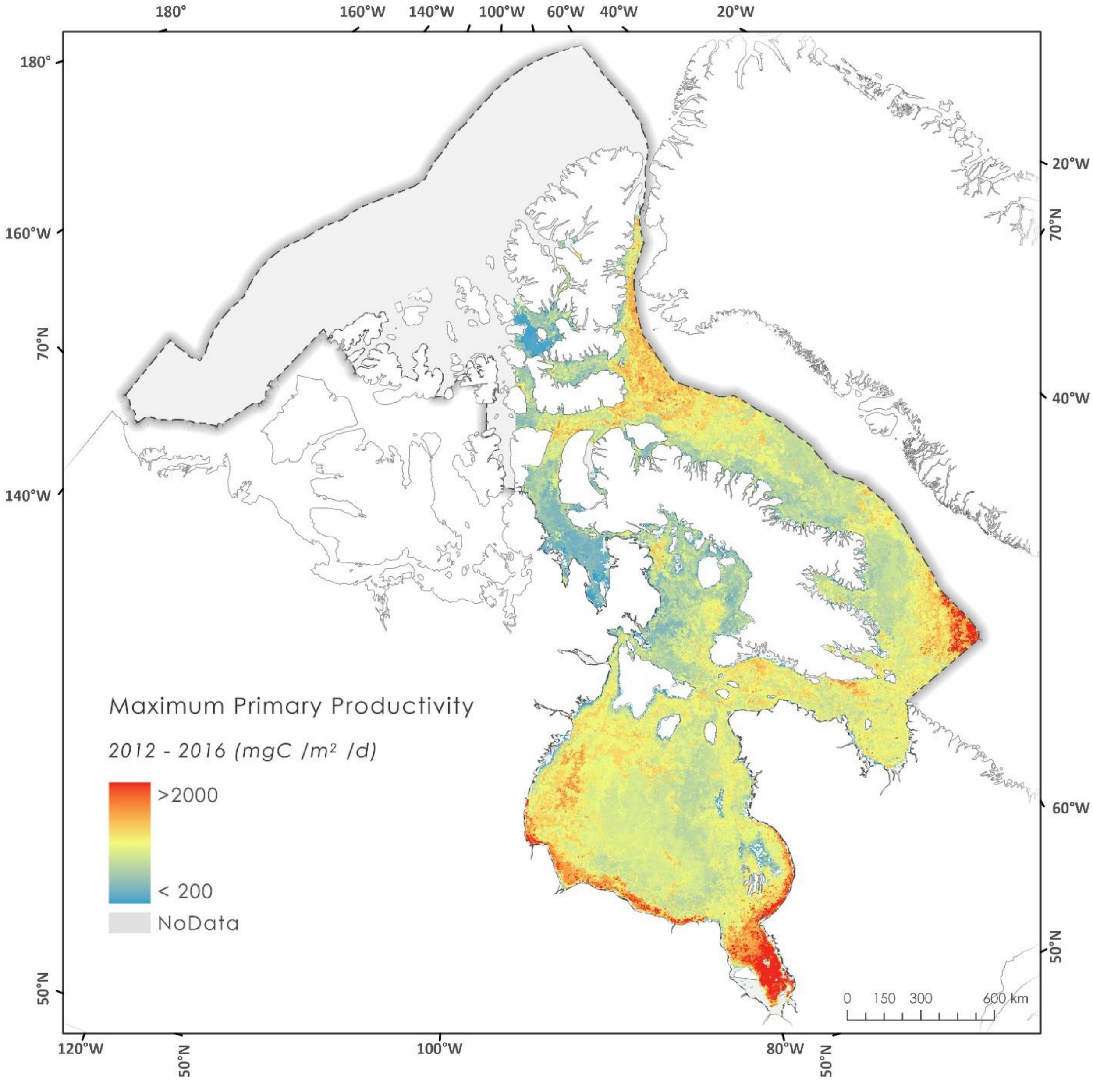

Figure 5.1. Maximum modelled rate of primary productivity (mgC/m²/day) for the years 2012–2016 inclusive. Areas in Beaufort Sea are not included. Areas further north than shown (Arctic Archipelago and Arctic Basin) are assumed to have values lower than the lowest shown (<200 mgC/m²/day). Data provided by the Remote Sensing Unit at BIO based on Platt et al. (2008).

BENTHIC TAXONOMIC ASSEMBLAGES

Sampling of the benthic community in the Canadian Arctic has been scattered in space and has been conducted ad hoc over many years. In addition, taxonomy has changed over time, and reports often lack data on the type of sampling apparatus used and type of substrate sampled. The following synthesis of available data should, therefore, be interpreted with caution, although the broad outlines and patterns are likely robust, especially concerning more recent collections and taxa of conservation concern.

This part of the report focuses on benthic community composition. Individual taxa of conservation concern—including sponges, sea pens and corals (Kenchington et al., 2011)—and patterns of taxonomic richness, all of which were considered as distinctive areas, are reported in Chapter 6. A summary of how benthic data were considered in representative and distinctive areas, is given in Table 5.2.

Table 5.2. Use of benthos and fish data in both representative and distinctive features analyses.

BENTHOS		
Representative Areas (Chapter 5)	**Distinctive Areas** (Chapter 6)	
Characterize Bioregions	Overall Taxon Richness	Families
		Species
Characterize Bathymetry, depth intervals	Individual Taxon Conservation, e.g. Corals, Sea pens, Sponges	
FISH		
Representative Areas	**Distinctive Areas**	
Characterize Bioregions	Overall Taxon Richness	Families
		Species
Characterize Bathymetry, depth intervals	Individual Taxon Conservation	
	Individual Species – Commercial (Chapter 11)	

Four main sources of records comprised the main data set (Table 5.3), but many further records were examined. Several of the data sources were already accessible from the Ocean Biogeographic Information System (OBIS, https://www.dfo-mpo.gc.ca/science/data-donnees/obis/index-eng.html) and the Global Biodiversity Information Facility (GBIF, https://www.gbif.org/country/ca), two of the largest repositories for species records on the internet. OBIS houses over 45 million observations of a spectrum of marine species, collected and organized by 500 global institutions. These observations were collected from a variety of sources from historical records. Other major sources of records were Curtis (1972), Cusson et al. (2007), and Roy and Gagnon (2016). A full listing and report are available from WWF- Canada on request.

A total of 13,705 entries were selected for the benthic dataset, comprising the representative areas. The distribution of available data was fairly high across taxonomic levels ranging from 100% of entries including information for Kingdom (Animalia) to 71% of entries including information for Subspecies. Very few entries (~2%) included information for subgenus (Figure 5.2). Family and species level information were chosen for further analysis.

The data comprised 343 families, with Cirratulidae, Spionidae, and Nephtyidae having the highest number of entries. There were 1,023 species recorded, with *Chaetozone setosa*, *Aglaophamus malmgreni*, and *Lumbrineris minuta* having the highest number of entries. Although benthic samples were located in each marine bioregion (Figure 5.3), sampling locations have evidently been much more abundant in the Eastern Arctic and Hudson Bay Complex compared to the Arctic Archipelago and Arctic Basin.

Table 5.3. Major sources of records for benthos in the Canadian Arctic.

Main Data Sources and Reference	Number Records
Roy V., Gagnon J.-M. 2016. Natural history museum data on Canadian Arctic marine benthos. Marine Biodiversity. doi: 10.1007/s12526-016-0610-2 (a review of museum specimens; GBIF resource–museum specimens; DwC dataset accessible from Canadensys data repository-IPT)	6242
GBIF-CMNcollections-Filtered for Arctic Bioregions (Conlan datasets) (GBIF resource–museum specimens; DwC dataset accessible from CMN data repository-IPT)	8914
Cusson, M., Archambault, P., and Aitken, A. 2007. Biodiversity of benthic assemblages on the Arctic continental shelf: historical data from Canada. Marine Ecology Progress Series 331:291-304. (a review of published datasets; data in EXCEL format)	7869
Curtis, M.A. 1972. Depth distribution of benthic polychaetes in two fjords on Ellesmere Island, NWT. J FRB, 29:1319-1327 Curtis, MA. 1970. Depth distributions of benthic polychaetes in Hare Fjord and Tanquary Fjord, Ellesmere Island, NWT. McGill University Marine Sciences Centre MS rep 16:62p. (University thesis and associated publication; pdf)	1845
Kumlien, Ludwig. 1879. The Howgate Polar Expedition, 1877-78, Bull of the US Nat Museum No 15. (an historical exploration; pdf)	24

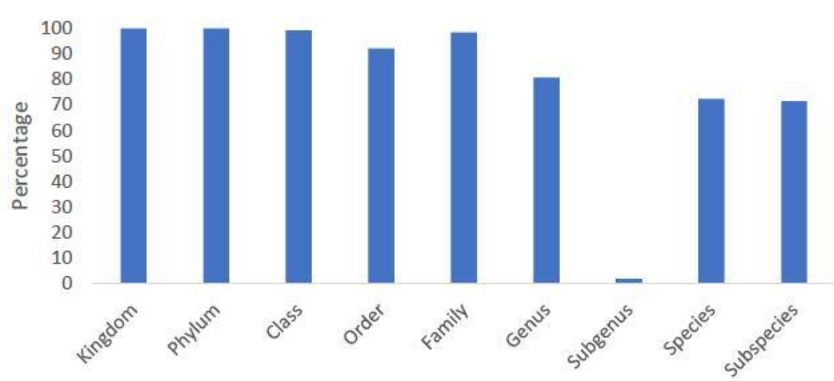

Figure 5.2. Information available in the benthic dataset by taxonomic level.

The taxonomic distribution data were analysed by Non-metric Multidimensional Scaling (NMDS), to examine whether there were differences in community species composition or family composition (taxonomic assemblages) of the benthos among marine bioregions or with respect to depth. At both the family level and the species level, clear differences in taxonomic assemblages were apparent among the four marine bioregions. Family level data are shown in Figure 5.4; species level data (not shown) follow essentially the same pattern. This confirms and strongly reinforces the appropriateness of separate recognition of these four marine bioregions, from both geomorphic and biogeographic evidence (also see Chapter 3). Again, at both the family level and at the species level there are clear differences in composition of the taxonomic assemblages according to depth strata. Family level data are shown in Figure 5.5; species level data (not shown) follow essentially the same pattern. Again, this confirms the appropriateness of selecting these depth intervals for other analyses.

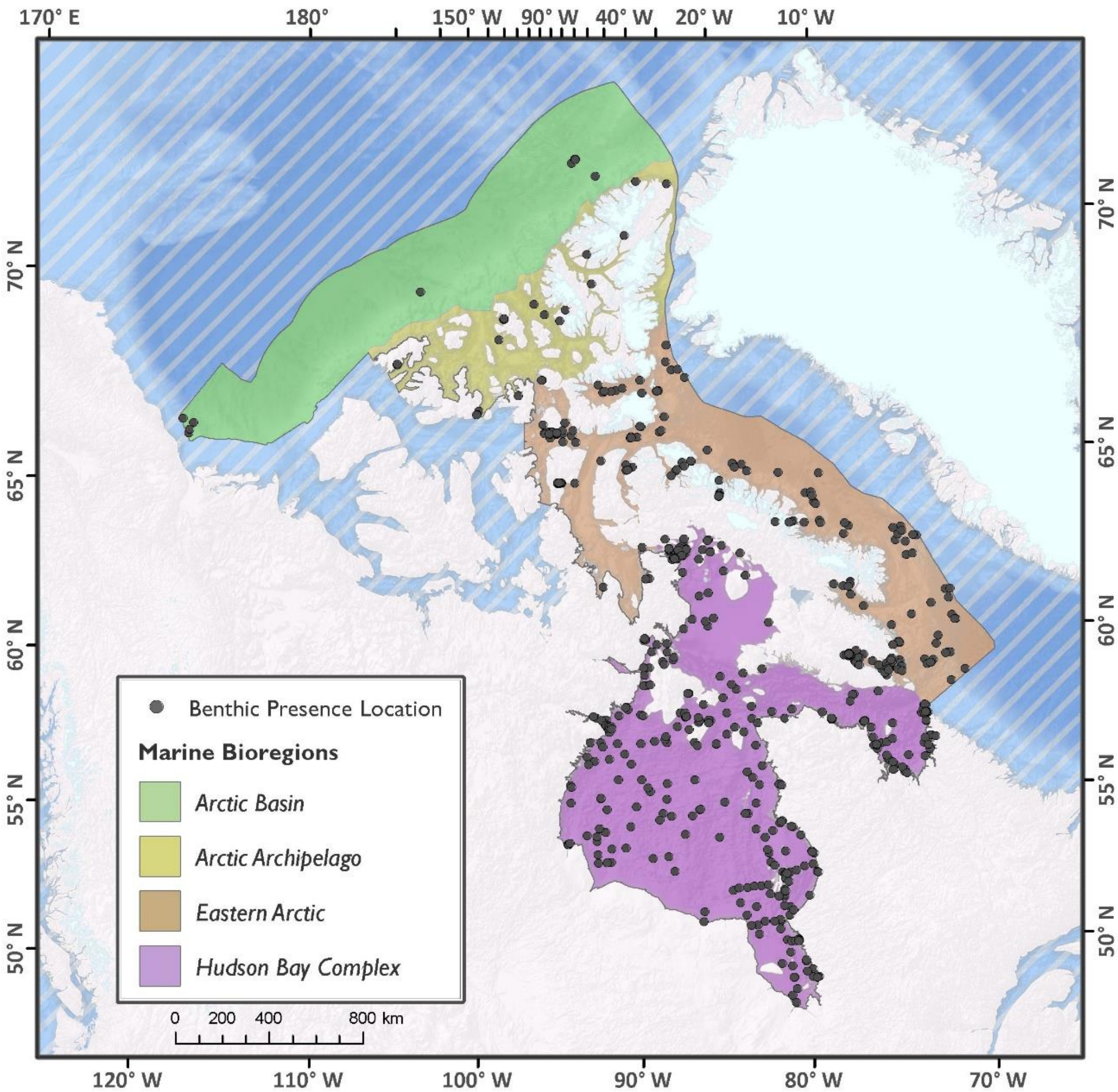

Figure 5.3. Distribution of benthos samples across the MECCEA study area bioregions.

No further analyses of taxonomic assemblages at spatial levels below those of marine bioregions and depth were attempted, due to the paucity of data. No further statistical analysis of these relationships is offered here, because of the very uneven distribution of data points. However, support for the two spatial levels of the classification system presented in Chapter 2 (see Table 2.1) is evident. Recent and on-going research into benthos taxa and communities and genetics (Hardy et al., 2011) should throw considerably more light on Arctic marine biogeographic boundaries—in both in the Canadian marine Arctic (Cusson et al., 2007) and the marine Arctic as a whole (Pipenburg et al., 2011), and on population connectivity.

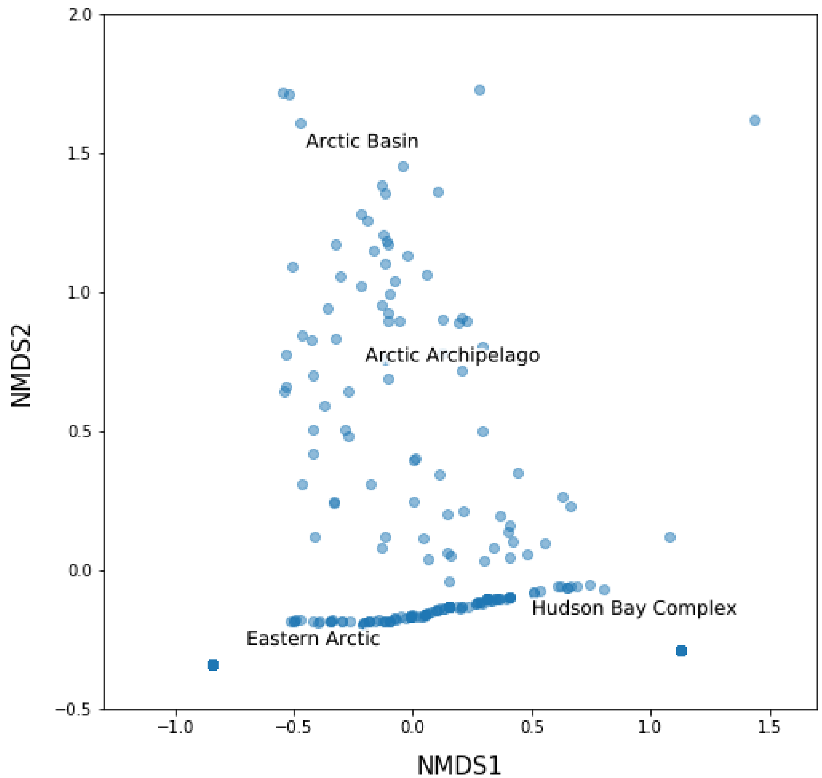

Figure 5.4. Non-Metric Multidimensional Scaling (NMDS) ordination analysis of benthos at the family level to assess differences in taxonomic assemblages among *marine bioregions*.

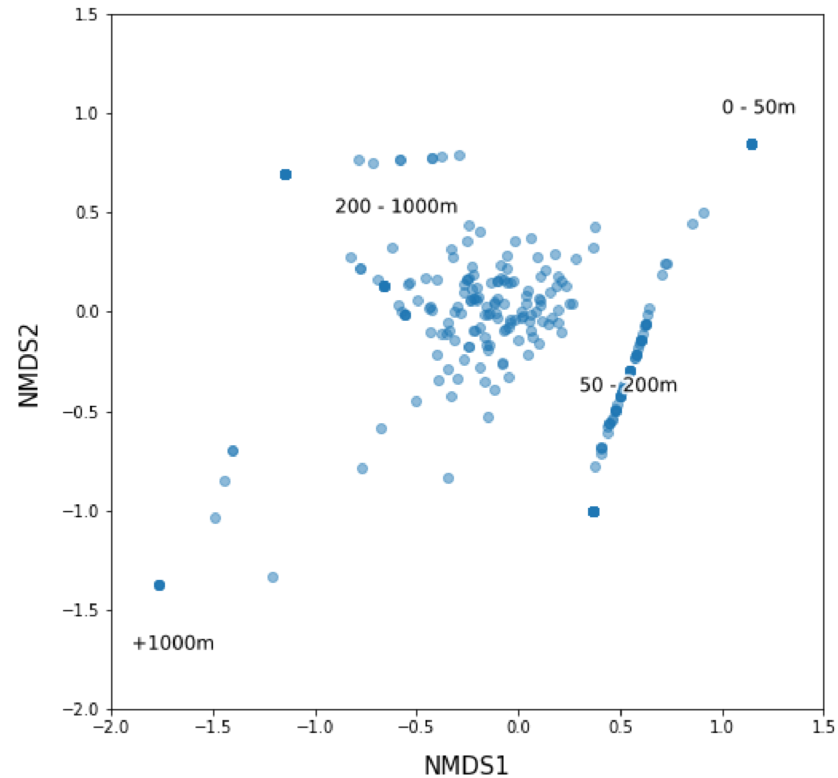

Figure 5.5. NMDS ordination analysis of benthos at the family level to assess differences in taxonomic assemblages among *depth intervals*.

FISH TAXONOMIC ASSEMBLAGES

As for the benthic community, sampling of fish in the Canadian Arctic has been scattered in space and by technology, and it has been conducted both ad hoc and in systematic surveys over many years. The following interpretations of available data should, therefore, be interpreted with caution, although the broad outlines are likely robust. This part of the report focuses on fish community composition. Individual taxa of conservation concern and patterns of taxonomic richness are reported in Chapter 6. A summary of how fish data were considered in representative and distinctive areas, is given in Table 5.2.

The recent publication by Coad and Reist (2018) *Marine Fishes of Arctic Canada* is considered the most robust catalogue of fish species in the Canadian Arctic. This text lists all marine, brackish water and extra-limited fish species found or known to be in the Canadian Arctic. The text also includes locations of records and further explains the details of life history, morphology, commercial importance, and general distributions. This text, along with records in OBIS (https://www.dfo-mpo.gc.ca/science/data-donnees/obis/index-eng.html) and GBIF (https://www.gbif.org/country/ca), was used as a baseline reference for MECCEA to verify the fish species and their locations. Additional data were collected to supplement gaps in the OBIS and GBIF data. A full listing and a report on fish species are available from WWF-Canada on request.

Data were cleaned to remove records with incorrect lat./long. or depth information. A “working fish database” resulted in a total of 39,085 records with 208 species (Table 5.4). The differences in numbers in Table 5.4 are primarily due to the selection of locations for the MECCEA study (the four designated marine bioregions out of a total of five Arctic marine bioregions). Locations of fish sampling sites are shown in Figure 5.6; the biases in terms of geographic locations are clearly evident.

The fish species distribution data were also analysed by NMDS to examine whether there were differences in taxonomic assemblages of fish among marine bioregions or with respect to depth. At the species level, the clearest differences are between the Arctic Archipelago plus the Arctic Basin, on one hand, and the Hudson Bay Complex (HBC) plus the Eastern Arctic (EA), on the other (Figure 5.7), with strong connections evident between HBC and EA. Thus, although differences in fish assemblages among the marine bioregions can be seen, they are not as clear as for the benthos.

However, at the species level, the axes of the NMDS plots for depth show clear differences in the taxonomic assemblages according to depth strata (Figure 5.8), again confirming the appropriateness of selecting these depth intervals for other analyses.

No further analyses of taxonomic assemblages at spatial levels below those of marine bioregions and depth were attempted, due to the paucity of data. No further statistical analysis of these relationships is offered here, because of the very uneven distribution of data points.

Table 5.4. Comparison of records in the “working Fish database” and Coad and Reist (2018).

	Working Fish Database	Coad and Reist (2018)
Total Species	**208**	**375**
Marine Species	170	220
Brackish Species	9	34
Extra-limited Species	11	121

At-Risk Species	16	26

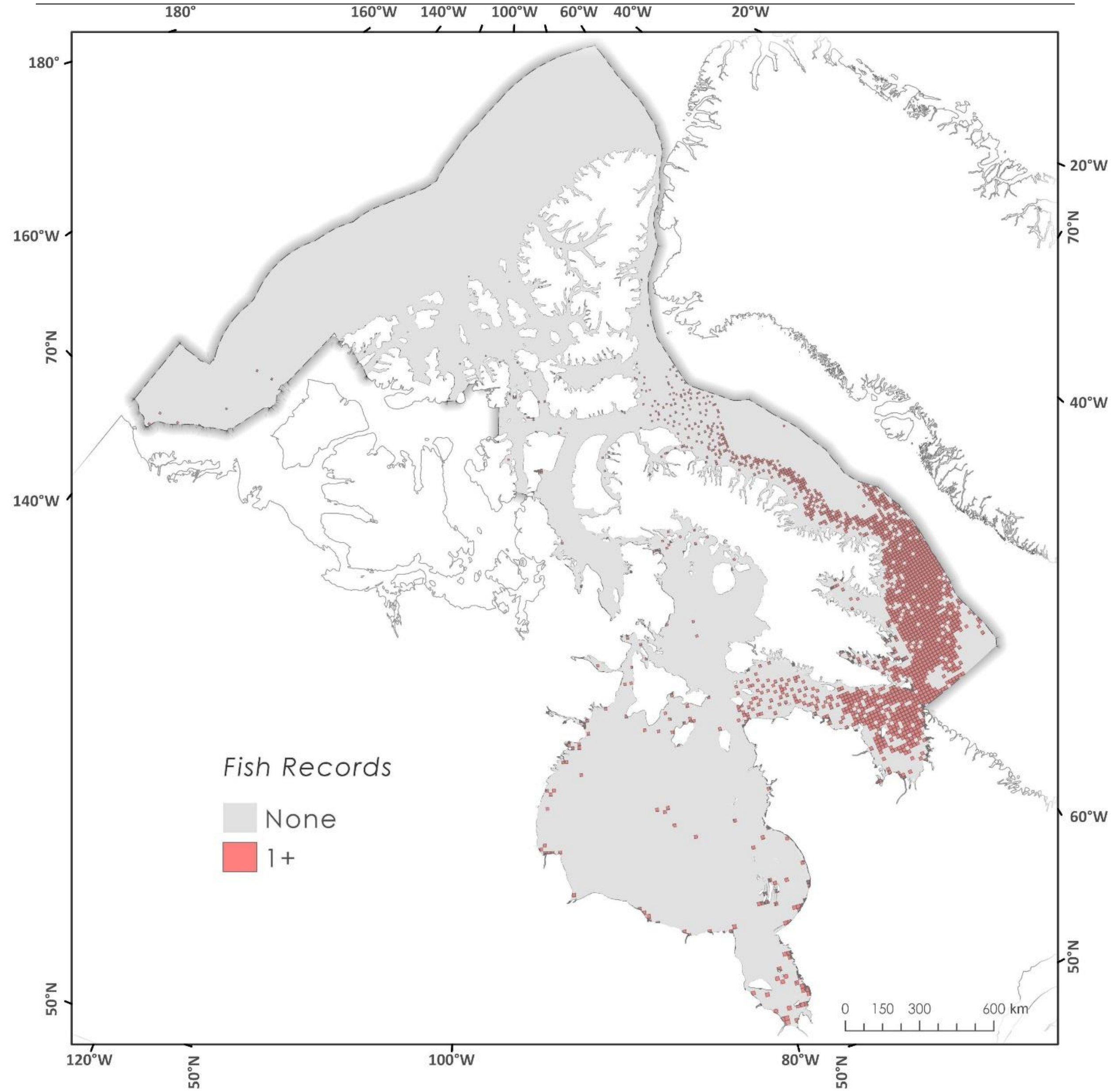

Figure 5.6. Distribution of all fish records for the four MECCEA bioregions.

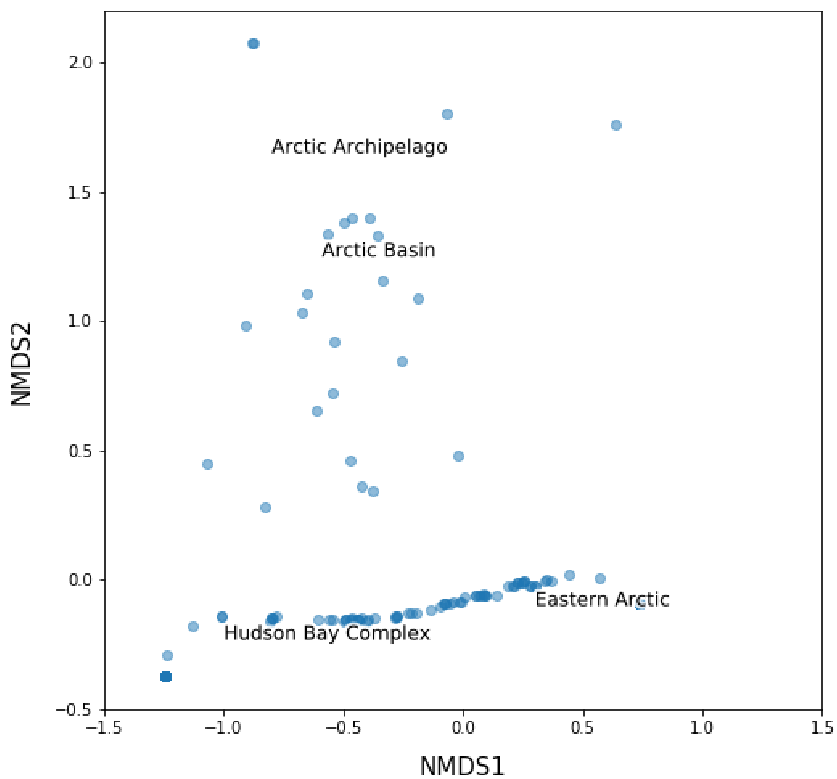

Figure 5.7. NMDS ordination analysis of fish at the species level to assess differences in taxonomic assemblages among *marine bioregions*.

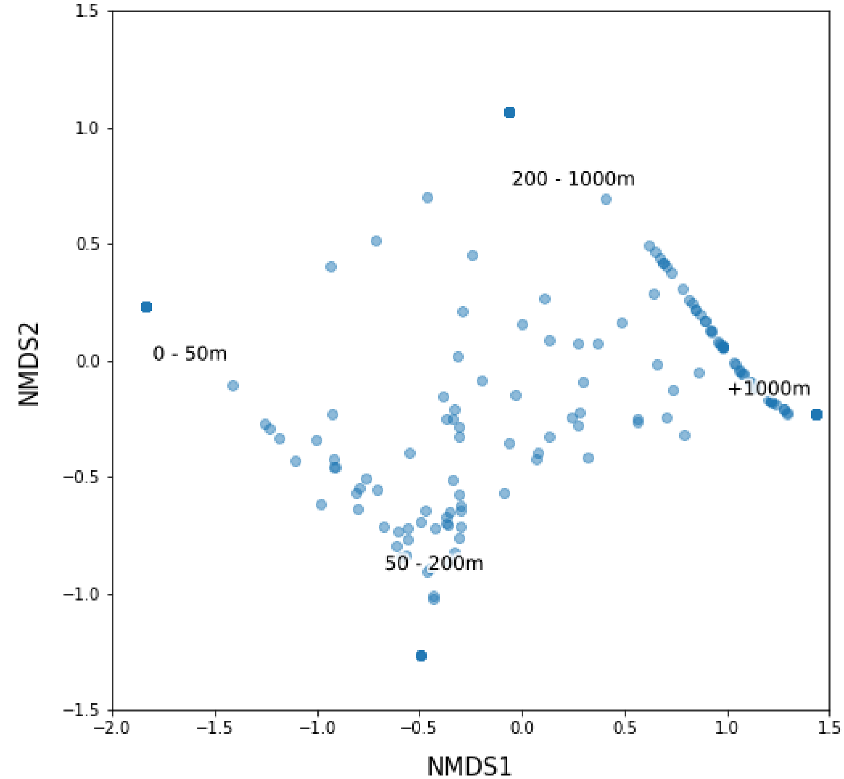

Figure 5.8. NMDS ordination analysis of fish at the species level to assess differences in taxonomic assemblages among *depth intervals*.

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CHAPTER 6: DISTINCTIVE AREAS AND PRIORITY SPECIES

INTRODUCTION

Chapters 4 and 5 reviewed the geophysical and biological data used to describe representative areas, to which all parts of the four MECCEA marine bioregions belong. This chapter presents the data for distinctive areas, priority species and key habitats. Distinctive areas (Roff and Evans, 2002) are defined by geophysical and/or biological anomalies, which set them apart from surrounding areas. They may have some features in common with EBSAs (see DFO, 2011), but are not synonymous with them. Priority species are partially congruent with focal species (see Zacharias and Roff, 2001). Their significance, according to WWF-Canada, is described in Text Box 6.1 and will become apparent below. Key habitats are defined below.

Text Box 6.1. Various characteristics of priority species as defined by WWF-Canada.

Priority species are species that:

- form a key element of the food chain;
- help the stability or regeneration of habitats;
- demonstrate broader conservation needs;
- are important for the health and livelihoods of local communities;
- are exploited commercially; and
- are important cultural icons.

A "priority species" is reflective of an identified key threat for that species across an ecoregion such that conservation of the species will contribute significantly to a broader threat mitigation outcome. It is often crucial to the economic and/or spiritual wellbeing of peoples within that ecoregion.

- See also, WWF's definitions online:
    - "Know your flagship, keystone, priority and indicator species"
    - "Priority Species"

AREAS OF HIGH PRODUCTIVITY

Making any assessment of primary producer communities in the Arctic must rely on three sources of information: remote sensing of ocean colour, models based on environmental data, and in situ measurements. For the purposes of planning in the MECCEA study, we had to decide whether to treat data in either the distinctive or the representative category. The differences in how data were treated and analyzed within these two categories will become clear in Chapter 7. For present purposes, their assigned categories are indicated in Table 5.1, and below.

Areas of high Chlorophyll a

A suite of ocean colour data (modelled to give chlor a as mg/m^3) is provided by NASA's OceanColor Web[1]. The Bedford Institute of Oceanography (BIO) recommended the Suomi National Polar-Orbiting Partnership (SNPP)[2] Visible Infrared Imaging Radiometer Suite (VIIRS) 4 km resolution chlor a data product for our purposes, covering the years 2012–2017, as 8-day composite mean images. Averaging over a short time period had the benefit of smoothing out anomalously high returns, while maintaining much of the natural variability.

Selecting areas of high productivity, as indexed by chlor a, is relatively straightforward in areas of similar geography and seasonal cycles. However, the four Arctic marine bioregions vary

[1] https://oceancolor.gsfc.nasa.gov

[2] https://eospso.nasa.gov/missions/suomi-national-polar-orbiting-partnership

considerably in seasonal cycles, including seasonal ice and cloud cover. We examined several criteria for appropriate indices of chlor a, including measures of maxima and persistence (see e.g. CLF-WWF, 2006).

It was finally decided that two products were required to adequately visualize areas of high chlor a concentration: maximum observed chlor a concentration (Figure 6.1); and a measure of chlor a persistence. The rationale behind this was that looking only at the absolute maximum recorded chlor a concentration did not account for the distribution of persistent periods of high chlor a. In order to put these high areas into this context, the maximum values were mapped with respect to the standard deviation of chlor a concentration over the whole data set. Standard deviations of 4, 5 and 6 were calculated, and a figure of mean +5 SD (Figure 6.2), which shows clear locations of high chlor a, was selected for use in Marxan analyses. Further details on methods and selection of data are available from WWF-Canada.

Ice Edge Zone Community

Air-water, water-substrate, and water-organism interfaces are the locations of greatest biogeochemical activity in the marine environment. The ice-water-air interfaces (ice edge zone) are additional regions of important geophysical and biological interactions in Arctic regions. These are key habitats of high productivity and feeding for organisms ranging from phytoplankton and ice algae to polar bears. The ice edge community can be considered to consist of at least four separate features, including polynyas, open shore leads, the edge of seasonal ice retreat, and edges of floating ice including icebergs. Shore lead polynyas (see Hannah et al., 2009), which may be of major importance for migrations of marine mammals, are considered further in Chapter 9.

However, unlike polynyas (considered below), most of the seasonal ice edges are variable, seasonally mobile and unpredictable in location. Because of their variability in time and space, seasonal ice edges are not suitable candidates for protection within static PACs. Their possible management is considered further in Chapter 11.

Polynyas

An analysis of annually recurrent polynyas in the Canadian Arctic, was carried out for the years 2002–2013 by Currie (2014); results are shown in Figure 6.3. Using daily sea ice temperature grids produced from MODIS optical satellite imagery, polynya occurrences in the Canadian Arctic and Northwest Greenland were mapped with a spatial resolution of 1 km^2 and a temporal resolution of one week. The eleven-year dataset was used to identify and measure those locations with a high probability of open water occurrence. This approach was deemed most suitable for the spring months when polynyas and shore leads represent the only open water in the region. There is considerable yearly variation in the extent of polynyas, making the identification of trends difficult. The complete set of polynyas or shore leads in any given year is therefore not indicated in Figure 6.3, but only those most consistent in location among years. These are the most appropriate candidates for place-based PACs.

Zostera marina

There is only one report of *Zostera marina* (eelgrass) presence within the MECCEA study area, along the Northeast Coast of James Bay (Lalumiere et al., 1994; see Figure 6.4). This survey indicated large variations, both in density and biomass, with depth and season, and from year to year. The eelgrass beds here are not reported to support a high diversity of associated fauna. However, this marine plant community, and associated terrestrial vegetation, is of major significance for migratory geese. See the section below on birds for the further significance of the Northeast Coast of James Bay.

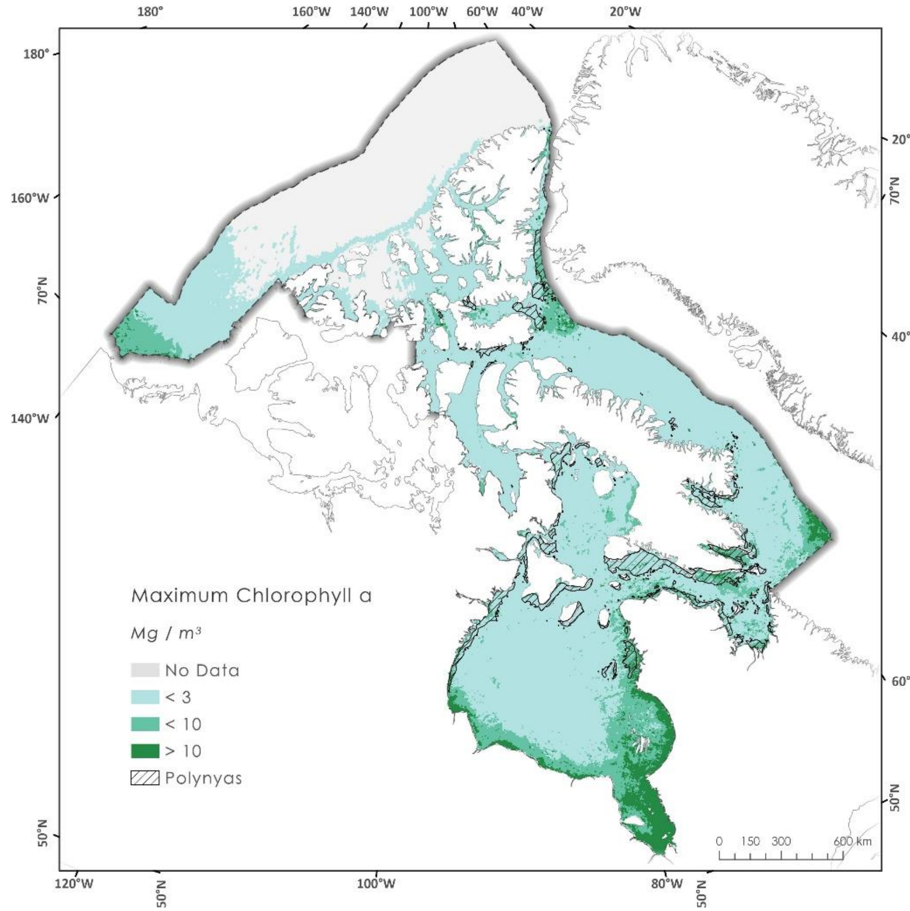

Figure 6.1. Maximum chlor a concentrations (from ocean colour) observed between 2012 and 2017. Locations of major polynyas and coastal leads also shown.

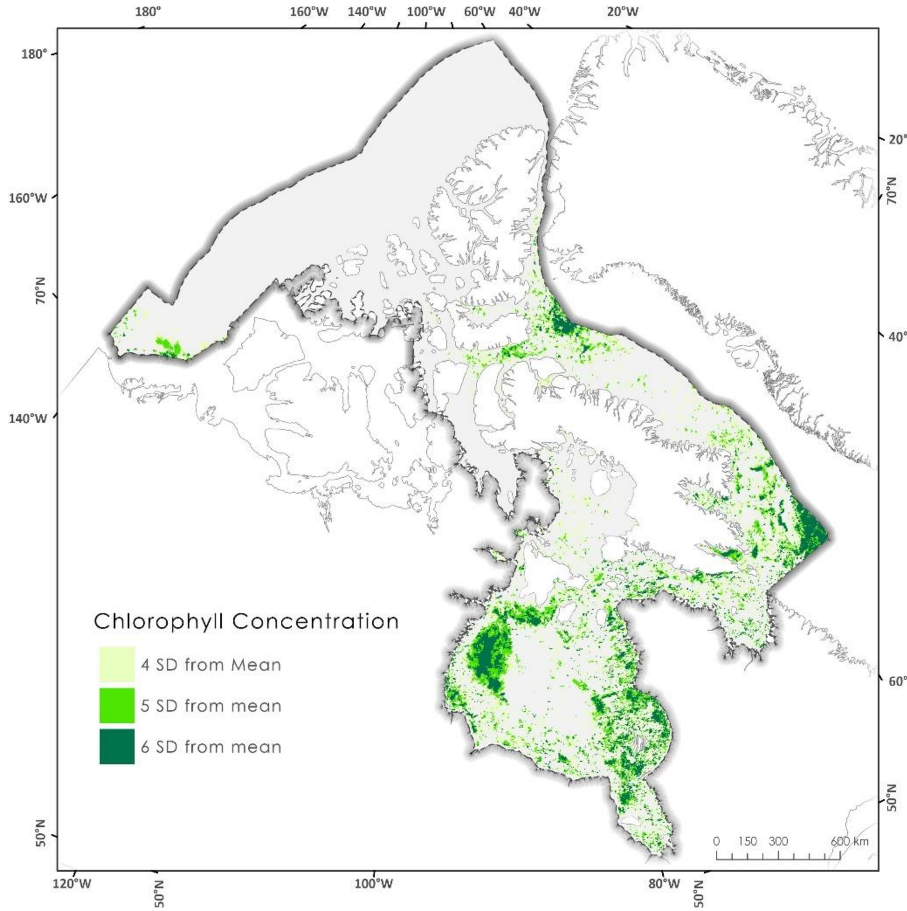

Figure 6.2. Locations of persistent chlor a concentrations (from ocean colour) observed between 2012 and 2017, shown as 4, 5, and 6 standard deviations from mean values.

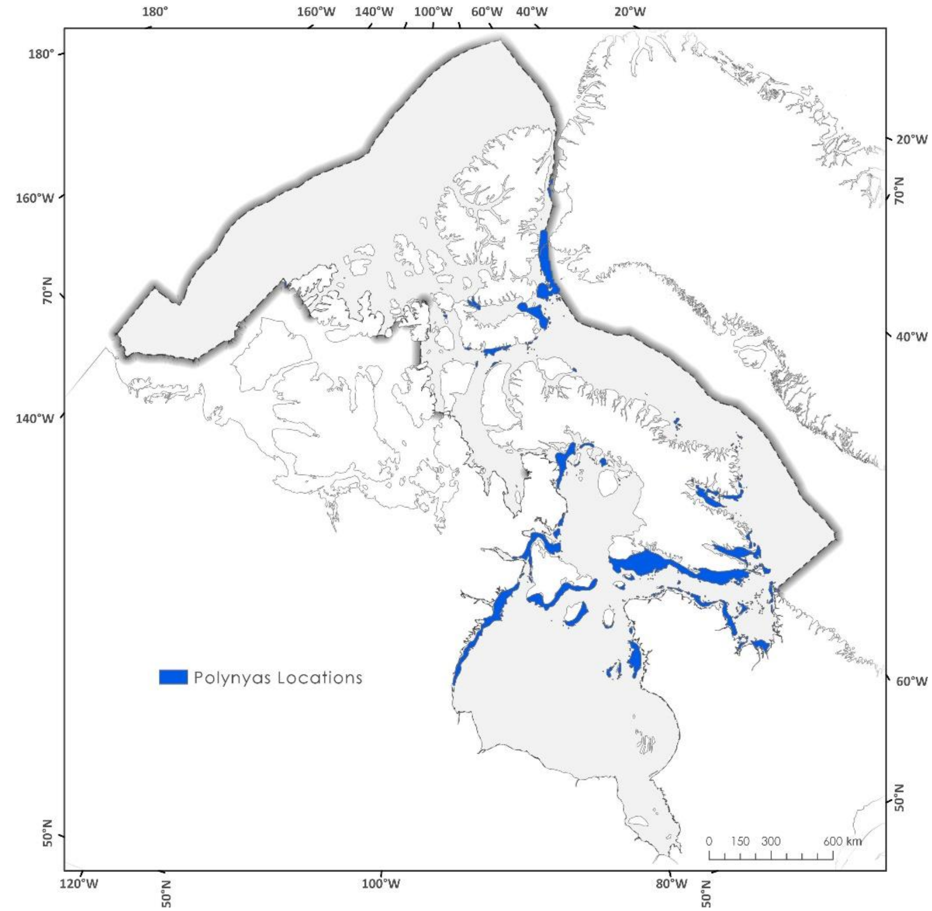

Figure 6.3. Locations of major polynyas and shore leads.

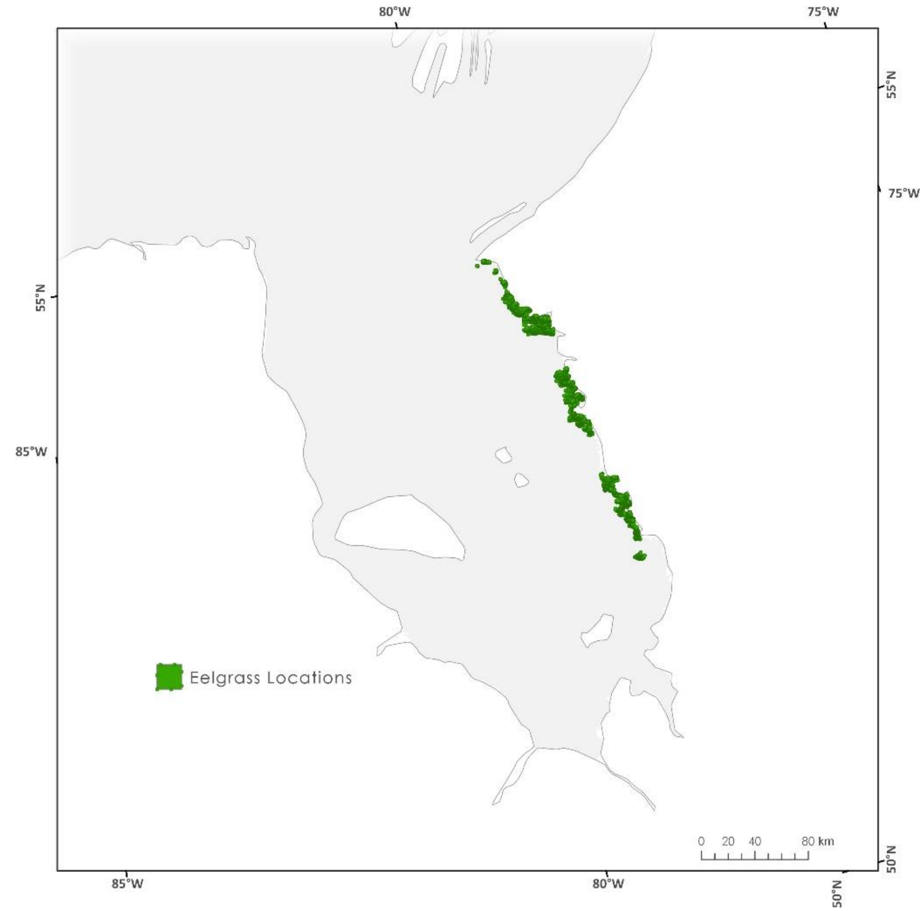

Figure 6.4. Locations of major beds of eelgrass (*Zostera marina*) in eastern James Bay.

BENTHOS

Areas of Taxonomic Richness

The data obtained from sources listed in Table 5.3 was merged with additional data on distribution of sponges, corals and sea pens from Beazley et al. (2016), Beazley et al. (2017), and ICES VME[1]. A 30 by 30 km grid was created and clipped to the MECCEA study area, and the number of species and number of families per grid cell were calculated (Figure 6.5 and Figure 6.6, respectively). The species richness and family richness distributions show a similar pattern with subtle differences. The area with the highest species richness and family richness was south of Baffin Island, near Ungava Bay and within Frobisher Bay; there was also a high family richness value near Cornwallis Island.

Note that there is no established criterion for what constitutes high versus low species richness. Therefore, arbitrarily, we defined high species richness as >40 (approximate upper 10th percentile) for families. Note also that records for numbers of species and families are strongly dependent on sampling effort and this effort is inevitably biased among the four MECCEA marine bioregions. Nevertheless, we present a summary of the data per bioregion in Table 6.1. Due to this biased among regions, and the fact that most significant taxa (sponges, corals and sea pens) are already accounted for, species richness was not included in the Marxan analysis.

Deep-sea Corals, Sea pens, Sponges

Sponges, corals, and sea pens are taxonomic groups of special interest to the MECCEA project, and to marine conservation more generally, because they are particularly vulnerable to physical disturbance, especially by bottom trawling. Data for these groups were provided courtesy of Ellen Kenchington (DFO, BIO, Halifax), and are summarized in the distributions of Kenchington et al. (2016) and modelled distributions of Beazley et al. (2017). These data, which extend from Davis Strait to Baffin Bay and Hudson Strait, were supplemented by data from the sources listed in Table 5.3. These additional data expand the area where these taxa have been found into the Hudson Bay Complex and further into the Eastern Arctic. Present records for distributions of sponges, corals and sea pens are presented in Figure 6.7, Figure 6.8 and Figure 6.9, respectively.

Table 6.1. Species richness of zoobenthos (as number of species collected) for each marine bioregion. Note the low averages indicate that most of the 30 by 30 km grid cells have a value of 0.

Bioregion	Minimum	Maximum	Average/cell
Eastern Arctic	0	92	0.1
Hudson Bay Complex	0	126	0.26
Arctic Archipelago	0	1	0.0
Arctic Basin	0	36	0.0

[1] http://vme.ices.dk/webservices.aspx

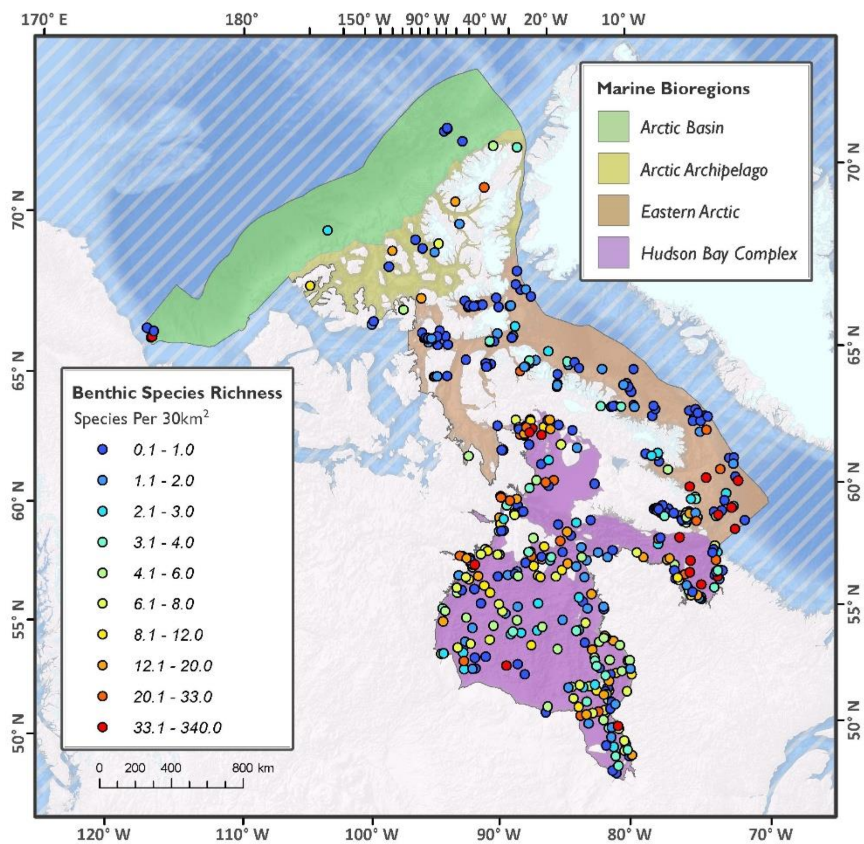

Figure 6.5. Benthic species richness—as number of species per 30 km².

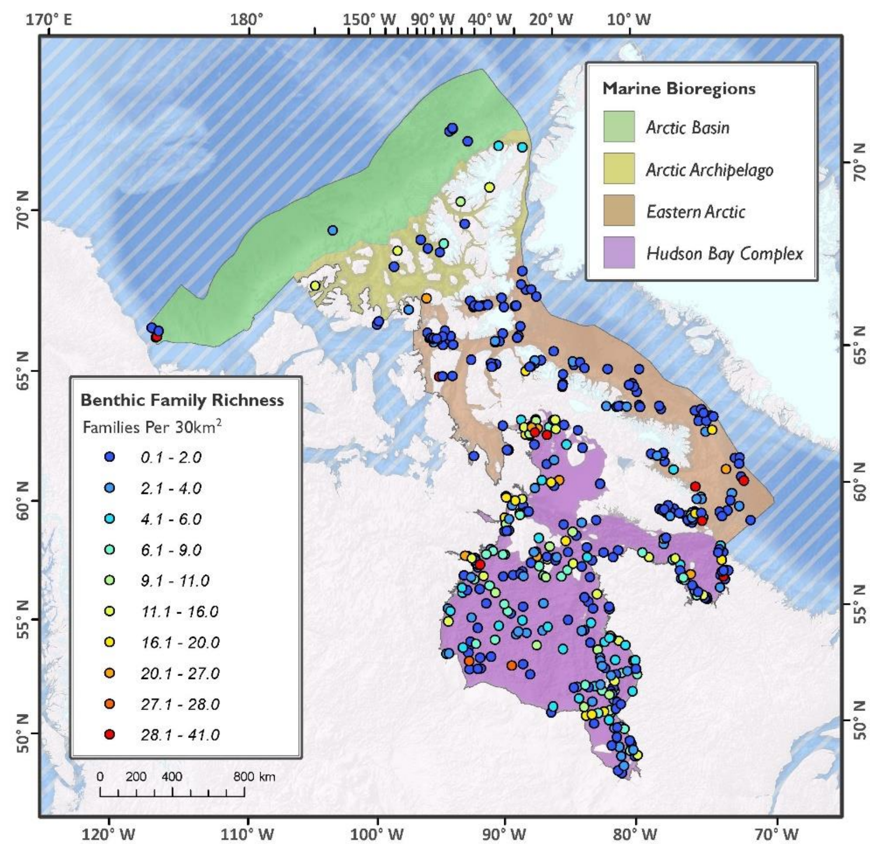

Figure 6.6. Benthic family richness—as number of families per 30 km².

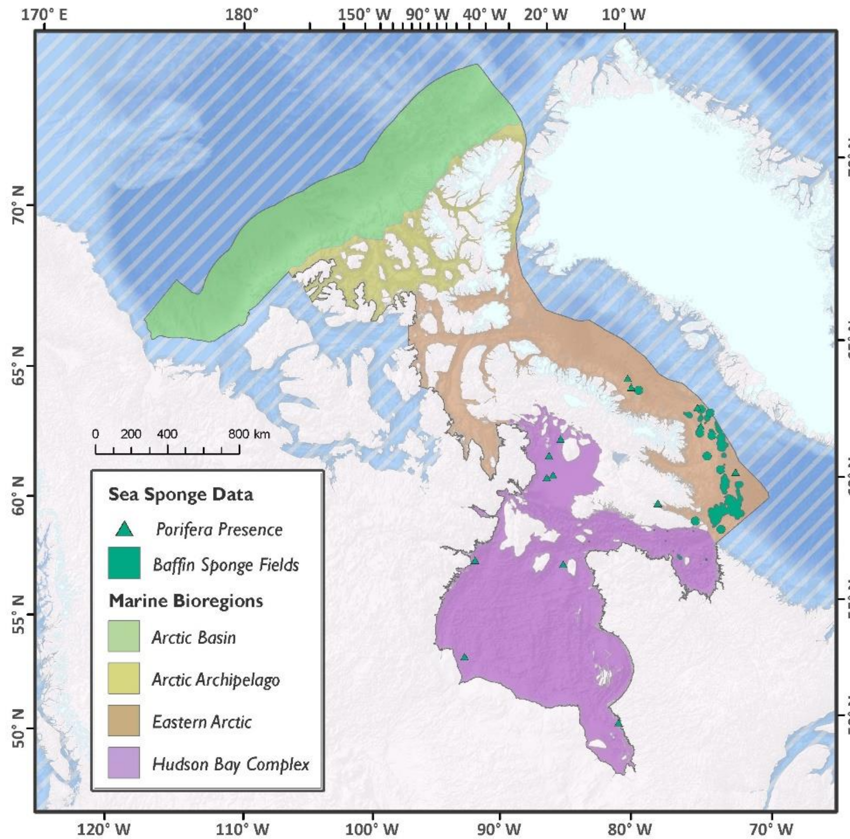

Figure 6.7. Distribution records for sea sponges (Porifera) in the four MECCEA marine bioregions.

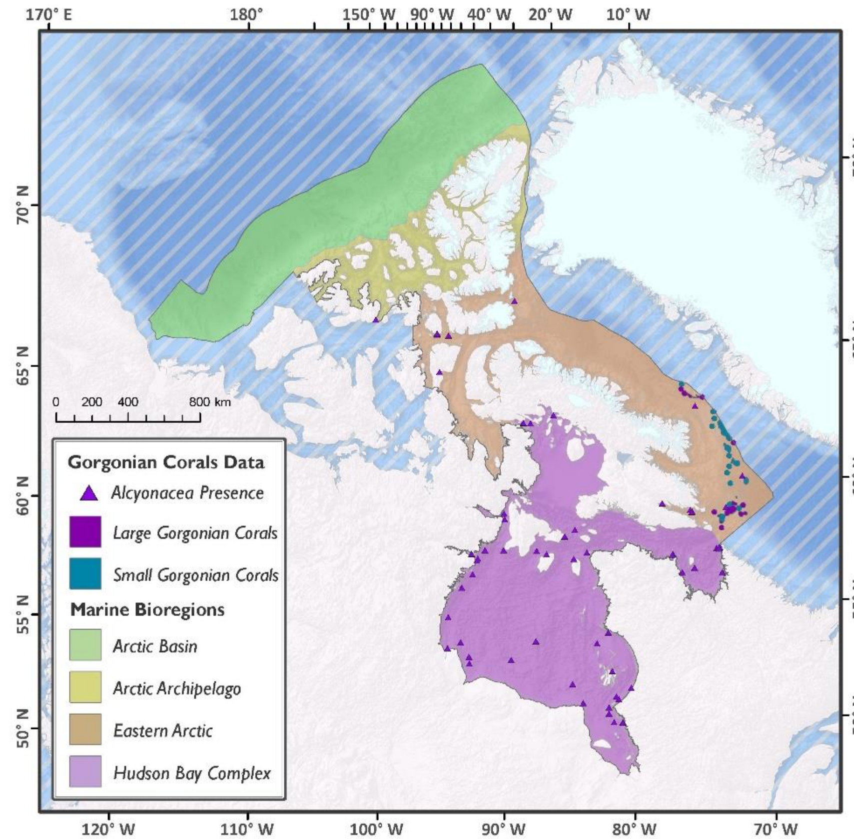

Figure 6.8. Distribution records for Alcyonacea, and “large” and “small” gorgonian corals in the four MECCEA marine bioregions.

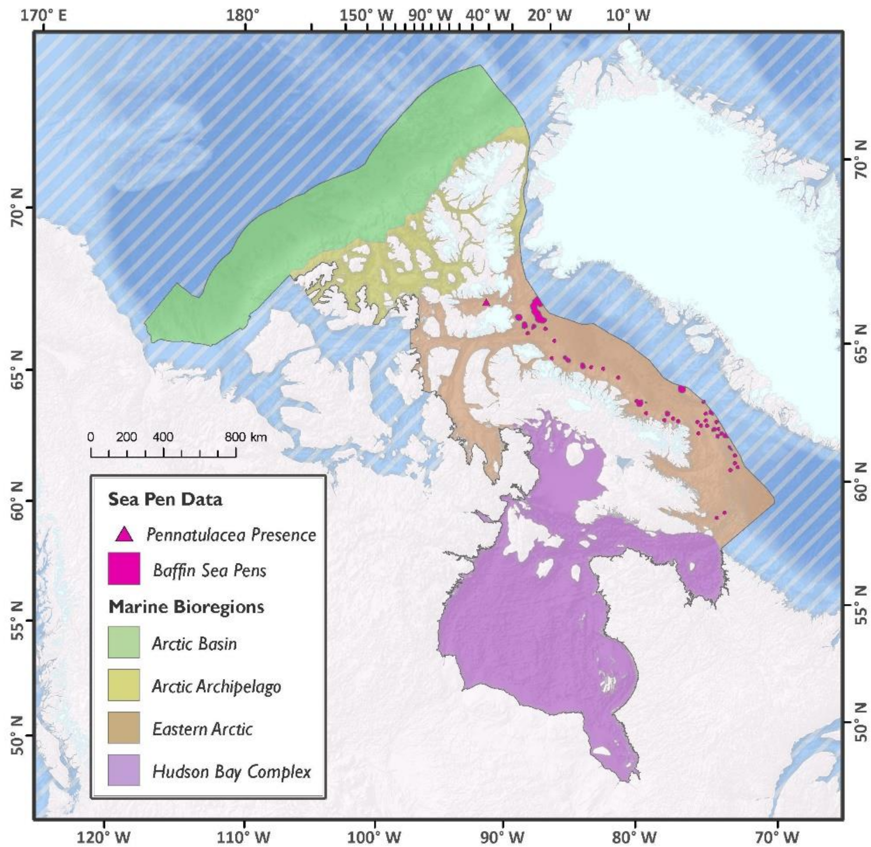

Figure 6.9. Distribution records for sea pens in the four MECCEA marine bioregions.

FISH

Areas of Taxonomic Richness

The data listed in the "working fish database" (Table 5.4) were used to examine patterns of distribution of taxonomic richness–for species and families. A 30 by 30 km grid was again created and clipped to the MECCEA study area, and the number of species and families per grid cell were calculated for each depth interval (0–50, 50–200, 200–1,000, and 1,000+ m) and for all depths combined. The species richness and family richness distributions show similar patterns, and similar patterns with depth. Only the combined data for all depths are shown in Figure 6.10 and Figure 6.11.

Note also that records for numbers of species and families are strongly dependent on sampling effort, which was most intense in Hudson Strait, Davis Strait and Baffin Bay. Nevertheless, we present a summary of the data per bioregion, in Table 6.2. Because the distributions of several individual fish species overlapped significantly with fish taxonomic richness at both the species and family level, and because of biases in these measures among the marine bioregions, they were not represented in the Marxan analyses.

Table 6.2. Species richness of fish (as number of species collected) for each marine bioregion. Note the low averages indicate that most of the 30 by 30 km grid cells have a value of 0.

Bioregion	Minimum	Maximum	Average/cell
Eastern Arctic	0	34	1.35
Hudson Bay Complex	0	27	0.64
Arctic Archipelago	0	7	0.03
Arctic Basin	0	10	0.0

Anadromous Species

Anadromous Arctic char (*Salvelinus alpinus*) occur in rivers and lakes throughout Arctic Canada (Coad and Reist, 2018). It is a key component of northern aquatic ecosystems and an important food resource for northerners (Paulic et al., 2014). Anadromous Arctic char migrate to the sea to feed and then move back into freshwater to overwinter and spawn. Moore et al. (2016) showed that Arctic charr migrate from lakes, where they spend approximatively 9 months, to the marine environment where they feed during the summer. Stocks mix while feeding in coastal waters (Paulic et al., 2014).

Among salmonids, lake trout (*Salvelinus namaycush*) is also known to be anadromous in Canadian Arctic waters, although there does not appear to be any systematic knowledge of its geographic extent or ecological significance (Harris et al., 2014). Several other species are reported as anadromous in the Canadian Arctic (Coad and Reist, 2018; see Table 6.3). In combination they are very widespread (Figure 6.12) but records are clearly very incomplete, and they were not included in Marxan analyses.

Taxa of Conservation Concern

From the "working fish database" described in Chapter 5, a suite of key species or taxa were identified by two criteria. Species were either: listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as endangered, threatened, or of special concern; or were identified by experts (specially convened by WWF-Canada) as being of conservation concern (Table 6.4). Since the COSEWIC status is assigned at the population level, not the species level, care was taken to record the correct status for the population, which made the most geographic sense for the MECCEA project.

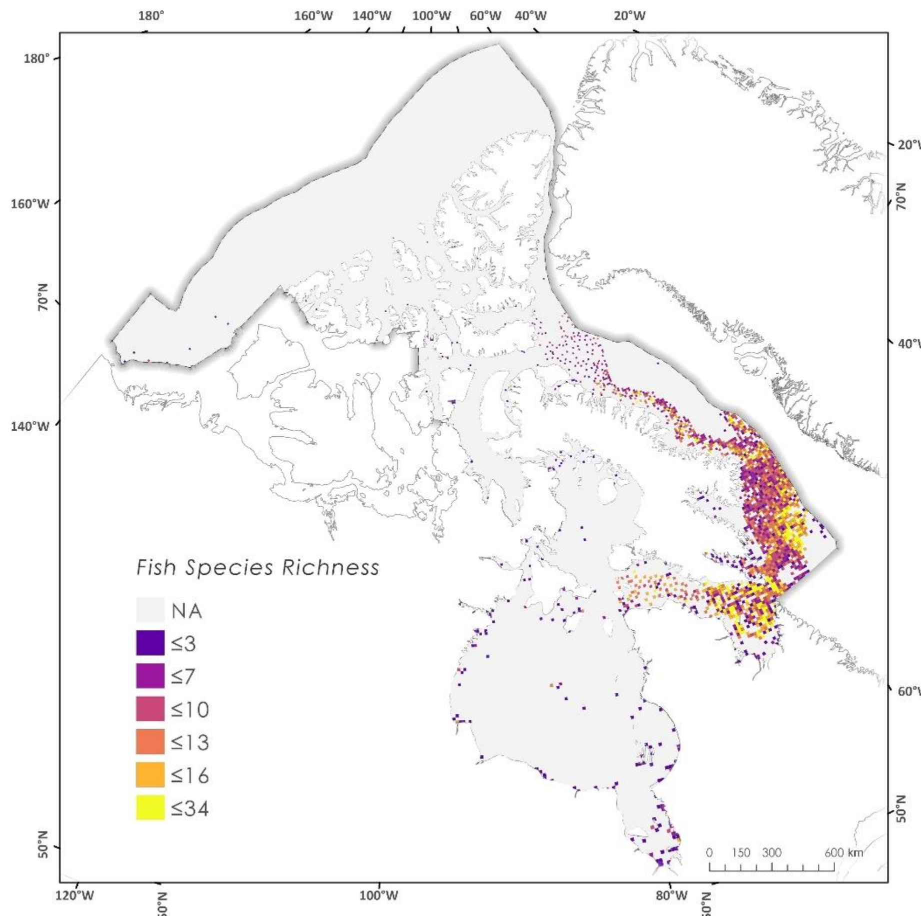

Figure 6.10. Fish species richness—as number of species per 30 km².

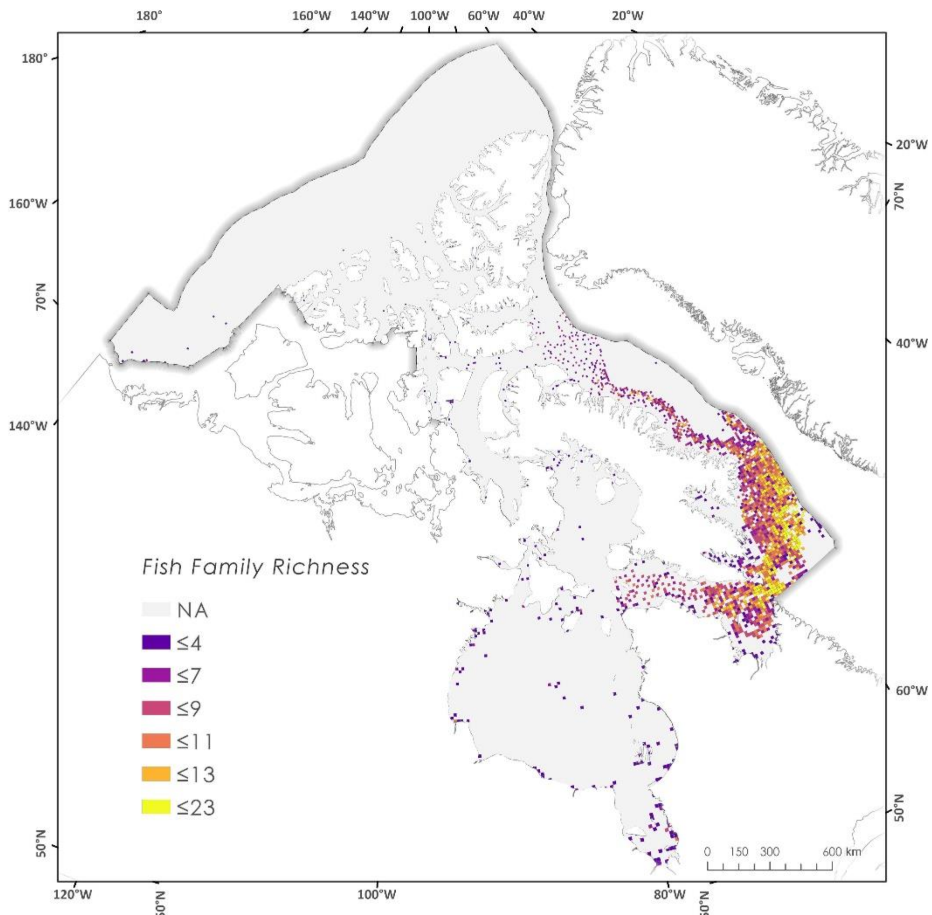

Figure 6.11. Fish family richness—as number of families per 30 km².

Table 6.3. List of fish species reported as anadromous in the Canadian Arctic (Coad and Reist, 2018). Their combined distributions are shown in Figure 6.12.

Anadromous fish species in the Canadian Arctic
Coregonus artedi
Coregonus autumnalis
Coregonus clupeaformis
Coregonus sardinella
Gasterosteus aculeatus
Lethenteron camtschaticum
Mallotus villosus
Pungitius pungitius
Salmo salar
Salvelinus alpinus
Salvelinus fontinalis

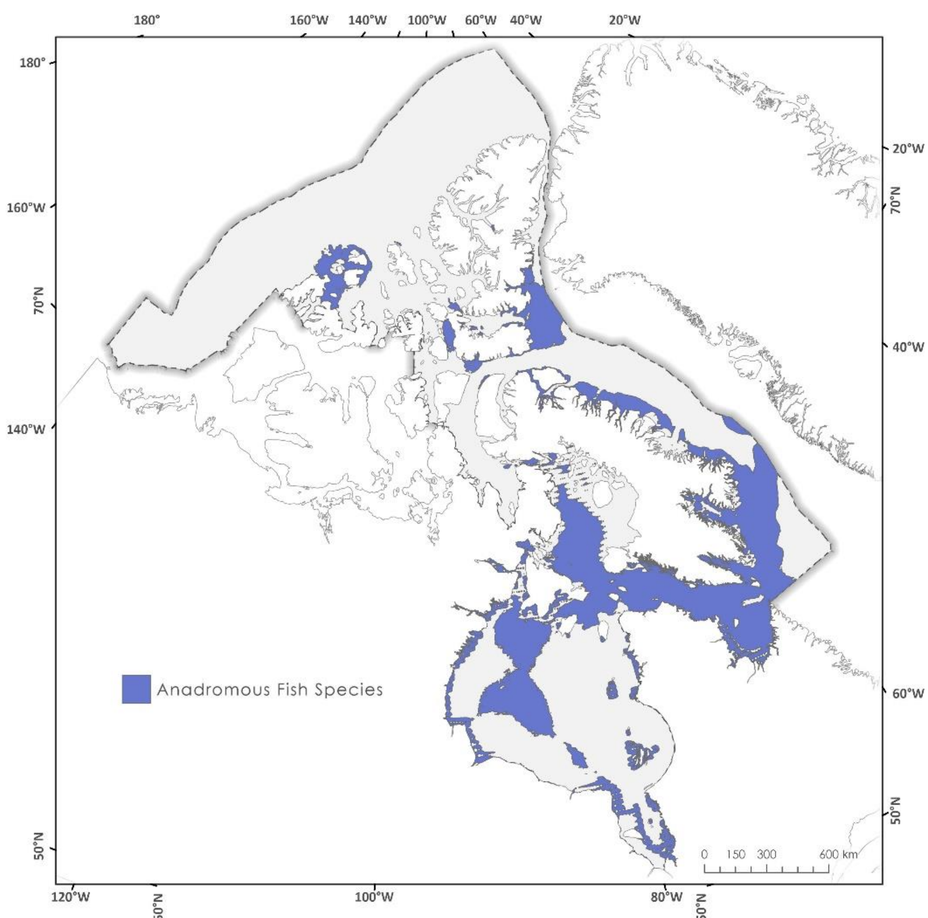

Figure 6.12. Distribution records for anadromous fish species in the MECCEA study area.

Table 6.4. Key species of fish identified by COSEWIC and a panel of experts convened by WWF-Canada as being of conservation concern.

Species (or taxon) Name	Common Name	Species (or taxon) Name	Common Name
Amblyraja radiata	Thorny skate	*Gaidropsarus ensis*	Threadfin rockling or phycid hake
Ammodytes dubius	Northern sandlance	*Hippoglossoides platessoides*	American plaice
Anarhichas denticulatus	Northern wolffish	*Liparis fabricii*	Gelatinous snailfish
Anarhichas lupus	Atlantic wolffish	*Liparis gibbus*	Variegated snailfish
Anarhichas minor	Spotted wolffish	*Lycodes* (genus)	Eelpout
Arctogadus glacialis	Arctic cod	*Lycodes eudiplerostictus*	Eelpout
Arctozenus risso	White barracudina	Macrouridae (family)	Grenadiers
Artediellus atlantius	Atlantic hookear sculpin	*Macrourus berglax*	Roughhead grenaider
Aspidophoroides olrikii	Arctic alligatorfish	*Mallotus villosus*	Capelin
Bathyraja spinicauda	Spinytail skate	*Myoxocephalus quadricornis*	Fourhorn sculpin
Benthosema glaciale	Glacier lantern fish	Rajiformes (order)	Skates
Boreogadus saida	Polar cod	*(Ambly)Raja hyperborea*	Arctic skate
Clupea harengus	Atlantic herring	*Reinhardtius hippoglossides*	Greenland halibut
Coregonus (genus)	Whitefish	*Salvelinus* (genus)	Charr
Coregonus clupeaformis	Lake whitefish	*Salvelinus alpinus*	Arctic charr
Coryphaenoides rupestris	Rock grenadier	*Sebastes* (genus)	Redfish
Cottidae (family)	Sculpins	*Sebastes mentella*	Deepwater redfish
Cyclopterus lumpus	Lumpfish	*Somniosus microcephalus*	Greenland shark
Gadidae (family)	Cods	*Trachyrincus murrayi*	Roughnose grenadier
Gadus morhua	Atlantic cod	*Triglops nybelini*	Sculpin

Distributions of each of these key species were then modelled using the program Maxent (Phillips et al., 2018), which is suitable for the type of fish occurrence data in the MECCEA project. Maxent uses taxon occurrences and environmental data to predict a distribution based on maximum entropy (Phillips et al., 2017). Relationships between demersal fishes and environmental variables in the North Atlantic/Arctic have been described by many (e.g. Swain and Benoit, 2006; Lenoir et al., 2011; Kessel et al., 2016). For the purposes of this project, we chose depth, surface temperature, and surface salinity as the environmental variables most likely to determine distributions, and because these data were already available for the study (see Chapter 4). Further details on models, distributions and statistical tests are available from WWF-Canada.

The distribution maps so produced were next examined for species co-occurrences and significant overlaps in geographic ranges among species. Some of the species recommended for inclusion by experts, when modelled, had virtually identical distributions. Therefore, these were grouped into single layers (see Table 6.5, and examples: Figure 6.13–Figure 6.17) instead of each being included separately in order to avoid the network design being dominated by sheer numbers of layers. Represented by their grouped layer, these individual species were then removed from the conservation features list (Appendix 2) and from subsequent Marxan analysis. The rationale for this decision was that, by including the layer for one species, we would also capture habitat for the other species in a group when their habitat distribution is essentially the same.

Table 6.5. Fish conservation features (CFs) that also include other species. The other fish CFs (see Appendix 2) are not grouped with any other species.

CF Name in Appendix 2: *Coregonus* (genus) habitat
Includes: Lake whitefish, whitefish species group
CF Name in Appendix 2: Northern wolffish habitat
Includes: Northern wolffish, roughead grenadier, white barracudina, skates, grenadiers, sculpins, American plaice, redfish, cods, Atlantic herring, Capelin, Greenland halibut, Arctic alligatorfish, polar cod, thorny skate, Atlantic hookear sculpin, eelpout
CF Name in Appendix 2: Rock grenadier habitat
Includes: Rock grenadier, Roughnose grenadier
CF Name in Appendix 2: Spotted wolffish habitat
Includes: Spotted wolfish, Deepwater redfish, Atlantic cod
CF Name in Appendix 2: Arctic skate habitat
Includes: Threadfin rockling, Arctic skate
CF Name in Appendix 2: Rajiformes (order) habitat
Includes: Thorny skate, Spinytail skate

PRIORITY SPECIES

Priority species in the MECCEA study include: species assessed by COSEWIC as having a conservation status of special concern or higher; endemic Arctic species; species recommended for inclusion through expert advice based on the species' ecological role; and species identified for other reasons (see Text Box 6.1). The species within the following sections of the report accord with these criteria.

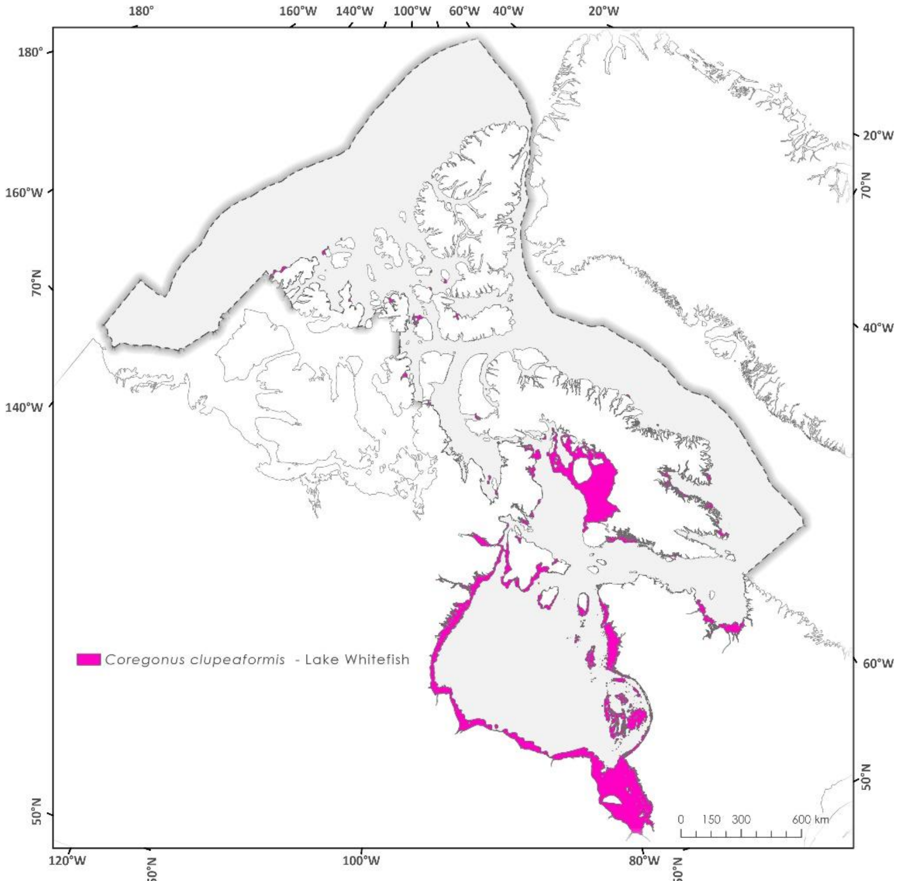

Figure 6.13. Distribution records for *Coregonus clupeaformis* (lake whitefish) in the MECCEA study area.

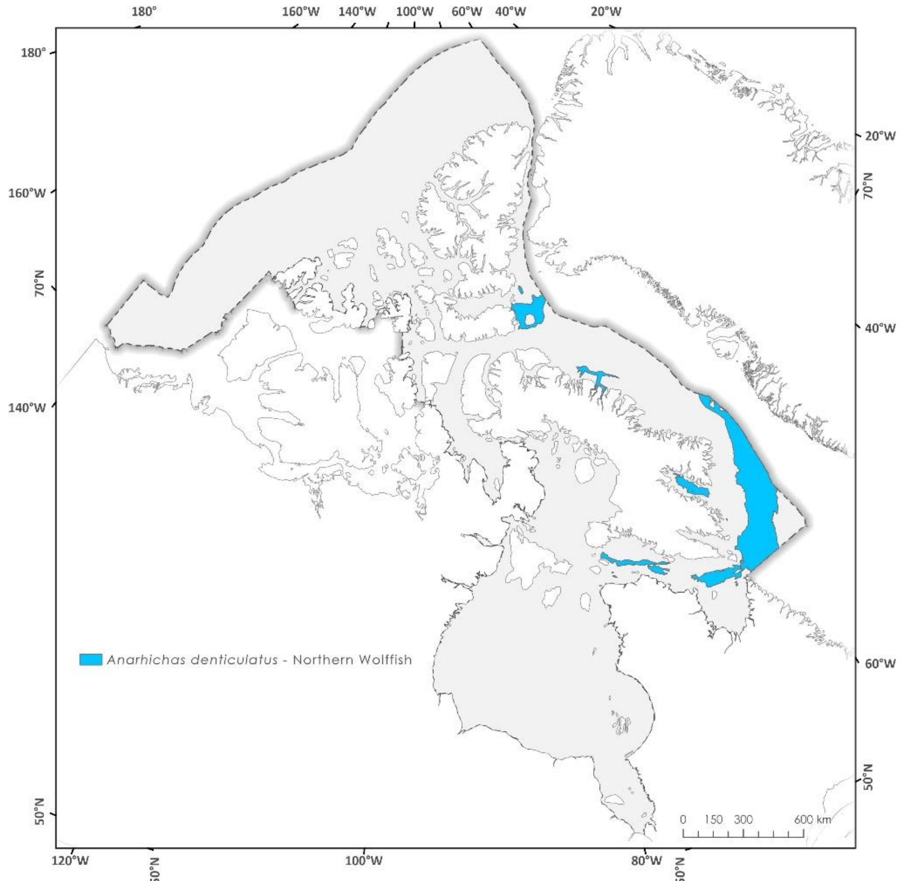

Figure 6.14. Distribution records for *Anarhichas denticulatus* (northern wolffish) in the MECCEA study area.

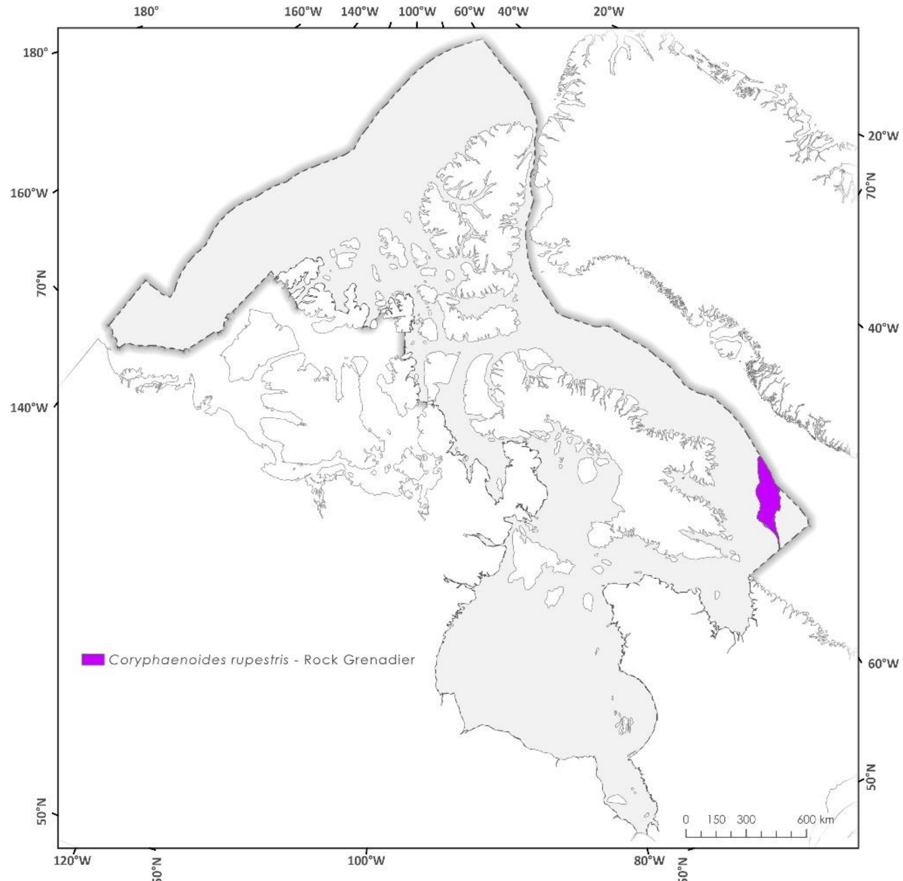

Figure 6.15. Distribution records for *Coryphaenoides rupestris* (rock grenadier) in the MECCEA study area.

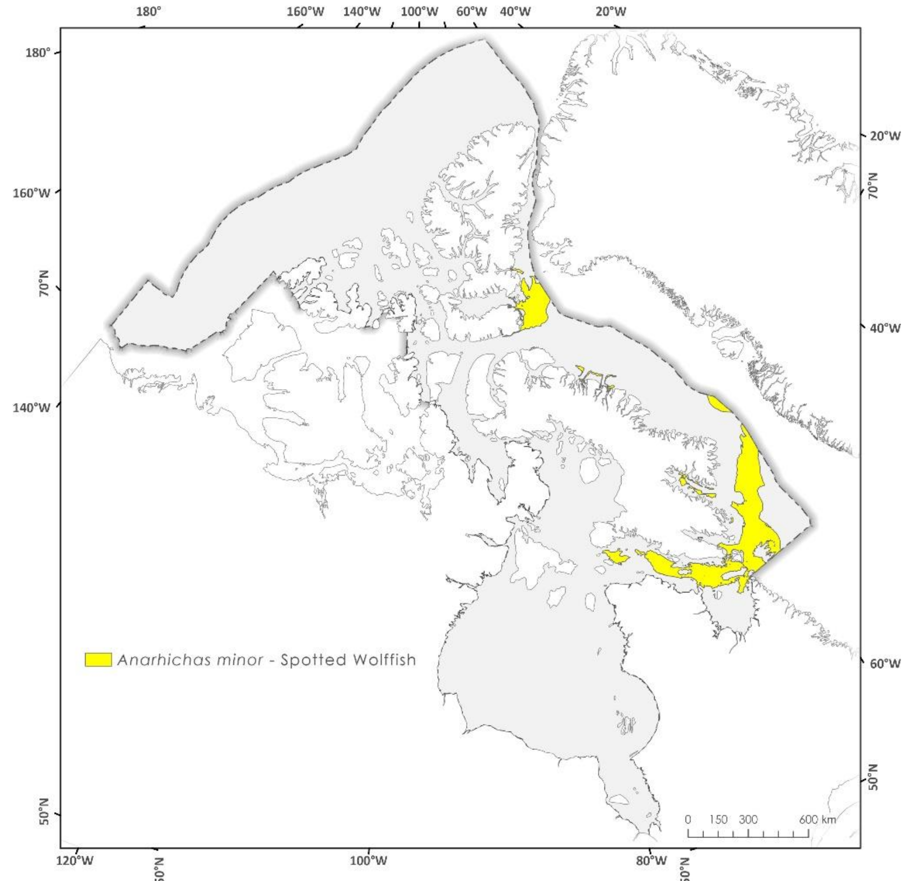

Figure 6.16. Distribution records for *Anarhichas minor* (spotted wolffish) in the MECCEA study area.

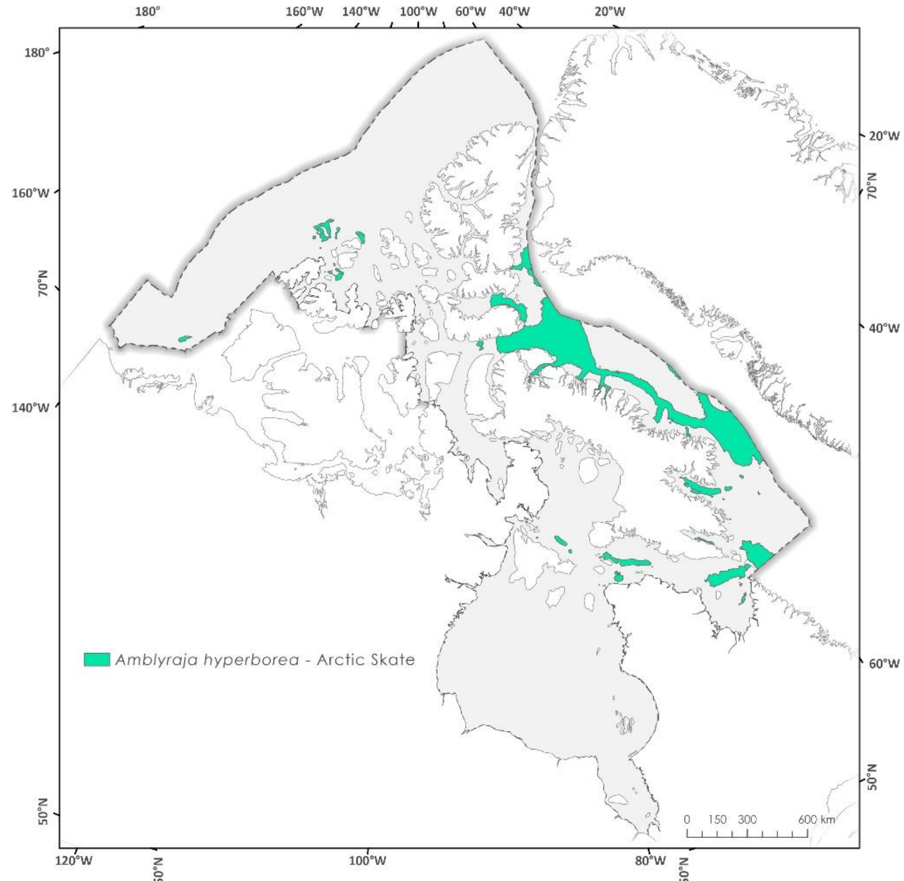

Figure 6.17. Distribution records for *Amblyraja hyperborea* (Arctic skate as representative of order Rajiformes) in the MECCEA study area.

Key Habitat Concept

The concept of a “key habitat” is considered here because it relates most importantly to MECCEA Conservation Objective 1a - Protect key habitats of Arctic priority species (see Text Box 2.1). These priority species are considered in the following sections of this report. We define a key habitat as follows: a habitat associated with a specific life history stage of a species, excluding habitat used exclusively by the species as a transit route during migration. This is similar to the concept of “critical habitat” in the *Species at Risk Act* (SARA).

A key habitat may, therefore, include any areas where critical life stage activities take place, or areas otherwise necessary to the survival of a species. Thus, it excludes knowledge of the general distribution of a species. We assessed key habitat areas, where known for each species, through a review of scientific literature, information from IK sources, and from expert workshop reports and participants. The various key habitats recognized for priority species are listed in Appendix 2.

MARINE MAMMALS

Data types, sources and references for marine mammals are summarized in Table 6.6. and Table 6.7. For further IK sources, see below.

Polar Bear – Ursus maritimus

Polar bears are found throughout the Canadian Arctic, where they are generally considered to exist in 13 sub-populations. Of these, 11 are represented within the MECCEA study area. Polar bears are listed as a species of “special concern” by COSEWIC due to the loss of ice habitat from climate change. In 2017, the Canadian population was estimated to be approximately 17,300 individuals, with 26,000 estimated across the Arctic as whole. Polar bears rely on seasonal ice for hunting seals, their primary prey. Generally, polar bears track seals on ice in early winter and along the land-fast/floe ice edge in the spring. Females will often den to give birth on coastal areas in their range; however, denning on land-fast ice has been observed. Locations of these key habitat areas are shown in Figure 6.18.

Beluga Whale – Delphinapterus leucas

Beluga have a circumpolar Arctic/sub-Arctic distribution and occur in high concentrations throughout the western and eastern Canadian Arctic. It is estimated that 142,000 individuals reside in Canada of 200,000 globally. Within Canada there are seven distinct stocks, with one stock in Ungava Bay being potentially extirpated. Generally, belugas migrate seasonally, moving from estuaries and open water in the summer, to foraging grounds in the fall, and mobile pack-ice in the winter. Their calving areas are shown in Figure 6.19.

Bowhead Whale – Balaena mysticetus

Bowhead are found throughout the Arctic, with the exceptions of the Arctic Basin and the Scandinavian/Siberian coast. They are a year-round Arctic resident and generally prefer straits and inlets to deep open water. Furthermore, they spend much of the year at the ice edge, migrating north or south as the ice expands and contracts. There are an estimated 10,000 individuals left globally, the majority of which reside in the Bering-Chukchi-Beaufort and Baffin Bay-Davis Strait stocks. While these two stocks are believed to be stable/increasing, there is concern around the effect climate change may have on their preferred habitat. Their seasonal habitat use is shown in Figure 6.20.

Table 6.6. Summary of marine mammal data sources.

Species	Conservation Feature (CF)	Source Title	Description	Data Processing
Polar Bear[1]	Denning Areas	International Polar Bear Conservation Center (IPBCC) Polar Bear Denning Areas Map for Canada, 2018.	Polar bear denning data obtained from a compilation by the IPBCC, commissioned by WWF. This identified 97 polar bear denning areas within Canada. Sources came from peer-reviewed research, IK (Indigenous Knowledge), government surveys, and local community input.	Denning polygons were split into separate conservation features spatially based on Canadian subpopulations producing 16 CF layers.
Beluga[2]	Summer Range	The Arctic Marine Workshop, 2010	Seasonal use areas were obtained from data produced at the 2010 DFO Arctic Marine Workshop. Species experts prepared reports and maps for species/groups based on their expertise. Beluga ranges were delineated based on synthesis of 28 years of aerial surveys, 20 years of satellite tracking, as well as reports from local Inuit communities.	Polygons were split into separate conservation features spatially by stock and marine bioregion producing 5 CF layers.
	Winter Range			Polygons were split into separate conservation features spatially by stock and marine bioregion producing 3 CF layers.
	Summer High Density			Na
	Year-Round High Density			Na
	Foraging	Mapping Critical Whale Habitat in the Nunavut Settlement Area Report	WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Beluga foraging grounds were identified from 2 local community IK surveys (Kimmirut & Iqaluit) and satellite tagging studies in Peel Sound.	Polygons were split into separate conservation features spatially based on stocks and marine bioregion producing 3 CF layers.
	Overwintering		WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Overwintering areas were delineated, representing more specific habitat than general winter range areas.	Na

Species	Conservation Feature (CF)	Source Title	Description	Data Processing
	Calving		WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Written and mapped sources delineated beluga calving grounds. This work drew largely on surveys of IK as well as monitoring data in Prince Regent Inlet.	Polygons were split into separate conservation features spatially based on stocks producing 4 CF layers.
Bowhead[3]	Summer Range	The Arctic Marine Workshop, 2010	Seasonal bowhead ranges were obtained from data produced at the 2010 DFO Arctic Marine Workshop. Experts prepared reports and maps for species/groups, which were reviewed by the workshop. The report notes that Bowhead range is based on scientific survey data, IK and reports from communities with very little extrapolation of range distribution.	Polygons were split into separate conservation features spatially by stock and marine bioregion producing 3 CF layers.
	Winter Range			Polygons were split into separate conservation features spatially by stock and marine bioregion producing 3 CF layers.
	Foraging Area	Diet, feeding behaviour and habitat-use patterns of bowhead whales in the Eastern Canadian Arctic	As means of investigating feeding patterns of Canada-West Greenland Bowheads, 25 adult individuals were tagged with satellite loggers. Through analysis of bowhead movements logged by the tags, area restricted movement (ARM) was identified from transit movement. Areas of ARM were collated with diet/ prey information and Cumberland Sound was identified as being of high importance for feeding.	A generalized polygon was manually constructed to capture the concentration of ARM telemetry points present in Cumberland Sound.
	Summer Foraging/ Calving Area	Mapping Critical Whale Habitat in the Nunavut Settlement Area Report	WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Reviewed sources for bowhead calving and foraging showed areas important for both activities.	Separate polygons for summer foraging and calving were dissolved as they were nested within each other. Polygons were split into separate conservation features spatially based on stocks and marine bioregion producing 3 CF layers.
	Foraging areas		WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut, including overwintering sites. These areas represent more specific use areas than general	Na
	Overwintering			

Species	Conservation Feature (CF)	Source Title	Description	Data Processing
			the general winter ranges of the species/ stocks.	
	Calving		WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. 8 written and mapped sources identifying calving habitat were used to delineate bowhead calving grounds. This work drew largely on surveys of IK compiled from local communities, with many areas being corroborated by scientific monitoring.	Polygons were split into separate conservation features spatially based on stocks and marine bioregion.
Narwhal[4]	Summer Range	The Arctic Marine Workshop, 2010	Seasonal narwhal use areas were obtained from data produced at the 2010 DFO Arctic Marine Workshop. Experts prepared reports and maps for species/groups, which were reviewed by the workshop. Narwhal ranges were delineated based on a synthesis of summer/ winter aerial surveys, and satellite tagging studies.	Polygons were split into separate conservation features spatially based on stocks and marine bioregion producing 5 CF layers.
	Winter Range			Polygons were split into separate conservation features spatially based on stocks and marine bioregion producing 2 CF features.
	Summer High Density			Na
	Winter High Density			Na
	Summer Foraging/ calving areas	Mapping Critical Whale Habitat in the Nunavut Settlement Area Report	WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Narwhal foraging areas where identified from existing spatial data and corroborating descriptive sources. Evidence from 9 different studies where used to identify important areas.	Separate polygons for summer foraging and calving in Peel & Eclipse Sound were dissolved as they were nested. within each other. Polygons were split into separate conservation features spatially based on stocks and marine bioregion.

Species	Conservation Feature (CF)	Source Title	Description	Data Processing
	Summer Calving		WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on critical cetacean habitat within Nunavut. Narwhal calving areas were identified from existing spatial data and corroborating descriptive sources. Evidence from 24 different studies where used to identify important areas.	Polygons were split into separate conservation features spatially based on stocks producing 2 CF layers.
Walrus[5]	Wintering Areas	The Arctic Marine Workshop, 2010	Seasonal Walrus use areas were obtained from data produced at the 2010 DFO Arctic Marine Workshop. Species experts prepared reports and maps, which were reviewed by the workshop. Walrus stock ranges were developed based on synthesis of scientific research and IK surveys conducted between 1995-2010.	Polygons were split into separate conservation features spatially based on population producing 3 CF layers.
	Terrestrial Haulout Sites	Walrus haulouts in the eastern Canadian Arctic: a database to assist in land use planning initiatives	WWF commissioned Higdon Wildlife Consulting to compile existing knowledge on terrestrial walrus haulout sites within Nunavut. Sources included assessment of the status of Atlantic walrus populations .	Polygons were split into separate conservation features spatially based on population and marine bioregion producing 5 CF layers.
		Estimates of Abundance and Total Allowable Removals for Hudson Bay-Davis Strait and South and East Hudson Bay Atlantic Walrus Stocks	Aerial surveys were flown during September 2014. Walruses were counted in the northern Hudson Bay-Hudson Strait portion of the Hudson Bay-Davis Strait stock, and the South and East Hudson Bay stock. Identified haulout sites were mapped spatially.	Polygons were split into separate conservation features spatially by marine bioregion.
Hooded Seal[6]	Whelping Patch	The Arctic Marine Workshop, 2010	Hooded seal whelping patch was obtained from data produced at the 2010 DFO Arctic Marine Workshop. Species experts prepared reports and maps for species/groups, which were reviewed by the workshop. Hooded seals are known to whelp on the pack-ice of southern Davis Strait. The report notes that exact location and shape varies annually with ice conditions.	Na

Species	Conservation Feature (CF)	Source Title	Description	Data Processing
	Core Summer Feeding Areas	Drift Diving by Hooded Seals (Cystophora cristata) in the Northwest Atlantic Ocean	Through use of Satellite Relay Loggers, 51 adult seals were tagged between 2004-2008. Changes in dive rates were mapped spatially and can be used as a proxy of feeding behavior/success.	A generalized polygon was manually constructed to capture the concentration of telemetry points present in the known summer feeding range of the species. After delineation, polygons were reviewed by the data provider for accuracy.
Harp Seal[7]	Core Summer Feeding Areas	Unpublished Harp Seal Tagging Data	Time-series spatial location data from tagged harp seals in the Northeast Atlantic was obtained from the DFO. Tagging occurred in 1995-97 (n= 21) & 2004-05 (n =13). Individuals were tagged in the Maritimes and tracked to their summer feeding zones in Baffin Bay.	A generalized polygon was manually constructed to capture the concentration of telemetry points present in the known summer feeding range of the species. After delineation, polygons were reviewed by the data provider for accuracy.

[1]Leatherdale International Polar Bear Conservation Centre (2018).
[2]Higdon (2017); Stephenson and Hartwig (2010).
[3]Fortune (2018); Higdon (2017); Stephenson and Hartwig (2010).
[4]Higdon (2017); Stephenson and Hartwig (2010).
[5]DFO (2015); Higdon (2016).
[6]Andersen et al. (2014).
[7]Stephenson and Hartwig (2010); Stenson (1997) unpublished data; Stenson (2005) unpublished data.

Table 6.7. Conservation features are based on the Nunavut Coastal Resources Inventory (Government of Nunavut, 2008) and Nunavut Department of the Environment reports (Nunavut Department of Environment, Fisheries and Sealing, 2008, 2009, 2010, 2012, 2013, 2014, and 2015). Data from Cape Dorset, Hall Beach, Pond Inlet, Rankin Inlet and Resolute was provided to WWF-Canada through a data sharing agreement with the Department of Fisheries and Sealing and has not been published yet.

CF Group	Conservation Feature	Included populations/ management units	MB†	Notes/Data Processing
Polar bear key habitats	Polar bear locally identified habitat	Baffin Bay, Davis Strait, Foxe Basin, Gulf of Boothia, Lancaster Sound, Norwegian Bay	EA, HBC, AA	
Beluga key habitats	Beluga locally identified habitat	Cumberland Sound, Eastern High Arctic-Baffin Bay, Eastern Hudson Bay, Western Hudson Bay	EA, HBC	CF labelled as “Coastal Baffin Island” in the CF table may be habitat for Cumberland Sound and/or East High Arctic-Baffin Bay management units CF labelled as “Eastern Hudson Bay/Western Hudson Bay” in CF table may be habitat for either the Western Hudson Bay or Eastern Hudson Bay management units
	Beluga locally identified winter habitat	Cumberland Sound, Eastern High Arctic-Baffin Bay	EA	
Bowhead key habitats	Bowhead locally identified habitat	Davis Strait, Coastal Baffin Bay, East Canada-West Greenland	EA, HBC	EA subdivided into three clusters: Davis Strait cluster, Coastal Baffin Bay cluster, and “EA” these are all from the same management unit, East Canada-West Greenland) but were subdivided within the bioregion for replicability
Narwhal key habitats	Narwhal locally identified habitat	Baffin Bay stocks, Northern Hudson Bay	HBC, EA,	EA subdivided into three clusters for replicability (all pertaining to the Baffin Bay narwhal stocks): Lancaster Sound/Baffin Bay, East Baffin Island, and South Baffin Bay
Walrus key habitats	Walrus locally identified year-round habitat	Canadian Central Arctic	HBC	
	Walrus locally identified habitat	Canadian Central Arctic, Canadian High Arctic, Canadian Low Arctic	HBC, EA, AA	

CF Group	Conservation Feature	Included populations/ management units	MB†	Notes/Data Processing
Hooded seal key habitats	Hooded seal locally identified habitat	N/A	EA, HBC	
Harp seal key habitats	Harp seal locally identified habitat	N/A	HBC, EA	EA bioregion subdivided into two clusters for replicability: Lancaster-Boothia and South Baffin Bay
Bearded seal key habitats	Bearded seal locally identified habitat	N/A	HBC, EA	EA bioregion subdivided into two clusters for replicability: Lancaster-Boothia and South Baffin Bay
Ringed seal key habitats	Ringed seal locally identified habitat	N/A	AA, HBC, EA	
Fish key habitats	Arctic charr locally identified habitat	N/A	HBC, EA, HBC	EA bioregion subdivided into two clusters for replicability: Lancaster-Boothia, South Baffin Bay
	Arctic cod locally identified habitat	N/A	EA, HBC	
	Greenland shark locally identified habitat	N/A	EA	

†Marine Bioregions (MB) are Arctic Archipelago (AA), Arctic Basin (AB), Eastern Arctic (EA), and Hudson Bay complex (HBC).

Narwhal – Monodon monoceros

Narhwal are largely distributed in the Eastern Canadian Arctic and West Greenland, with some in the north Atlantic/Svalbard region. Of the estimated global population of 160,000, 90% (142,000) are thought to reside in Canada/East Greenland. In Canada, narwhal generally migrate seasonally from the north coast of Baffin Island, to the deeper waters of Baffin Bay and Davis Strait where mobile pack-ice is present in the winter. There are 7 stocks recognized in Canada, ranging from Jones Sound and Smith Sound, to North Hudson Bay/Southampton Island. The 7 stocks comprise two populations, the Northern Hudson Bay population (one stock) and the Baffin Bay population (consisting of the high Arctic stocks, which have distinct summering areas but mix together in their overwintering areas). Identified calving areas are shown in Figure 6.21.

Atlantic Walrus – Odobenus rosmarus

Walrus are found throughout the Arctic, where they have been divided into 3 subspecies, of which the Atlantic walrus is primarily found in Canada/Greenland. Furthermore, in Canada this subspecies is recognized as having 3 distinct populations with 8 distinct stocks among them. Canadian stocks contain an estimated 23,000 individuals, but it is recognized that there is a lack of knowledge around population sizes, stability, and sustainable harvest rates.

In terms of habitat preference, walrus spend much of the winter on ice near the floe edge, and on pack-ice or terrestrial coastal areas in the summer. These haulout sites (Figure 6.22) are usually selected in areas that give them preferential access to shallow waters where they forage (<100 m).

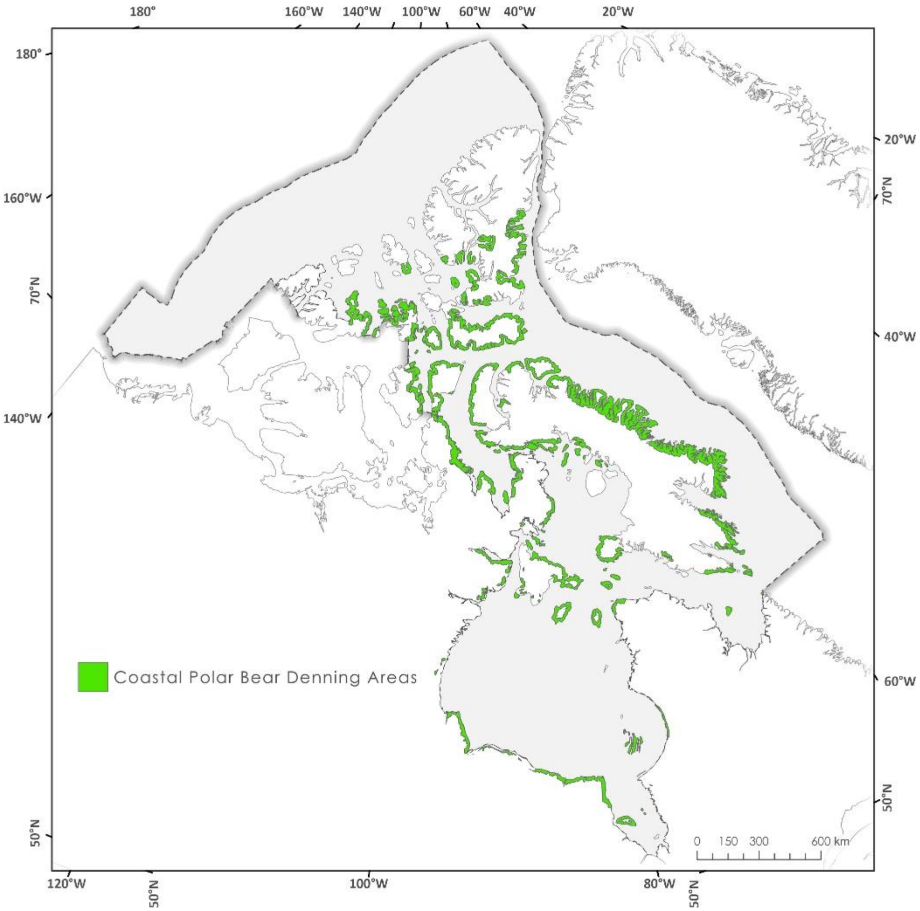

Figure 6.18. Known polar bear denning areas in the Canadian Arctic.

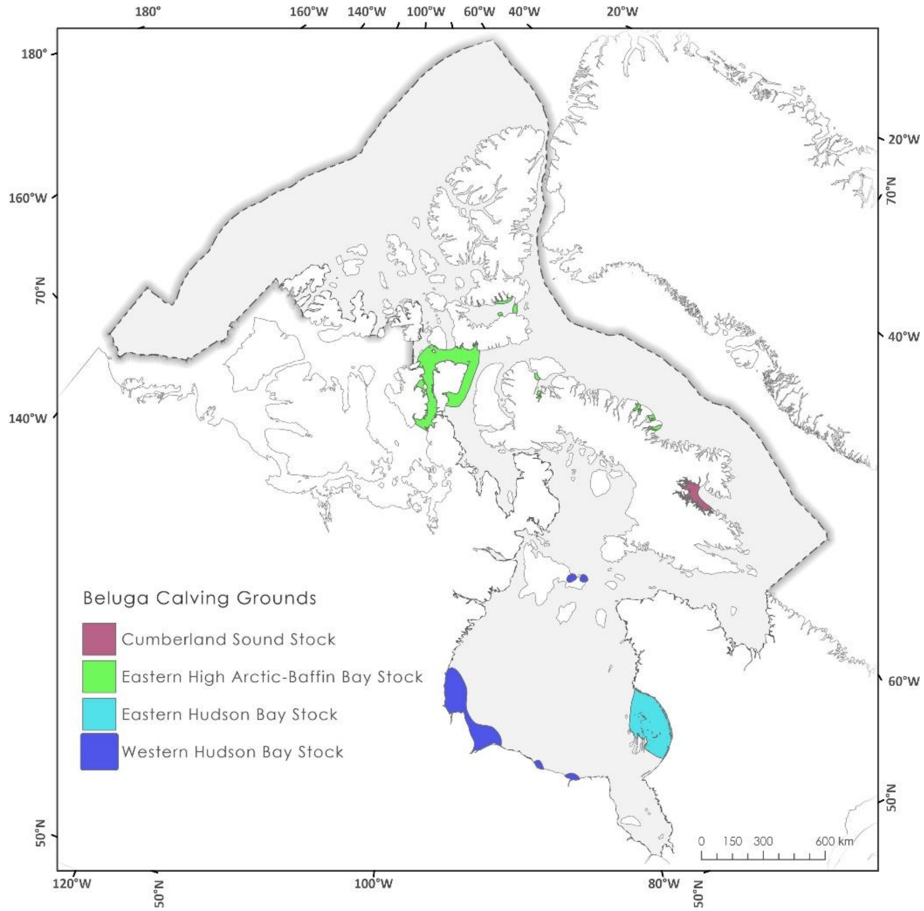

Figure 6.19. Distribution of beluga calving areas in the MECCEA study region.

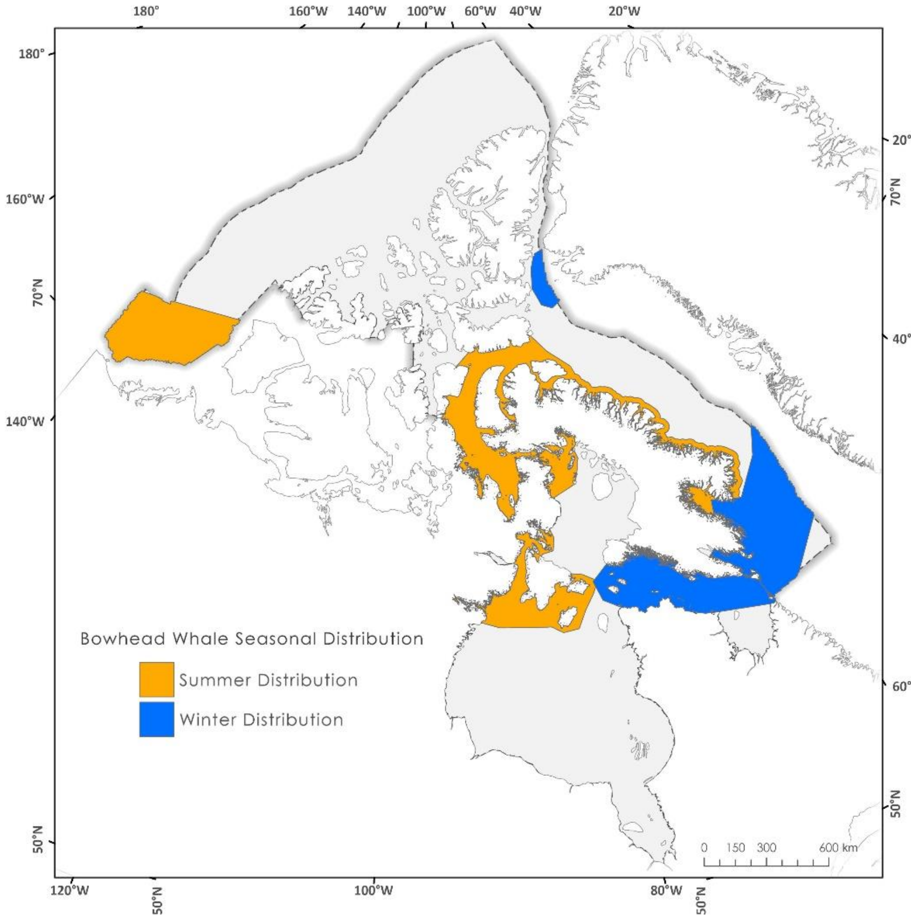

Figure 6.20. Bowhead seasonal distribution and habitat in the MECCEA study region.

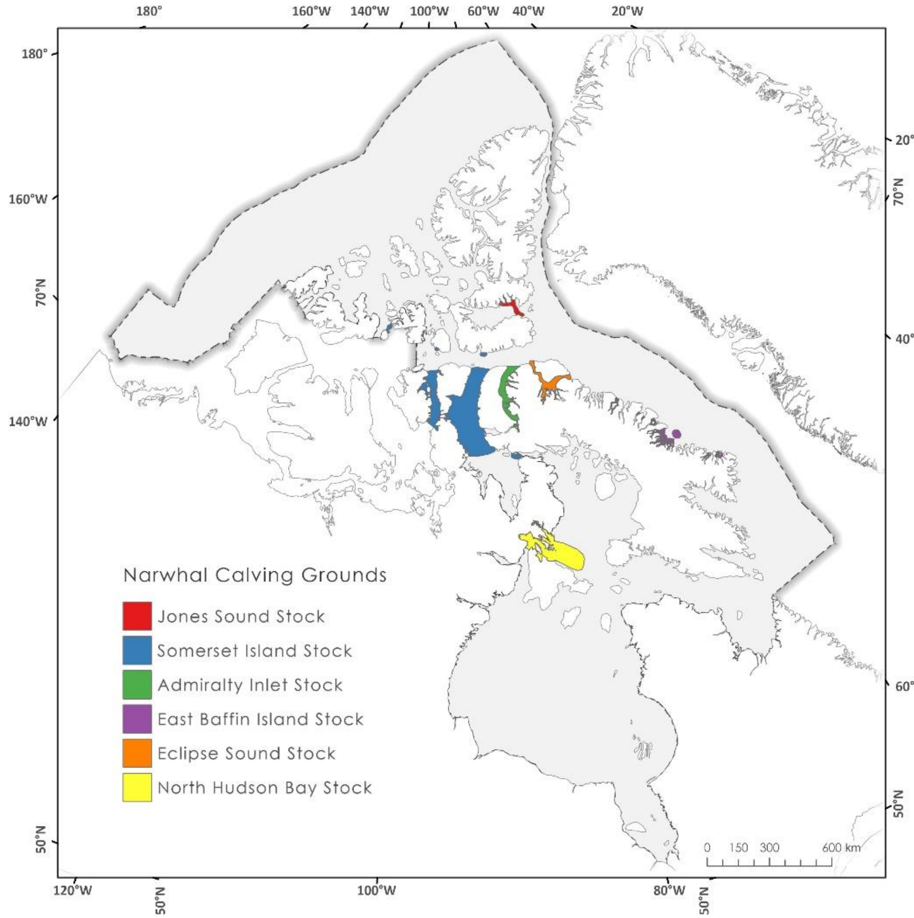

Figure 6.21. Narwhal calving areas in the MECCEA study region.

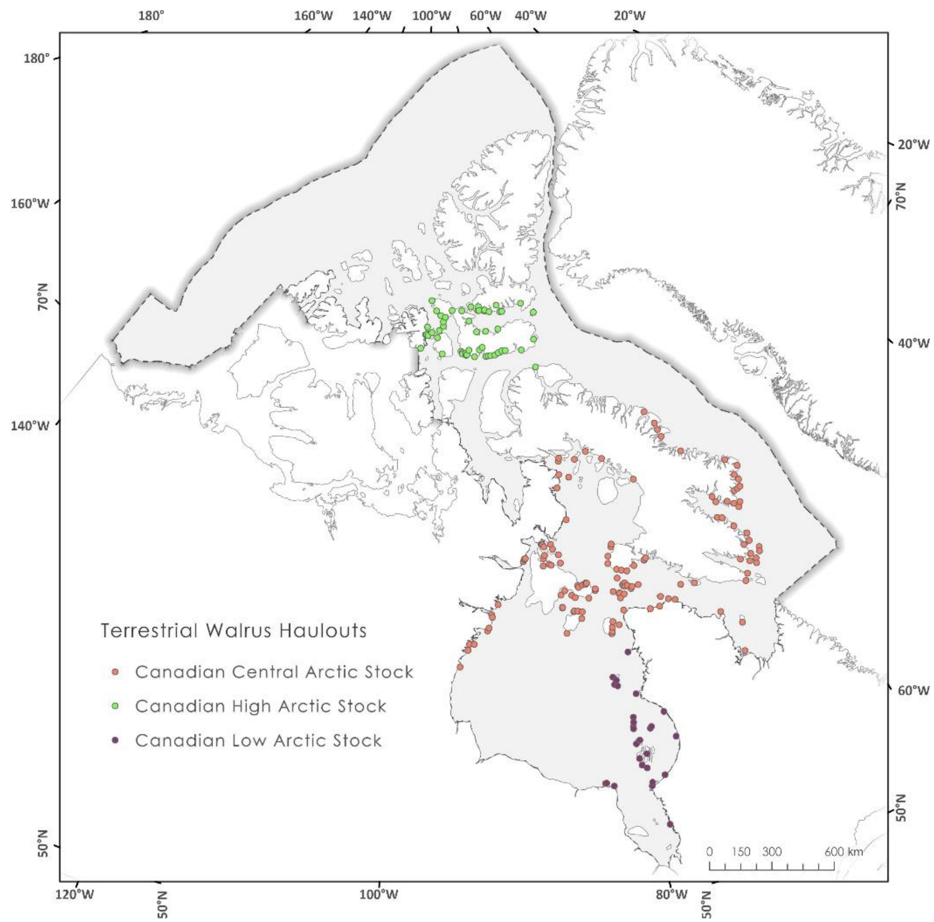

Figure 6.22. Walrus key habitat in the MECCEA study region.

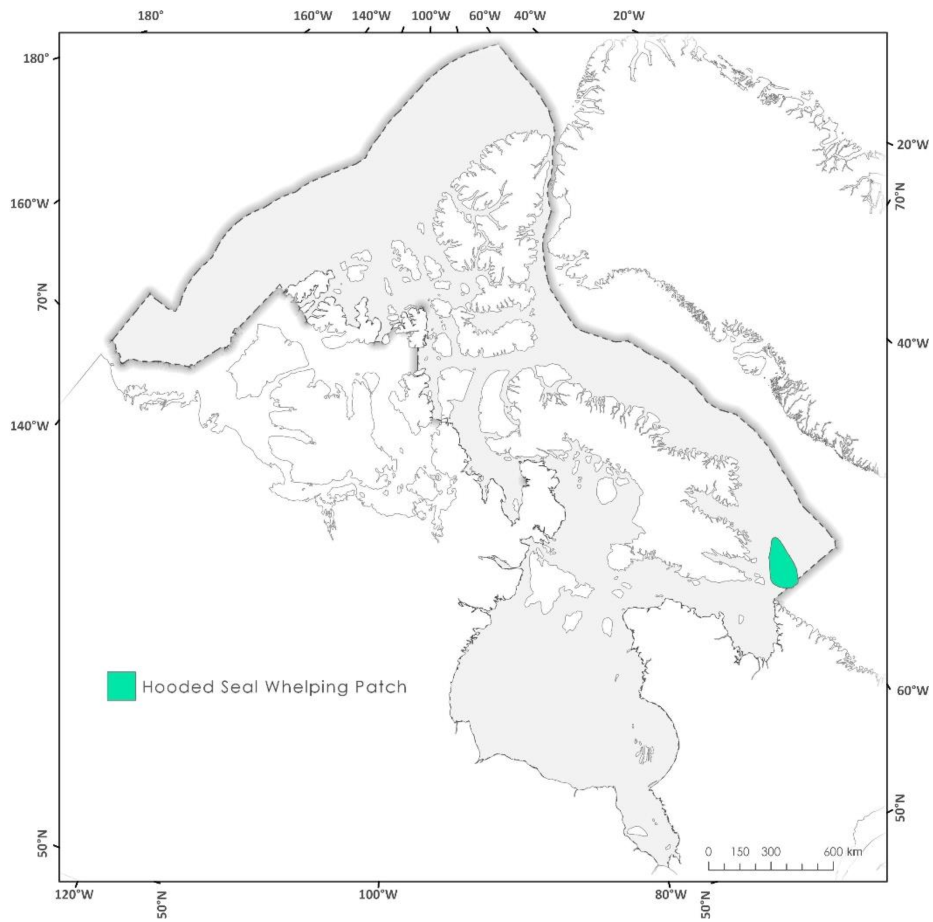

Figure 6.23. Hooded seal whelping patches in the MECCEA study region.

Hooded Seal - Cystophora cristata

Hooded seals are found from New England, north to Baffin Bay, and across Greenland to Jan Mayen. The Northwest Atlantic population is estimated to contain approximately 600,000 individuals. In Canada, the population is migratory, moving from summer feeding areas in Baffin Bay, south to pack-ice in Southern Davis Strait and beyond in the winter. Although the majority of the seals whelp further south, there is a number that whelp on the ice in Davis Strait annually (Figure 6.23). Hooded seals make use of the ice edge, and are deep water divers, generally foraging in water >200 m deep.

Harp Seal – Pagophilus groenlandicus

Harp seals are found from the central Canadian Arctic across Greenland and Scandinavia into the East Siberian Sea. The global population is thought to be approximately 6 million and increasing as sea ice becomes reduced with global warming. In Canada, the population is highly migratory moving from Baffin Bay for summer feeding, south to Newfoundland and the Gulf of the St. Lawrence in the winter where their whelping patches are found. In the summers they make use of pack-ice as a platform for foraging and tend to make dives in shallow-to-moderately deep water.

Ringed Seal – Pusa hispida

Ringed seals are a very abundant and widespread across the Arctic. Although reliable population estimates do not exist for much of their Pan-Arctic distribution, they have been listed as “not at risk” by COSEWIC. In Canada, surveys have noted high densities of ringed seals on the shore-fast ice of Baffin Island and the Arctic Archipelago in the winter months. This behaviour is consistent with the seals’ life history traits, as they are known to maintain breathing holes in the ice and keep birthing lairs close to land. In summer months, they can be found foraging in most regions of the Canadian Arctic. It is unknown how this ice-dependent species will respond to changing ice conditions associated with climate change. Data for this species came from NCRI (Nunavut Coastal Resources Inventory).

Bearded Seal – Erignathus barbatus

Bearded seals are found across the northern coastlines along, and adjacent to, the Arctic Ocean. In Canada, they are found in low densities in most coastal areas. Although population surveys do not exist, it has been observed that bearded seals spend most of their time in coastal waters shallower than 250 m where they perform foraging dives. Observations in deeper waters do occur; however, these likely consist mainly of sub-adult individuals. Bearded seals can maintain breathing holes similar to ringed seals. However, they appear to prefer to make use of polynyas. As such, it is possible they are found at lower densities in in areas of the central Canadian Arctic where ice-cover is more consistent. Data for this species came from NCRI. Due to their abundance, ranges and habitat, data were not collected for bearded seals. The exception to this is in areas identified by local communities as having importance relating to the species and/or to their harvest.

BIRDS

Seabird Colonies

The Canadian Arctic is considered one of the world’s key areas for migratory seabirds, supporting more than 10 million pairs of breeding seabirds every summer (Wong et al., 2014). Arctic seabirds occupy a range of trophic levels, and they play significant roles in biogeochemical cycles connecting marine and terrestrial ecosystems, and also support Inuit livelihoods.

Colony locations for seven species of seabirds (Figure 6.24) were identified from *Birds of Nunavut* (Richards and Gaston, 2018), which is based on a combination of literature reviews and personal observations by the primary authors. During the MECCEA second expert workshop and subsequent communications with Arctic bird specialists, the colony locations included in this publication were recommended as the most current and reliable records. Additional data of colony location/size for ivory gull and Ross's gull (Figure 6.24), two endangered species in the Arctic, were obtained through other sources (Robertson et al., 2007; Maftei et al., 2012; Mallory et al., 2006; Mallory, 2012).

Seabird Foraging Areas

Several methods of defining seabird key habitat, such as foraging areas, were initially explored, including a kernel density function based on foraging distance and colony size, so as to weight colonies for their importance due to their larger size. However, these analyses did not consider overall estimates of species populations for each colony site. Some of the colonies used in our analysis had only a pair of observed individuals, but there was no information on what that number represented for the national species population. This could represent a bias in the approach. In addition, poor monitoring as well the lack of strong survey coverage in the Arctic can make species population estimates unreliable. It is a global recommendation that key seabird colony sites should support at least 1% of a national population (UNEP-WCMC 2014). In Canada, this is a national criterion for the identification of candidate sanctuaries and national wildlife areas (Government of Canada, 2017).

Recently, Mallory et al. (2019) conducted a study to identify key marine habitat sites for seabirds that are considered to support at least 1% of a national population, using the most current population estimates for Canada. More importantly, their identification of seabird key habitats spans from the mere delineation of foraging areas (breeding season) to include other components of the life cycle of seabirds such as wintering and migration staging sites. On the recommendation of seabird experts, it was determined that the sites identified in Mallory et al. (2019) more accurately captured key marine habitat sites for Arctic seabirds, including foraging sites, and these data were used to describe seabird foraging areas rather than the initial kernel density analysis results (Figure 6.25, marine bird habitat).

Sites were also distinguished based on the life history stages of species (overwintering, foraging, breeding, staging, etc.), and thus, target setting for these areas considered the specific characteristics and conditions for which each site was selected as a key habitat (see Appendix 2).

Waterfowl and Shorebirds

We have not attempted to enumerate individual species of shorebirds or waterfowl by location. Rather, we have recorded the shoreline locations of Important Bird Areas (IBA) themselves, as enumerated and described by BirdLife International (1997) and IBA Canada (2017). These locations within the MECCEA marine bioregions are shown in Figure 6.25 (coastal bird habitat), and a listing is given in Table 6.8. A full listing of the species of shorebirds and waterfowl observed within these regions is given in Table 6.9 (shorebirds) and Table 6.10 (waterfowl), though not referenced by location.

These coastal habitats, including eelgrass beds, salt marshes, and heath, are vital staging areas for many species, and provide the essential food resources to fulfill the birds' critical need for nutritive reserves, for continued migration, and for reproduction (see e.g. Bellrose, 1980; Thomas and Prevett, 1982).

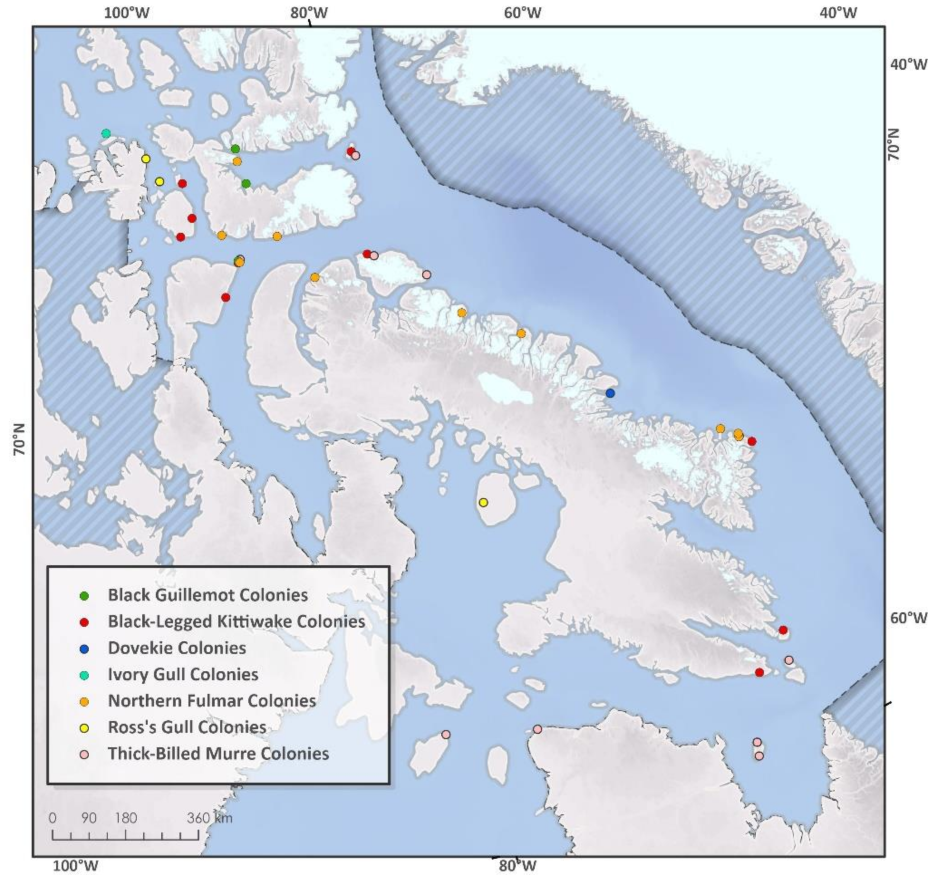

Figure 6.24. Colony locations for seven species of seabirds in the MECCEA study region.

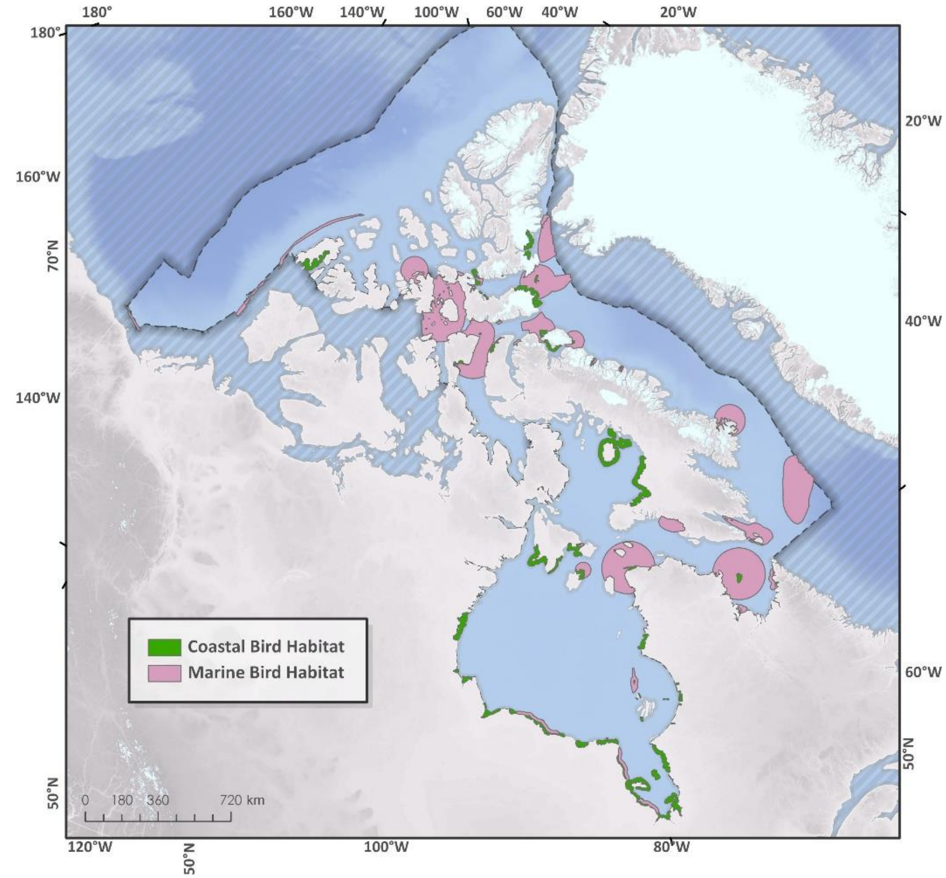

Figure 6.25. Key coastal and marine bird habitats in the MECCEA study region.

Table 6.8. Important Bird Areas (IBAs) for shorebirds and waterfowl habitat, taken from IBA Canada. (2017).†

MECCEA Grouping	IBAs Included*
Hudson Bay west coast	MB003, MB006, MB008, MB013
IBAs of Northern Hudson Bay	NU001, NU005, NU018, NU022, NU023, NU024
IBAs of Ungava/Frobisher Bay	NU007
IBAs of Foxe Basin	NU011, NU021, NU078
Hudson Bay west coast	NU020
Western Quebec coastline & Belcher islands	NU030, NU031, NU032, NU034, NU097, NU100, QC143, QC145, QC146, QC147, QC148
IBAs of Northern Ontario coastline	NU036, ON123, ON124, ON125, ON127, ON129, ON130, ON133, ON134, ON135, ON137, ON138, ON139, ON140, ON141, ON142, ON143, ON147
IBAs of Eastern Baffin Island	NU069, NU070
IBAs of Lancaster Sound	NU004, NU013, NU068
IBAs of Barrow Strait	NU006, NU059, NU060, NU062, NU065
IBAs of north Baffin Bay	NU010, NU014, NU057
IBAs of Jones Sound/strait	NU052, NU052, NU053, NU054, NU055
Eastern Prince Patrick Island	NT044

†Retrieved from IBA Canada. Alpha-numeric designations refer to IBA locations.
*IBAs that straddle bioregions appear multiple times.

HOTSPOTS

In Chapter 4, we presented seascapes of representative areas – composites of geophysical data – that act as surrogates of biological attributes such as productivity and biodiversity. Biological attributes can also be combined directly into distinctive area seascapes – now generally referred to as "hotspots". There is a substantial body of literature on marine hotspots, which can spatially define regions of high taxonomic richness (e.g. see above), diversity of endemic species, areas of predator abundance, etc.

Arctic Trails Study

In the MECCEA marine bioregions, a study of predator guilds has recently been undertaken (Yurkowski et al., 2019) that defines regions where groups of priority species at higher trophic levels are disproportionately abundant because of seasonal availability of food resources.

Yurkowski et al. (2019) have compiled the largest existing dataset of telemetry data for Arctic marine predators, consisting of 1,282 individuals from 21 species. They identified abundance and species diversity hotspots for four species groups: cetaceans and pinnipeds; seabirds; polar bears; and fishes. These hotspots (within the MECCEA marine bioregions), during summer-autumn and winter-spring, were identified in Baffin Bay, Davis Strait, Hudson Bay and Hudson Strait. Hotpots occurred nearshore and within the continental slope in summer-autumn, and offshore in areas of moving pack-ice in winter-spring – both areas with oceanographic features that enhance productivity and foraging opportunities (example Figures 6.26 and 6.27).

The results of this valuable study have been incorporated into the MECCEA Marxan analyses (specifically, results for polar bears, seabirds, and marine mammals - see Appendix 2 entries under "Hotspots").

Table 6.9. Shorebird species found within the MECCEA study area (represented by IBA conservation features). See Table 6.8 for reference and list of areas.

Shorebirds	**Status**		
	COSEWIC	**SARA**	**IUCN**
American bittern (*Botaurus lentiginosus*)	N/A	N/A	Least concern
Baird's sandpiper *(Calidris bairdii)*	N/A	N/A	Least concern
Black-bellied plover (*Pluvialis squatarola)*	N/A	N/A	Least concern
Buff-breasted sandpiper (*Tryngites subruficollis)*	Special concern	Special concern (S1)	Near threatened
Common ringed plover (*Charadrius hiaticula)*	N/A	N/A	Least concern
Dunlin (red-backed sandpiper) *(Calidris alpinae)*	N/A	N/A	Least concern
Great blue heron (*Ardea herodias*)	N/A	N/A	Least concern
Greater yellowlegs (*Tringa melanoleuca*)	N/A	N/A	Least concern
Horned grebe (*Podiceps auritus*)	Special concern	Special concern (S1)	Vulnerable
Hudsonian godwit (*Limosa haemastica*)	N/A	N/A	Least concern
Least sandpiper *(Calidris minutilla)*	N/A	N/A	Least concern
Lesser golden plover (*Pluvialis dominica)*	N/A	N/A	Least concern
Lesser yellowlegs (*Tringa flavipes*)	N/A	N/A	Least concern
Long-billed dowitcher (*Limnodromus scolopaceus*)	N/A	N/A	Least concern
Marbled godwit (*Limosa fedoa*)	N/A	N/A	Least concern
Pectoral sandpiper *(Calidris melanotus)*	N/A	N/A	Least concern
Purple sandpiper (*Calidris acuminate)*	N/A	N/A	Least concern
Red knot islandica (*Calidris canutus islandica)*	Special concern	Special concern (S1)	Near threatened
Red knot rufa (*Calidris calidris rufa)*	Endangered	Endangered (S1)	Near threatened
Red phalarope *(Phalaropus fulicarius)*	N/A	N/A	Least concern
Red-necked phalarope *(Phalaropus lobatus)*	Special concern	No status	Least concern
Ruddy turnstone *(Arenaria interpres)*	N/A	N/A	Least concern
Sanderling *(Calidris alba)*	N/A	N/A	Least concern
Sandhill crane (*Antigone canadensis*)	Not at risk	N/A	Least concern
Semipalmated plover *(Charadrius semipalmatus)*	N/A	N/A	Least concern
Semipalmated sandpiper (*Calidris pusilla)*	N/A	N/A	Near threatened
Short-billed dowitcher (*Limnodromus griseus*)	N/A	N/A	Least concern
Spotted sandpiper (*Actitis macularius*)	N/A	N/A	Least concern
Stilt sandpiper *(Calidris himantopus)*	N/A	N/A	Least concern
Whimbrel (*Numenius phaeopus*)	N/A	N/A	Least concern
White-rumped sandpiper *(Calidris fuscicollis)*	N/A	N/A	Least concern
Wilson's snipe (*Gallinago delicata*)	N/A	N/A	Least concern

Table 6.10. Waterfowl species found within the MECCEA study area (represented by IBA conservation features. See Table 6.8 for reference and list of areas.

Waterfowl	**Status**		
	COSEWIC	**SARA**	**IUCN**
Arctic loon (*Gavia arctica)*	N/A	N/A	Least concern
Brant goose (*Branta bernicla)*	N/A	N/A	Least concern
Canada goose *(Branta canadensis)*	N/A	N/A	Least concern
Common eider (*Somateria mollissima)*	N/A	N/A	Near threatened
Common loon (*Gavia immer)*	Not at risk	N/A	Least concern
Harlequin duck (*Histrionicus histrionicus)*	Special concern	Special concern (S1)	Least concern
King eider (*Somateria spectabilis)*	N/A	N/A	Least concern
Long-tailed duck *(Clangula hyemalis)*	N/A	N/A	Vulnerable
Northern pintail (*Anas acuta)*	N/A	N/A	Least concern
Pacific loon *(Gavia pacifica)*	N/A	N/A	Least concern
Red-breasted merganser (*Mergus serrator)*	N/A	N/A	Least concern
Red-throated loon (*Gavia stellata)*	N/A	N/A	Least concern
Ross's goose (*Anser rossii)*	N/A	N/A	Least concern
Snow goose (*Anser caerulescens)*	N/A	N/A	Least concern
Tundra swan (*Cygnus columbianus)*	N/A	N/A	Least concern
White-fronted goose *(Anser albifrons)*	N/A	N/A	Least concern
Yellow-billed loon (*Gavia adamsii)*	Not at risk	N/A	Near threatened
Trumpeter swan *(Cygnus buccinator)*	Not at risk	N/A	Least concern
Surf scoter *(Melanitta perspicillata)*	N/A	N/A	Least concern
White-winged scoter *(Melanitta fusca)*	N/A	N/A	Least concern
Cackling goose *(Branta hutchinsii)*	N/A	N/A	Least concern
Black scoter *(Melanitta americana)*	N/A	N/A	Near threatened
Bufflehead *(Bucephala albeola)*	N/A	N/A	Least concern
Common goldeneye *(Bucephala clangula)*	N/A	N/A	Least concern
Hooded merganser *(Lophodytes cucullatus)*	N/A	N/A	Least concern
Common merganser *(Mergus merganser)*	N/A	N/A	Least concern
Ring-necked duck *(Aythya collaris)*	N/A	N/A	Least concern
Greater scaup *(Aythya marila)*	N/A	N/A	Least concern
Lesser scaup *(Aythya affinis)*	N/A	N/A	Least concern
Blue-winged teal *(Anas discors)*	N/A	N/A	Least concern
Gadwall *(Mareca strepera)*	N/A	N/A	Least concern
American wigeon *(Anas americana)*	N/A	N/A	Least concern
Mallard *(Anas platyrhynchos)*	N/A	N/A	Least concern
American black duck *(Anas rubripes)*	N/A	N/A	Least concern
Green-winged (common) *teal (Anas crecca)*	N/A	N/A	Least concern
Wood duck *(Aix sponsa)*	N/A	N/A	Least concern

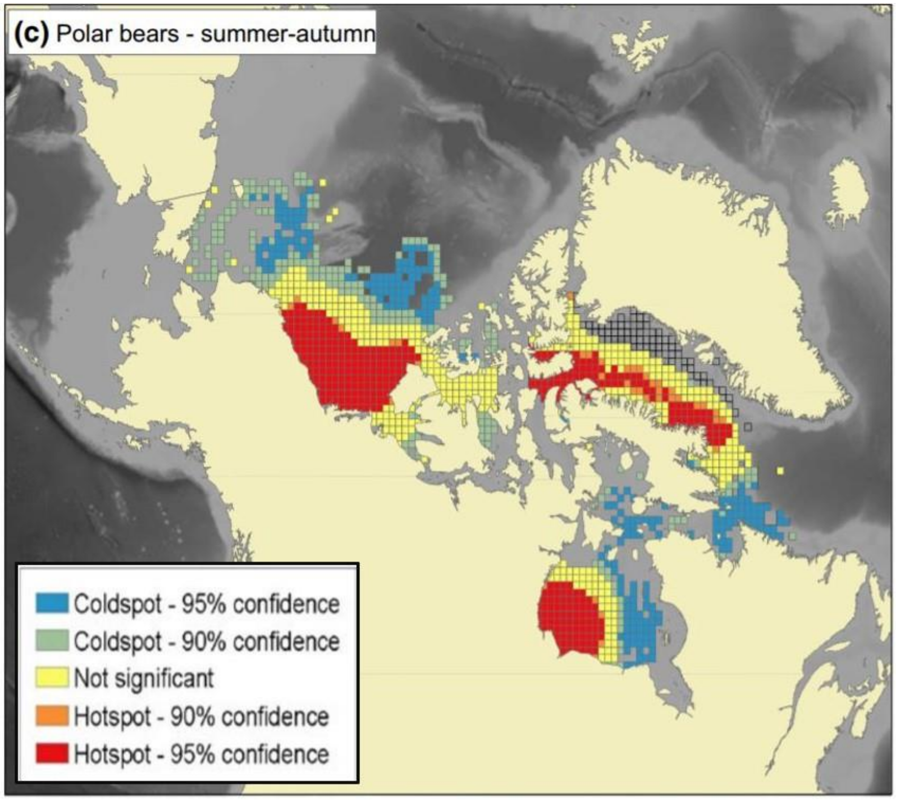

Figure 6.26. Locations of summer-autumn distribution hotspots for polar bear (from Yurkowski et al., 2019).

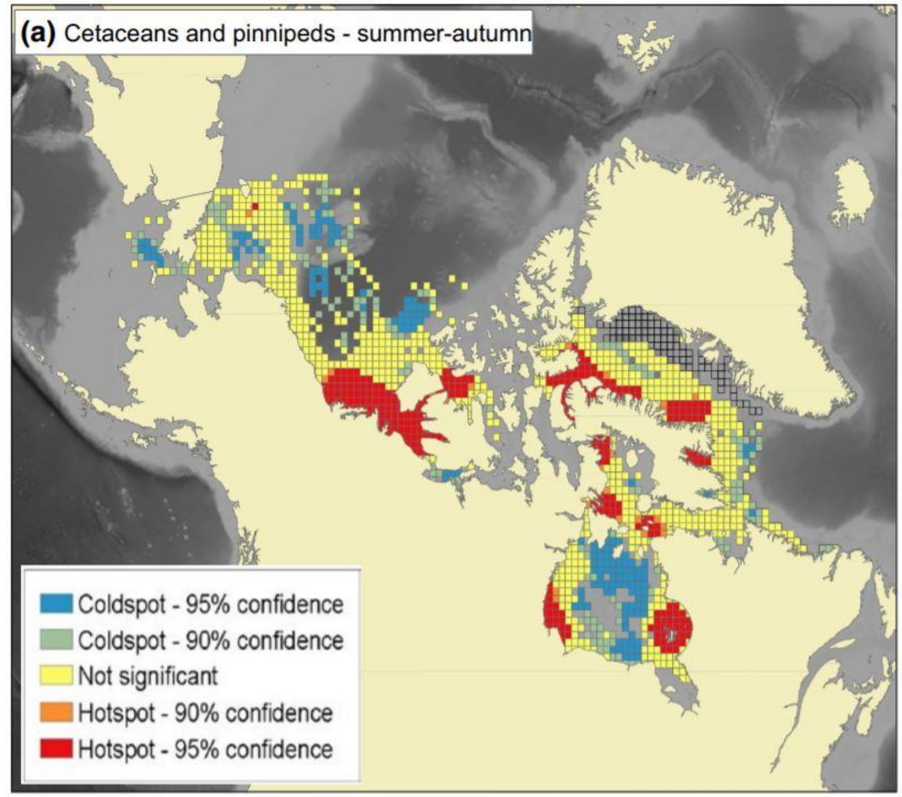

Figure 6.27. Locations of summer-autumn distribution hotspots for cetaceans and pinnipeds (from Yurkowski et al., 2019).

INDIGENOUS KNOWLEDGE SOURCES

As noted in Chapter 2, information from IK sources contributes to several of the data layers used in MECCEA. Many layers were derived from available NCRI data, whereas other data were from a compilations of information that included information from IK and other sources, e.g. data from the DFO Arctic Marine Workshop (Stephenson and Hartwig, 2010) and WWF-Canada-commissioned reports on important Arctic cetacean habitat (Higdon, 2017).

The NCRI datasets (e.g. Government of Nunavut, 2008) include information on a broad range of species, as well as human uses information (used in the post-Marxan analysis–see Chapter 10). We incorporated NCRI data from the communities within the MECCEA study area where inventories were completed between 2008 and 2017, pertaining to the species listed above.

Data from each community within the study area resulted in the creation of layers for each species. These layers were divided by bioregion and, where determined, by sub-population/ management unit. Some layers were subdivided into clusters within marine bioregions to enhance replicability of the feature in the network design. Conservation features with data based on information from the NCRI are listed in Table 6.7, which also references the specific studies (including NCRI).

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CHAPTER 7: SELECTING CONSERVATION FEATURES AND SETTING CONSERVATION TARGETS

SELECTING CONSERVATION FEATURES

In the preceding chapters, the information available to the MECCEA project has been presented. However, in the data there was much repetition, duplication and overlap of features. Our philosophy in preparing to run the Marxan analyses was not to include every piece of data or information we were able to find nor to include every component of the Arctic Marine environment; instead, we sought to include only data and information that directly addressed our stated conservation objectives (see Text Box 2.1). These objectives are now considered in sequence in this chapter. A listing of all conservation features (CFs) and associated conservation targets is summarized in Appendix 2.

In order to avoid double or multiple-counting of CFs and consequent biases, a process of data examination was implemented. This comprised a series of logical “decision trees” in order to refine an appropriate data set for Marxan analyses. This decision tree process was driven by the original MECCEA conservation objectives.

The selection of CFs for inclusion in the analysis was driven by the first two conservation objectives, focusing on conservation features that capture distinctive or representative examples of the Arctic marine environment.

The conservation objectives were refined through specific criteria in the form of the three decision trees, described below. The criteria were selected to filter out potential conservation features that were not the most important for the associated species or ecosystem process. For example, the criteria filter out general species range data if there was more specific life history or seasonal habitat information. This avoided the potential for different datasets representing the same feature to be considered and treated as if they represented different features. The criteria thus ensured that each conservation feature selected for the analysis contributed only unique information.

The criteria in each decision tree were then applied to potential CFs to screen out those that did not meet these objectives. All potential CFs were split by marine bioregion, and in some cases, split again to reflect different species subpopulations/management units. A conservation feature was only selected under one of the two conservation objectives; no features met criteria under multiple objectives.

In cases where one CF layer was used for multiple species, the resulting target (see below) was calculated as an average of the scores for all the species represented in the data layer (based on the grouping). However, if there was a species at risk included, we used the target assigned to that specific species for the whole layer, thereby adopting the practice of managing risk relative to the greatest threat.

Conservation Objective 1A: Protect Key Habitats of Arctic Priority Species

This objective applied only to CFs associated with an individual species or a species group. For species where subpopulations or management units were identified, available habitat information was divided by the subpopulation/management unit and assessed independently. For example, polar bear denning areas for the Lancaster Sound subpopulation are a distinct CF from Gulf of Boothia subpopulation denning areas.

In Figure 7.1, Questions 1–3 (dark blue) are focused on assessing the feature itself, and Questions 4–8 (light blue) assessed the data associated with the feature against other available data related to the same feature or species. This approach ensured that no conservation feature was overrepresented in the analysis—an important consideration in our study area where data are very unevenly distributed.

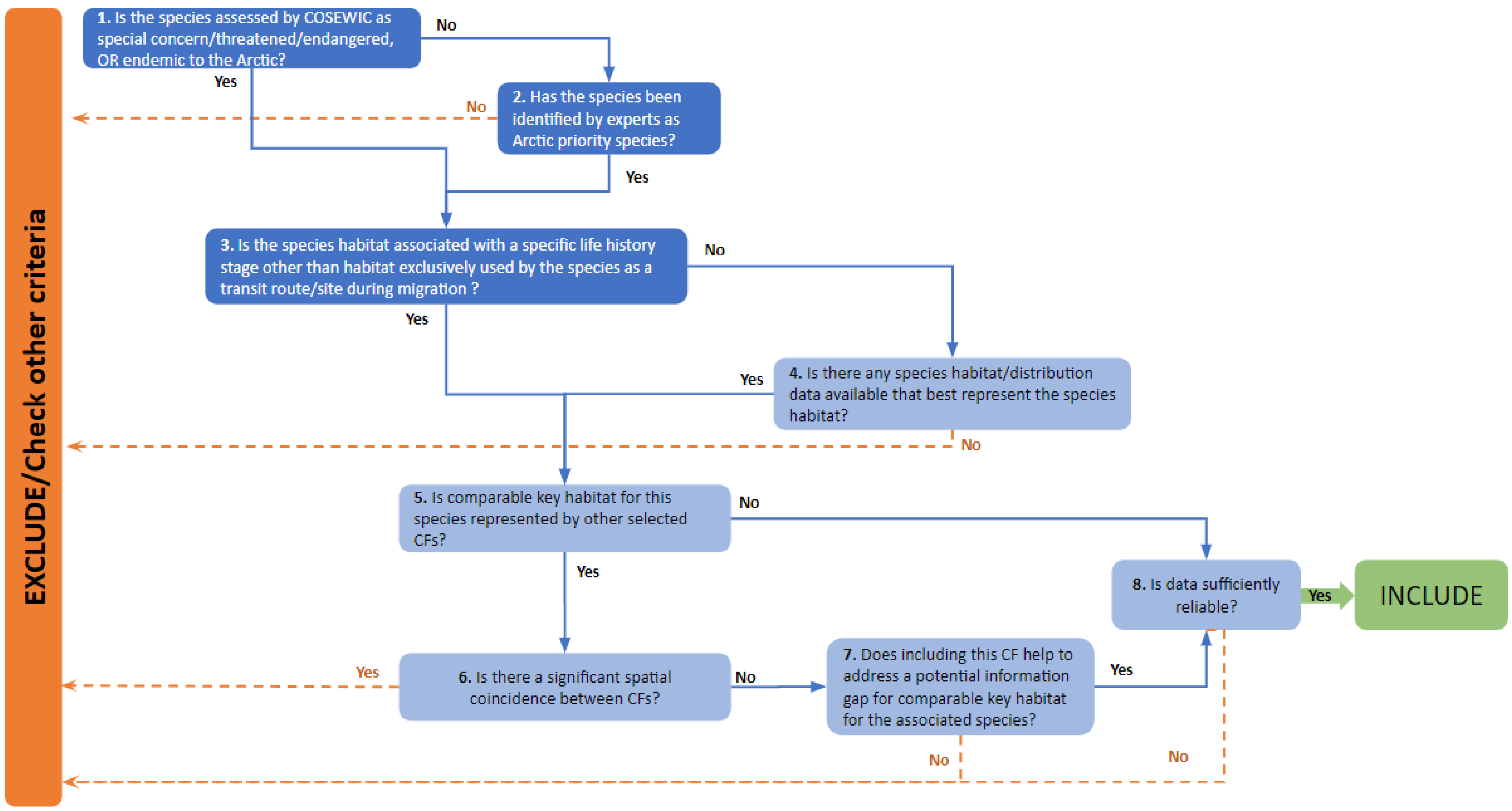

Figure 7.1. Criteria of the decision tree for *Conservation Objective 1A: Protect Key Habitats of Arctic Priority Species*

The criteria for consideration as an "Arctic priority species" include the following (see Questions 1–2 in Figure 7.1):

- Species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as *special concern*, *threatened*, or *endangered*, e.g. polar bears, narwhals, bowhead, walrus, ivory gulls, Ross's gulls, and Atlantic wolffish.
- Species that are endemic to the Arctic (defined as species that have adapted physically and behaviorally to the particular conditions of life in the Arctic), e.g. harp seals, ringed seals, and Eastern Beaufort Sea beluga.
- Species identified by specialists as priority species for conservation based on ecological roles, e.g. thick-billed murres, spinytail skate, and fourhorn sculpin.

For this analysis, "key habitat" is defined as an area where one or more specific life history stages for a species takes place, other than migration corridors (Question 3). Migration routes were not included as conservation features in the Marxan analysis because they were integrated into the post-Marxan connectivity analysis (see Chapter 9). General species ranges or distributions were also not included in the analysis, with the exception of fish species distributions. Due to data deficiencies for fish key habitat and distribution data, a model was used to identify suitable habitat for selected fish species and develop distributions for those conservation features (see Chapter 6).

For many of the selected species, life history stages are not well-defined. For this reason, Question 4 assessed whether data that are not specifically associated with a life history stage (e.g. data describing seasonal habitats) still contributed information that addressed a gap, based on whether other relevant data were available. As a result, in some cases seasonal ranges or other available data (e.g. distributions, locally identified habitat, or species hotspots) were included as key habitat (e.g. narwhal summer high density areas) where no other information was available or where there was a data gap. Thus, key habitat categories include conservation features that both directly represent specific types of key habitat (e.g. polar bear denning areas) as well as features that capture geographic areas of a species range associated with a particular behavior or season, as a proxy for key habitat.

Questions 5–8 ensured that each conservation feature selected for inclusion in Marxan contributed unique information. Question 5 assessed whether the potential CF was already represented through other selected CFs. In such a case, the spatial coincidence (i.e. similarities in size, scale, and shape of the polygons) was assessed through Question 6. In a case where a CF represented data that were comparable or similar to another selected CF (e.g. narwhal calving areas and narwhal summer high density areas), the second CF was only included if the actual polygon did not coincide with the polygon of the already-selected CF. For example, the CF list includes "Bowhead summer foraging/calving (Hudson Bay)" and "Bowhead summer distribution, East Canada-West Greenland (Hudson Bay)". These both seem to represent the same type of feature (i.e. Question 5 gives "yes"), but because the actual polygons do not have a strong spatial coincidence, applying the criteria in Question 6 (which gives "no") results in the inclusion of both on the basis that each represents a geographically distinct habitat. Question 7 served as a final assessment of the data's relevance to the conservation objectives, compared against other selected CFs associated with the same species. Question 8 ensured that the data associated with the CF were sufficiently reliable.

Data were deemed reliable when there was no reasonable cause to question its accuracy, fidelity, precision, contemporaneity, or other attribute of integrity. The intent of excluding any data on the basis of reliability was to remove information that could reduce the quality of the MECCEA project. Data vetting was generally conducted by expert review during workshops and the target setting process.

The application of these criteria resulted in the identification of 175 distinct conservation features (see Appendices 2.1 to 2.7).

Conservation Objective 1B: Protect Ecologically Sensitive Areas

This objective applied to benthic habitats that are uniquely sensitive to disturbance.

In Figure 7.2, Question 1 (dark blue) assessed the feature itself, and Questions 2–5 (light blue) ensured the CF was not overrepresented in the analysis.

The application of these criteria resulted in the identification of 8 distinct conservation features (see Appendix 2.8).

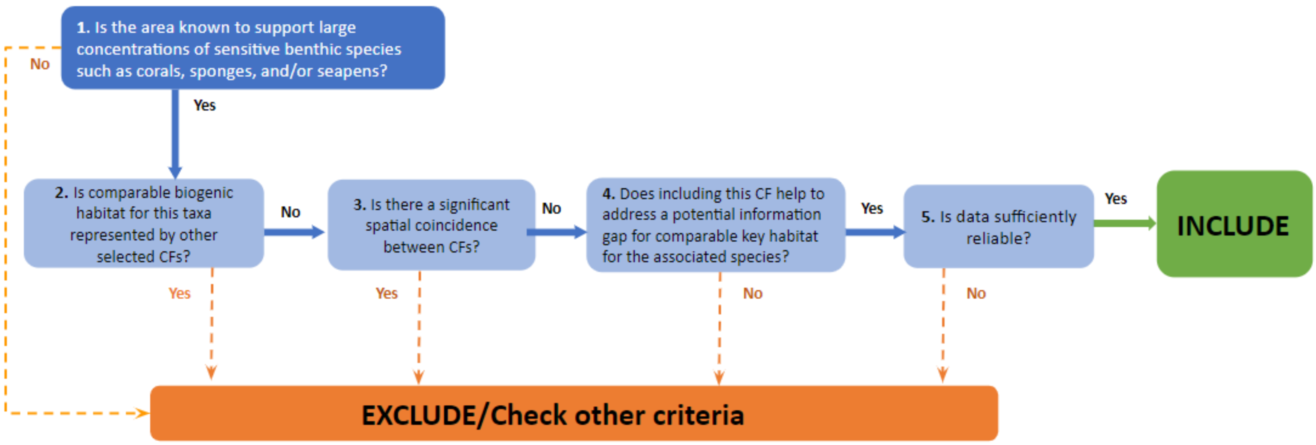

Figure 7.2. Criteria for decision tree for *Conservation Objective 1B: Protect Ecologically Sensitive Areas*.

Conservation Objective 1C: Protect Areas of High Productivity and High Species Richness/Concentrations

This objective applied to conservation features associated with multiple species and/or areas of high primary productivity.

In Figure 7.3, Questions 1–3 (dark blue) assessed the feature itself, and Questions 4–5 (light blue) ensured the CF was not overrepresented in the analysis.

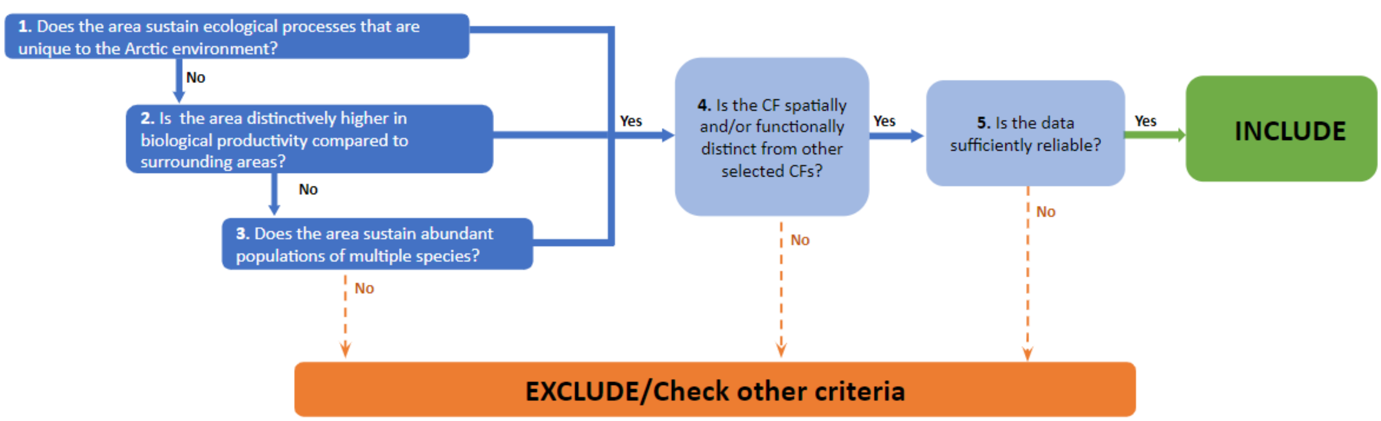

Figure 7.3. Criteria for decision tree for *Conservation Objective 1C: Protect Areas of High Productivity and High Species Richness/Concentrations.*

Question 1 applied primarily to polynyas. Question 2 applied to areas of high primary productivity. Question 3 applied to species hotspots (for multiple species, e.g. marine mammals, benthic species, etc.), and important bird sites, both seabird (multi-species) key habitat sites and Important Bird Areas.

The application of these criteria resulted in the identification of 56 distinct conservation features under Conservation Objective 1C (see Appendices 2.9 to 2.16).

Conservation Objective 2: To Protect Representative Examples of Each Type of Identified Ecosystem and Habitat

This objective applied to representative geophysical features and habitats, within the water column, on the sea floor and in coastal areas. There were 268 features recognized under this category, summarized in Appendices 2.17 to 2.23.

Conservation Objective 3. To Ensure that the PACs are Integrated into the Wider Landscape and Seascape by Patterns of Connectivity

This forms the subject of Chapter 9.

SETTING TARGETS FOR CONSERVATION FEATURES

Having defined and mapped conservation features from available information, the next step in the planning process was to decide how much of each feature should be targeted for protection. This required a series of decisions to be made and methods selected.

The main goal in defining conservation targets should be to set the minimum quantity required for a feature to be protected in order to achieve its long-term conservation. The target concept is therefore *intrinsically* linked to the conditions needed for biodiversity persistence. Rondinini and Chiozza (2010) explained the latter point of view through the concept of ecological thresholds. The likelihood of species extinction escalates significantly when its habitat loss exceeds a given threshold. In the same way, ecosystem health and functioning deteriorate when the number of species within it falls below a given threshold. Knowing such thresholds and setting targets above them could, therefore, theoretically reduce the loss of extinction and guarantee biodiversity persistence.

This is the transition from the question of "what to protect" to the more complex question of "how much to protect of what features". A sound answer would be based on best available knowledge of species and ecosystems, including life histories and ecological functioning, information that is not frequently available. We are forced to use more pragmatic solutions.

International Targets

The international conservation commitment is embodied in the Aichi Target 11, to conserve at least 10% of marine and coastal areas (CBD, 2011). This is an arbitrary decision, which has received widespread acceptance, but remarkably little comment in the way of origin, critique, or rationale. We presently have no idea if this target to protect 10% of marine environments is in fact compatible with the establishment of well-connected networks of protected areas (see Roff, 2009). How the 10% Aichi Targets, or the more ambitious IUCN 30% targets (WCC, 2016), are to be achieved is left entirely to each participating nation.

The strategy of starting with a baseline of 10% or 30% for each conservation feature, may lead to a very high percentage of a region being proposed for conservation, and the outcome may exceed requirements for a true network. This means that we should explore the option of adjusting the baseline of 10% for each feature—either up or down—while retaining the requirement for, and fundamental characteristics of, a true network.

Our philosophy in MECCEA, therefore, is that targets should be set individually for conservation features, rather than by a final overall arbitrary target. This also recognizes that, "…conservation targets are only provisional estimates of the requirements for persistence of a region's biodiversity made within the constraints of limited information" (Rondinini & Chiozza, 2010).

Methods for Target Setting

General approaches for setting targets for biodiversity conservation can be considered as either: the fixed target approach or the flexible target approach (Svancara et al., 2006; Rondininiand Chozza, 2010; Harris et al., 2014). Fixed targets are principally policy-driven, while flexible targets are principally based on expert opinion or scientific evidence. See Text Box 7.1 for details of methods.

MECCEA APPROACH FOR SETTING CONSERVATION TARGETS

MECCEA has adopted a more heuristic approach to setting conservation targets that adjusts to the limited biological data in the Canadian Arctic. This approach is summarized in the following guiding principles:

Guiding Principles

1. Conservation features (CFs) should be assigned targets ranging from a minimum of 10% to 100% of their distribution—a precautionary measure supported by the national and international calls for protection of at least 10% of the world's oceans. (CBD, 2011; DFO, 2017).
2. MECCEA considers that conservation targets should be based on an analysis of the priorities for conservation. To this end, qualitative categories of priorities (e.g. very high, high, median, minimum-median, and minimum) can be assigned to each conservation feature. In this way, features of very high priority receive the highest targets, whereas features of lower priority receive less stringent targets.
3. The definition of "priority categories" was based on the assessment of three criteria for each of the biodiversity features: a) current status of the feature; b) vulnerability of the feature; and c) rarity/uniqueness of the feature. Increasing priority was associated with weakening current status, increasing vulnerability, or rarer, more unique features.

Text Box 7.1. Methods for target setting.

Policy-Driven

Many countries are signatories to conventions or international agreements that require them to provide protection for a specific proportion of certain species, habitats, or bioregions (e.g. Aichi Target 11 to protect at least 10% of the worlds coastal and marine areas). Using these numbers for setting targets can be strategic for managers seeking MPA support while also making them defensible publicly. The policy-driven approach can be also used as a precautionary measure or baseline for targets when little information exists on the biodiversity features of a region. The result is often a fixed target that is constant across conservation features (e.g. protect 15% of each habitat type). However, although politically important, these targets are not ecologically robust for MPA network design, as their foundation lacks specific information on species and other ecological features necessary to ensure biodiversity persistence.

Expert Opinion

Conservation targets are often based on expert knowledge about ecological characteristics of the conservation features in question. This approach may be practical in data-poor situations. However, targets set through expert opinion may be unknowingly biased toward the research interests of the participants. Nevertheless, where target setting is based upon analysis of priorities for conservation, the rankings of taxonomic and ecological experts becomes necessary. Expert opinion was used in this MECCEA study.

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Text Box 7.1 (cont.). Methods for target setting.

Evidence-Based

The evidence-based approach to target setting is founded upon an adequate understanding and mapping of the distribution and viability of the conservation features identified. According to Rondinini and Chiozza (2010) there are four evidence-based methods that can be used to determine targets: species-area relationship; habitat-specific species-area relationship; heuristic principles; and spatially-explicit population viability analysis (PVA). A summary and comparison of such methods is shown below. Unfortunately, conservation projects rarely have sufficient data to undertake the analyses suggested in the first two options. Even more rarely is the detailed population demographic data required for PVA analysis available; such data is usually only available for individual endangered species, or for analysis of important fisheries populations.

Table 7.1.1 Summary of evidence-based target setting methods (Adapted from Rondinini and Chiozza 2010).

Method	Description	Rationale	Limitations
Species-area relationship	Expresses the relationship between habitat area and the number of species that an area can support. Method requires published data to parametrize species-area curve based on $S=c*A^z$ (see Rondinini and Chiozza 2010).	With increasing areal protection, return on ecological benefits for a given species community or biome will begin to flatten. Somewhere in this flattening section is where a target should be set.	Relies on generic literature; does not use data on biodiversity distribution, which can produce inaccurate estimates.
Habitat-specific-species-area relationship	Identifies habitat-specific targets based on the fit of a species-area curve from $S=c*A^z$. Method uses habitat-specific inventory data to estimate the habitat-specific value of z, hence the number of species contained in each habitat type.	Based on the ecological theory of island biogeography. From the previous equation, targets can be set based on the minimum area required to protect a certain number of species (e.g. 15% protection of a certain habitat is required to ensure representation of 80% of species).	Requires sufficient point samples of species presence in each habitat type which makes the method sensitive to data quantity. It does not identify targets for species persistence.
Heuristic principles	These are practical methods that rely on a number of assumptions to set approximate targets. It can be adapted to a variety of specific goals and take into account multiple criteria.	Allows target setting for a broader set of conservation features (e.g. ecosystem services, biodiversity processes, etc.). Examples include, rules of thumb, transformation of ordinal scales into quantitative thresholds, and educated guesses, all of which require planners to interpret qualitative knowledge of specific conservation features.	Target setting may depend on rough assumptions and subjective decisions. Difficult to communicate and defend because of subjectivity and current lack of accepted methodologies.
Spatially-explicit Population Viability Analysis (PVA)	Models that quantify habitat requirements for species to maintain viable populations over time. A data-intensive method that requires: demographic data (e.g. censuses, mark-recapture studies, surveys and observations of reproduction and dispersal events, presence/absence data); and habitat data. Method deals with species persistence; hence it is broadly recognized as one of the most scientifically robust.	Targets are set through measures of viability of species calculated in PVA models. Integration of single-species PVA models in MPA network planning can address key reserve design features such as size and connectivity.	Relies on huge amount of high-quality data which is often lacking.

4. When insufficient data or information limited the assessment of conservation priority, conservation targets were set and scaled or adjusted based on their relative overall abundance (by size or area) following the Lieberknecht et al. (2010) approach. Thus, smaller conservation features were assigned higher targets and vice versa.

The specific conservation target setting approach differed depending on the type of biodiversity feature in question and data/knowledge availability (Table 7.1). Specifically, different target methods were adopted for features either based on analysis of the priorities for conservation or based on size.

Table 7.1. Type of approach used in target setting for each of the CF-groups.

Conservation Objectives		CF-group	Target Setting Method
1. Distinctive features	**a.** Species key habitats	Polar Bear	Assessment of priority for conservation
		Cetaceans	Assessment of priority for conservation
		Pinnipeds	Assessment of priority for conservation
		Fish habitats	Assessment of priority for conservation
		Seabird colonies	Assessment of priority for conservation
	b. Sensitive benthic features	Coral/Sponges/ Sea-pen	Assessment of priority for conservation
	c. Ecological diversity & productivity	Eelgrass	Assessment of priority for conservation
		Important Bird Areas	Assessment of priority for conservation*
		Seabird habitats	Assessment of priority for conservation
		Hotspots	Size
		Polynyas	Size
		Primary Production and Max Chlorophyll	Size
2. Representative features	**a.** Representative habitats	Seascapes	Size
		Geomorphic	Size
		Coastal features	Size

*The assessment of priority for conservation for Important Bird Areas (IBAs) was based on Canadian IBA criteria (Moore and Couturier, 2011).

Target Setting Based on Analysis of the Priorities for Conservation

The assessment of priority categories for each of the biodiversity features was based on a set, or sub-set, of three criteria. See Text Box 7.2 for a full explanation of the criteria and target scores. The criteria are:

- Current *conservation status* of the feature;
- *Vulnerability* of the feature; and
- *Rarity/Uniqueness* of the feature.

Analysis of the priorities for conservation required specific knowledge about species life history and species/habitat vulnerability. Expert input to assess these aspects was sought according to their knowledge of the CF in question. We tried to include at least three experts external to WWF-Canada in the assessment of each CF. In cases of a lack of external experts for a specific CF, an internal assessment was carried out.

Experts were provided with forms about each CF including: a distribution map; a description of factors, criteria, and the scoring system for the assessment; and information on how to interpret those factors (see Text Box 7.3). The final score (e.g. 1, 2, or 3 as shown in the tables) for each factor represented the average of all expert scores for the assessment of that particular CF.

Text Box 7.2. Target setting based on analysis of the priorities for conservation.

The targets for priority categories were based on the assessment of three criteria for each of the biodiversity features:

- *Current conservation status* of the feature;
- *Vulnerability* of the feature; and
- *Rarity/Uniqueness* of the feature.

The three criteria were not all applied in the assessment of each feature. For features associated with individual species (e.g. key habitats), conservation status, vulnerability, and rarity/uniqueness were applied. Only vulnerability and rarity/uniqueness were used when assessing habitats, ecosystems, areas of high species richness, areas of high productivity, high resilience, etc. (i.e. features associated with multiple species with the exception of seabird key habitats and IBAs).

Each of these variables was quantified using a scoring system ranging from 1 to 3 (1 as the lowest, 3 as the highest) and applied to the relevant conservation features. Further explanation of scoring of these factors is given below. Separate scores were combined using:

$$Combined\ Target\ Score_{1-3} = \sqrt{\frac{\sum(x_i)^2}{n}} \qquad [1]$$

where x is the conservation feature score for a specific factor (e.g. vulnerability or conservation status) and n is the number of factors being assessed for a conservation feature.

Finally, the combined target score (which also ranged from 1 to 3) was translated into a target range based on the system shown in Table 7.2.1.

Table 7.2.1. Conversion system from target scores to target ranges.

Combined Target Score	Target Ranges
1.00–1.40	Minimum (10–20%)
1.41–1.80	Minimum–Median (20–40%)
1.81–2.20	Median (40–60%)
2.21–2.60	High (60–80%)
2.61–3.00	Very high (80–100%)

Current conservation status of the feature

Available COSEWIC assessments on current status were used to rank conservation features according to their level of threat (Table 7.2.2). In this assessment, species at the highest level of threat achieved a higher score.

Vulnerability of the feature

The vulnerability of a species/habitat can have several interpretations. One refers to the relative vulnerability of species or structural habitat features to disturbance (DFO 2004). We refer to this as “intrinsic vulnerability” because it depends on the internal characteristics of the system (e.g. slow growth rate, low recruitment etc.) prior to the occurrence of a hazard event. For instance, a conservation feature with low biological productivity and/or a limited capacity to regenerate may be vulnerable to external pressures (e.g. easily impacted by fishing gear).

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Text Box 7.2 (cont.). Target setting based on analysis of the priorities for conservation.

Table 7.2.2. Scoring system for current status based on COSEWIC status.

Conservation Status	Description	Score
Endangered	A wildlife species facing imminent extirpation or extinction.	3
Threatened	A wildlife species that is likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.	2
Special Concern	A wildlife species that may become threatened or endangered because of a combination of biological characteristics and identified threats.	1

The relative likelihood of sites being exposed to disturbance is another consideration to determine the degree of vulnerability of biodiversity features (DFO 2004). In MECCEA, we addressed only the intrinsic vulnerability of features.

An overall vulnerability score was determined by assessing four factors that influence the relative vulnerability of conservation features (Table 7.2.3). Life history traits, fragility, functional significance, and structural complexity are part of both the Convention on Biodiversity (CBD) and the Food and Agriculture Organization of the United Nations (FAO) criteria for analyzing the vulnerability of species or habitats (see Ardron et al. 2014). The overall vulnerability score (using Equation 1) was determined, based on how species/habitats scored against each of these factors (see Table 7.2.1). While uniqueness/rarity is part of one of the criteria for identifying vulnerable marine ecosystems, MECCEA considered this factor independently in determining overall target scores. Also, note that not all factors (e.g. Fragility, Structural complexity, etc.) were applied to every conservation feature. For instance, conservation features that represent the geographic range of a species were not assessed against structural complexity and will not apply when dealing with species richness factors such as life history traits.

Rarity/uniqueness

Independent of the type of biodiversity feature, all conservation features should be assessed under the same definition of rarity and uniqueness. For this criterion, the CBD definition of rarity and uniqueness is used. Rarity/uniqueness: When the planning region contains either: (a) unique (the only one of its kind), rare (occurs only in few locations), or endemic species, populations or communities; and/or (b) unique, rare, or distinct habitats or ecosystems; and/or (c) unique or unusual geomorphological or oceanographic feature. The scoring for this criterion was based on the spatial distribution of the feature (Table 7.2.4).

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Text Box 7.2 (cont.). Target setting based on analysis of the priorities for conservation.

Table 7.2.3 Scoring criteria for assessing overall vulnerability of conservation features. Description of factors is from FAO (2009) guidelines to identify Vulnerable Marine Ecosystems (VMAs).

Type of CF	Factors	Description	Scoring Criteria	Score
Species	Life history traits	Life history traits of species that make recovery difficult (slow growth rate, late age of maturity, low fecundity, low recruitment, long lived)	Has a minimum of 2 of the 3 following traits: slow growth rates, long-lived, low, or unpredictable recruitment	3
			Has minimum of 1 of the 3 these traits	2
			Has none of these traits.	1
Species/ Habitat	Fragility	The potential for damage or mortality resulting from physical disturbance*	Highly susceptible to damage or mortality by physical disturbance	3
			Moderately susceptible	2
			Slightly susceptible	1
Habitat/ Ecosystem	Functional significance	Discrete sites/habitats necessary for the survival, function, spawning/ reproduction, or recovery of fish stocks, particular life history stages (e.g. nursery grounds or rearing areas), or rare, threatened, or endangered marine species	Highly significant for the maintenance of species persistence —explicit presence/ evidence of key life history stages	3
			Moderately significant for the maintenance of species persistence	2
			Slightly significant for the maintenance of species persistence	1
Habitat/ Ecosystem	Structural complexity	Sites characterized by complex physical structures created by significant concentrations of biotic and abiotic features. Ecological processes are usually highly dependent on these structured systems. Such ecosystems often have high diversity, dependent on the structuring organisms.	Areas of high biological diversity, geophysical complexity, or highly dependent ecosystem processes	3
			Areas of medium biological diversity, etc.	2
			Areas of relatively low biological diversity, etc.	1

* Includes anthropogenic change.

Table 7.2.4. Scoring system for determining level of uniqueness/rarity.

Rarity/Uniqueness	Description	Score
High	Geographic scale of the feature is locally and globally unique	3
Median	Geographic scale of the feature is regionally (within a bioregion) unique	2
Minimum	Geographic scale of the feature is found repeatedly across the Canadian Arctic	1

Text Box 7.3. Example of a target setting form used for expert input on the assessment of conservation priority.

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Fax: (416) 489-3611
ca-panda@wwfcanada.org
wwf.ca

WWF-Canada Marine Ecological Conservation for the Canadian Eastern Arctic (MECCEA)
Conservation Target Setting Assessment
Species Group: BOWHEAD

Contact: Erin Keenan, WWF-Canada Eastern Arctic Specialist, ekeenan@wwfcanada.org

Expert Name: ______________________ Affiliation: _________________________

Email address: ____

This is a two part assessment.

Part 1 asks you to assess the species vulnerability based on life history traits according to the criteria in Table 1a (below).

Table 1a. Species Assessment Criteria

Factor	Score	Criteria
Species life history traits	3	Has a minimum of 2 of the 3 following traits: • slow growth rates • long-lived • low or unpredictable recruitment
	2	Has a minimum of 1 of the 3 following traits: • slow growth rates • long-lived • low or unpredictable recruitment
	1	Has none of the following traits: • slow growth rates • long-lived • low or unpredictable recruitment

Table 1b. Species Assessment

Species	Life History Traits Score (1-3)
Bowhead life history traits	

Part 2 is an assessment of aspects of the geographic areas (conservation features) associated with the species, based on the criteria in Table 2 (below). These will both be factored into a final target score for each conservation feature by the MECCEA team.

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Table 2a. Geographic Area Assessment Criteria

Factor	Score	Criteria
Fragility	3	Feature is highly susceptible to degradation by physical disturbance
	2	Feature is moderately susceptible to degradation by physical disturbance
	1	Feature slightly susceptible to degradation by physical disturbance
Functional significance	3	Highly significant for the maintenance of species persistence—explicit presence/evidence of key life-history stages
	2	Moderately significant for the maintenance of species persistence
	1	Slightly significant for the maintenance of species persistence
Rarity	3	Feature is unique in the Canadian Arctic
	2	Feature is regionally (within a bioregion) unique
	1	Feature is found commonly across multiple bioregions in the Canadian Arctic

Table 2b. Geographic Area Assessment

Geographic Area		Map Reference	Fragility	Functional Significance	Rarity
Bowhead Seasonal habitat	Summer Distribution (Bering Chukchi Beaufort)	Map 1 Bowhead Seasonal Habitat			
	Summer Distribution (East Canada West Greenland)	Map 1 Bowhead Seasonal Habitat			
	Winter Distribution (East Canada West Greenland)	Map 1 Bowhead Seasonal Habitat			
Bowhead - Important Areas[1]	East Canada West Greenland	Map 2 Bowhead Important Areas			

[1]Including foraging areas, migration routes, and overwintering areas based on a metanalysis of Arctic cetaceans key habitat literature review prepared for WWF-Canada (2015)

It is important to note that not all factors of the vulnerability component were applied to all CFs (see Table 7.2). This is because the vulnerability factor chosen (e.g. fragility versus functional significance versus structural complexity) was dependent on the type of CF (i.e. species range versus sensitive ecological areas such as sponges/corals) and on availability of existing knowledge (see explanation of vulnerability in Text Box 7.2). For instance, the structural complexity factor was not considered for species of marine mammals given the lack of knowledge, but also because of the type of data representing some of these CFs (e.g. species range). Conversely, structural complexity *was* included as part of the vulnerability assessment for seabird key habitats. Experts were able to rank the sites using knowledge on species abundance/diversity and the associated structural complexity of the surrounding environment.

Table 7.2. Conservation features (CFs), factors of vulnerability component applied, and conservation assessment.

CF Group	Factors applied	Assessment
Polar bear key habitats (denning)	Status; life history; fragility; functional significance; rarity	External & internal
Polar bear key habitats (locally identified habitat)	Status; life history; rarity	Internal
Beluga, bowhead, narwhal key habitats (seasonal habitats)	Status; life history; fragility; functional significance; rarity	External & internal
Beluga, bowhead, narwhal key habitats (locally identified habitat)	Status; life history; rarity	Internal
Pinniped key habitats (seasonal habitat)	Status; life history; fragility; functional significance; rarity	External
Pinniped key habitats (locally identified habitat)	Status; life history; rarity	Internal
Fish key habitats	Status; life history; fragility; rarity	External
Seabird key habitats (single species)	Status; life history; fragility; rarity	External
Significant benthic areas	Fragility; functional significance; structural complexity; rarity	External
Eelgrass	Fragility; functional significance; structural complexity; rarity	External
Important Bird Areas	IBA criteria (status; species range; congregations)	Internal
Seabird key habitats (multiple species)	Fragility; functional significance; structural complexity; rarity	External

The assessment for IBAs was one of the CF groups that had a distinct approach given the absence of experts in our project for Arctic terrestrial birds. We ranked each of the categories used by Bird International (e.g. globally significant, continentally significant, and nationally significant) from 1 to 3 based on the number of criteria for which each category is identified (e.g. conservation status, species range, congregatory species, and significant concentration). We then calculated an overall score using the formula Equation 1 in Text Bodx 7.2. This approach allowed us to be consistent with the methodology employed to set the targets for distinctive features.

The results of all these rankings for Conservation Objectives 1A, 1B and part of 1C, are presented in the series of Appendices (Appendices 2.1 to 2.12).

Target Setting Based on Size

The approach of Lieberknecht et al. (2010) was used to set targets based on size for CFs where data/knowledge/expertise were lacking. The method uses a square root transformation to scale features proportionally from a predefined target (area) of the largest feature (see Text Box 7.4 for full explanation). We used predefined targets of 2, 5, and 10% of the area of the largest feature for each of the CFs groups (Figure 7.4). We chose not to have predefined targets above 10% of the largest feature, because this creates a higher number of CFs with very high targets. We explored this in Figure 7.5, which shows how target scaling starting at 10% leads to more than half of CFs with a 100% target.

Text Box 7.4. Target setting based on size.

Conservation targets were based on size when analysis of the priorities for conservation were hindered by the lack of ecological knowledge or data. Size refers here to the total area covered by the feature to be conserved. The rationale is that smaller conservation features should be assigned a higher target range than larger features; this assumes that smaller features are more susceptible to changes or disturbances, including catastrophic events.

Following Lieberknecht et al. (2010)'s approach, targets were scaled proportionally based on their relative overall abundance relative to the largest baseline feature, which was assigned a predefined target. Thus, the distribution of targets for features of the same general kind (e.g. representative features) fell within a continuum roughly proportional to the square root of their respective total areas as given by:

$$(x_p / y_p) \approx (x_t / y_t)^{0.5} \qquad [2]$$

where y_p and y_t are the protection target (p) and total (t) areas, respectively, of the baseline conservation feature; and x_p and x_t are the protection target and total areas, respectively, for any given feature for which a protection target it sought.

Table 7.4.1. Example of the application of Equation 2 using data from the Scotian Shelf area.

CF Name	Area of CF (km^2)	CF target km^2 from Eq. 2 $(x_p / y_p) \approx (x_t / y_t)^{0.5}$		% of Feature Represented
		Calculation of Eq. 2	Target Area (km^2)	
Scotian Rise (y, baseline)	$y_t = 100$	N/A	$y_p = 10.00$	10
Scotian Slope West ($x1$)	$x1_t = 80$	10*(SQRT(80/100))	$x1_p = 8.94$	11
Middle Scotian Shelf ($x2$)	$x2_t = 50$	10*(SQRT(50/100))	$x2_p = 7.07$	14
Outer Scotian Shelf: Bank ($x3$)	$x3_t = 10$	10*(SQRT(10/100))	$x3_p = 3.16$	32
Outer Gulf of Maine Shelf: Basin ($x4$)	$x4_t = 1$	10*(SQRT(1/100))	$x4_p = 1.00$	100
Inner Bay of Fundy: Shallow Basin ($x5$)	$x5_t = 0.5$	10*(SQRT(0.5/100))	$x5_p = 0.70$	~100

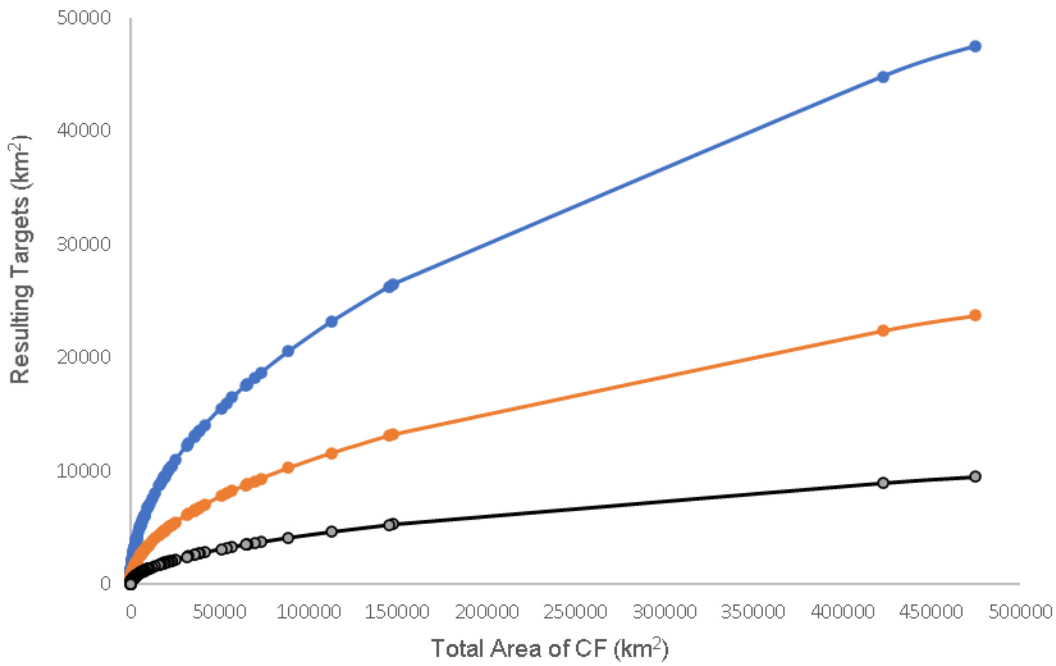

Figure 7.4. Example of resulting targets (using the square root transformation method) for benthic seascapes with predefined targets of 2% (black), 5% (orange), and 10% (blue) of the largest conservation feature (CF).

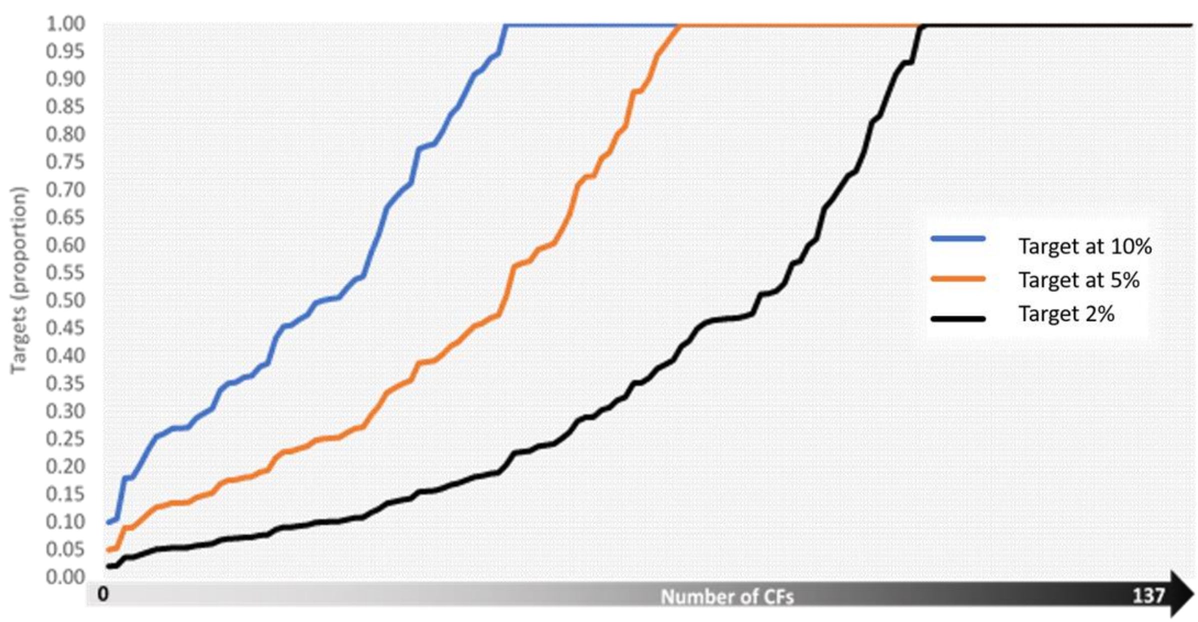

Figure 7.5. Benthic seascapes targets resulting from scaling features from 2%, 5%, and 10% of the largest benthic seascape feature.

We then chose target ranges for each CF from the calculations made using the predefined targets. Targets ranges using 5% and 10% were used for CFs groups pertaining to Conservation Objective 1C (distinctive features, high ecological diversity and productivity) while 2% and 5% were used for Conservation Objective 2 (representative features). The results of applying these formulae on targets are shown in Appendices 2.13 to 2.16 for Conservation Objectives 1C and in Appendices 2.17 to 2. 23 for part of Conservation Objectives 2.

Target Setting: Conclusions and Recommendations

A target range was assigned to 513 features using either of the two methods described above.

Analysis of resulting targets at the top of the range showed that approximately 70% of all CFs (353 features) received targets above 30% of their distributions. More specifically, there were 73 features with a 100% target, 78 features with a 40% target, and 131 features with a 60% target. No CFs had targets less than 10%, and 42 received targets of 10% (which represents 8% of the total number of CFs). The overall distribution of resulting targets is relatively even (Figure 7.6).

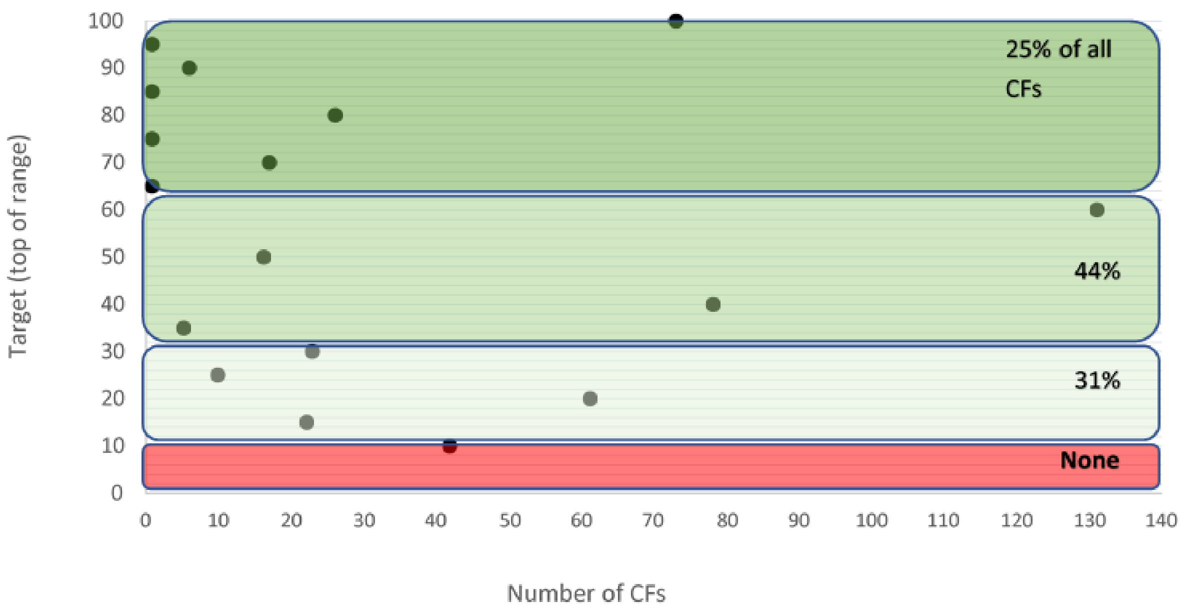

Figure 7.6. Number of conservation features by the target assigned (top of the range), showing a relatively even distribution of conservation features among target ranges.

Analysis of resulting targets at the bottom of the range showed a different picture with 56 features under the 10% target threshold for which protection would not be recommended. In addition, selecting targets at the bottom of the target range resulted in more than half of all CFs (i.e. 270 out of 513 features) with targets equal to or below 30%.

Analysis of targets by method and type of feature can help to explain the differences in the distribution of target ranges. Overall, target setting based on analysis of the priorities for conservation resulted in a greater number of CFs with relatively high target ranges, around 120 CFs with a 40–60% target range (see Figure 7.7A). Amongst all CF groups, sensitive benthic features were the group that received higher target ranges.

Conversely, target setting for representative features, for which a size method was employed, showed more balanced results among high and minimum target ranges (i.e. a high and equal number of CFs with 100% and 10–20% targets, see Figure 7.7B). Thus, target setting using the square root transformation method provided a high number of CFs with targets at both ends of the target spectrum.

While assessment of the priority for conservation can be time a time-consuming process (participation of experts to conduct species assessment takes time) it can be a pragmatic and effective way to provide estimates of species requirements for conservation. Compared to methods that rely only on size, factors such as vulnerability, uniqueness/rarity and conservation status are better indicators to assess species area needs. Thus, using this method for CFs such as hotspots and polynyas would have resulted in targets that appropriately capture their ecological significance and conservation needs. It is recommended to use a heuristic method (as used here in MECCEA) for these kinds of CFs.

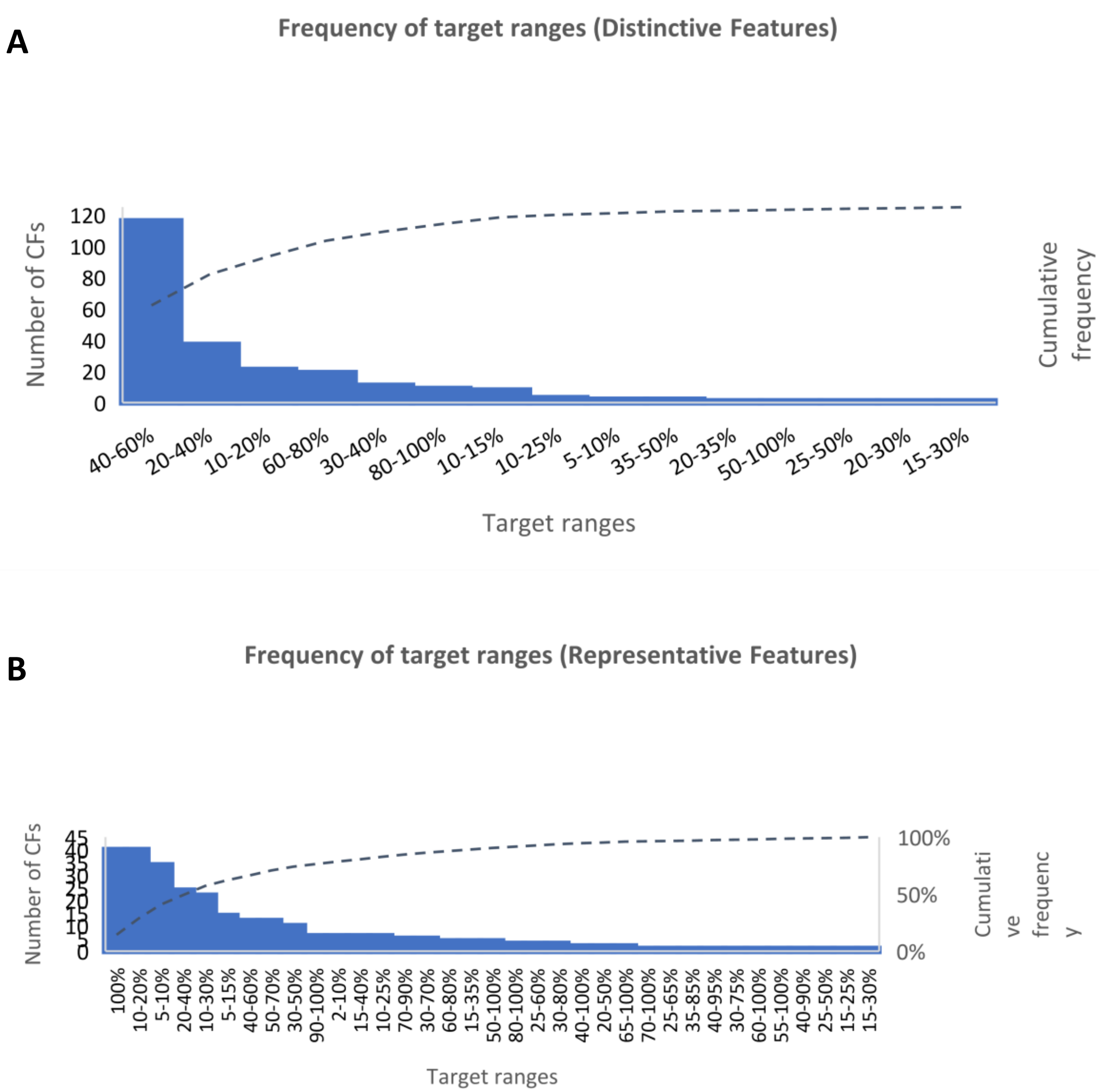

Figure 7.7. Frequency of resulting target ranges by conservation feature. A) distinctive features; and B) representative features.

When scaling features using a square root transformation (i.e. the target-setting method based on size), CFs with a very large area should be excluded because it can bias the distribution of results towards generally high targets.

Conservation targets have a direct effect on Marxan outputs. While higher targets imply solutions with larger areas, it also means that Marxan has less flexibility in the spatial requirements for conservation. In other words, Marxan should not be used when identifying features that all have very high targets (e.g. greater than 90% targets for all CFs). While conservationists usually advocate for higher targets, it is important to remember that protected areas are not the only tool for biodiversity conservation planning. Thus, establishing a 100% target can be viewed as unrealistic and not suitable for conservation planning exercises that deal with spatial prioritization. Conversely, systematic conservation planning is more about finding an amount of area for which some spatial measures make sense for a specific biodiversity feature.

Finally, it is recommended that Marxan scenarios should be presented using different combinations of targets, and that ensuing implications should be examined from a management perspective. This is what we proceed to do in the following chapters.

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CHAPTER 8: IDENTIFYING PRIORITY AREAS FOR MARINE CONSERVATION

INTRODUCTION

There are basically three options for ecologically siting marine protected areas:

1. Independent establishment of sites for individual purposes. This is unlikely to lead to efficient protection of biodiversity on any scale larger than the individual site, or to a true network.
2. A Delphic process based on expert opinion, which can be strongly influenced by individual experiences and can be subject to bias.
3. Objective systematic conservation planning, using tools such as Marxan, that is able to spatially include all recognized biodiversity components of a region.

Systematic conservation planning can be approached by selecting the locations, design, and management of Priority Areas for Conservation (PACs) that collectively represent the biodiversity of a region. This requires an integrated approach that defines the tasks and actions necessary both prior to, and after the identification of PACs. A flow diagram to illustrate the MECCEA planning process was provided in Figure 2.2 and is provided again here in Figure 8.1. The present chapter deals with the second step—identification of PACs using Marxan.

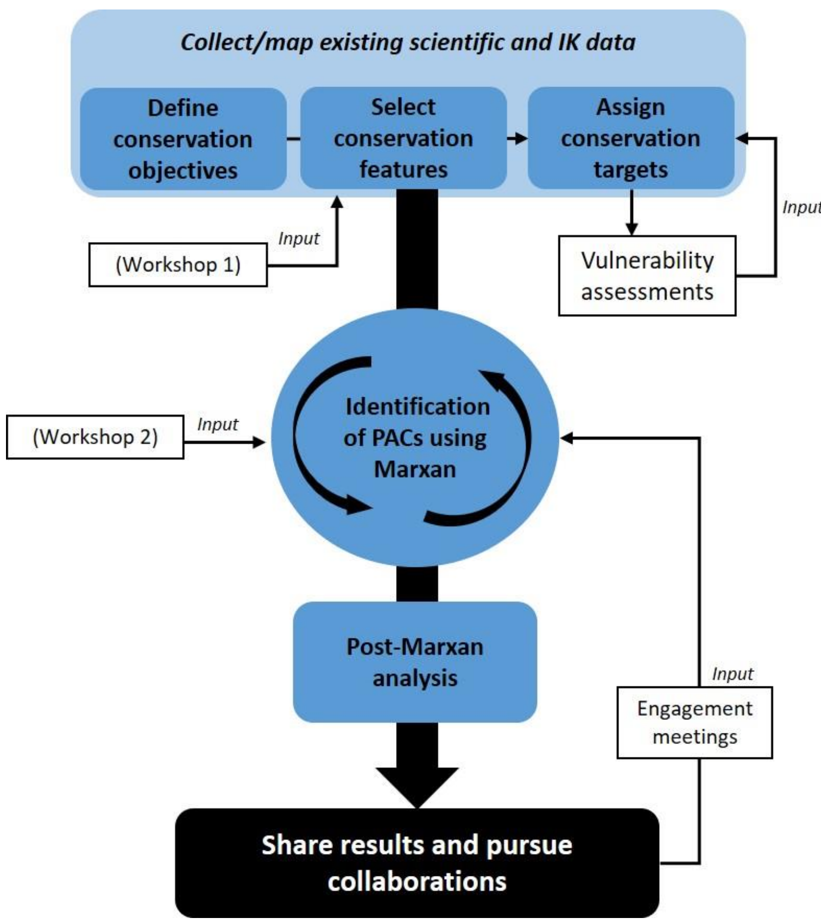

Figure 8.1. The MECCEA systematic planning process, showing the central importance of Marxan. IK = Indigenous Knowledge; PAC = Priority Area for Conservation. Note that this figure was also provided in Figure 2.2.

Marxan is a decision support tool that can inform scientists, policy makers, managers, and stakeholders alike throughout different stages of the systematic conservation process. This planning software has been widely utilized in the identification of biodiversity gaps, the selection of cost-effective areas for conservation investment, multiple-use zoning, and trade-off analysis (Guru et al., 2015). Given Marxan's ability to address fundamental conservation goals (i.e. representativeness, adequacy, complementarity, and efficiency), it has become a very popular tool for designing protected area network systems across the globe. A brief description of Marxan is given in Text Box 8.1, and it is fully described in Ardron et al. (2010).

SOME PRINCIPLES IN SYSTEMATIC CONSERVATION PLANNING

Systematic conservation planning (SCP) offers a framework to inform spatial decision making around the efficient conservation of biodiversity (McIntosh et al., 2017). In practice, this approach is widely used to guide the selection of protected area networks. However, the goals and objectives of SCP extend beyond spatial prioritization. Key stages of SCP allow for the processes to be transparent (e.g. goals/objectives defined, participatory target setting process, accountability of trade-offs), inclusive (e.g. stakeholder engagement, input from various data types), integrated (complementary of other regional management plans), and efficient (e.g. minimize different types of costs; Ban et al., 2014). However, it is the underpinning ecological principles that makes SCP a particularly defensible and rigorous frameworks of conservation planning.

Representativeness

A fundamental characteristic of SCP is the principle of representativeness (see e.g. Day and Roff, 2000). Representativeness refers to how well protected area networks represent the full array of biodiversity components of a given region (Margules and Pressey, 2000). For the marine environment, the basis of this principle lies in the evidence that marine species show high affinity for particular habitats (e.g. substrate, depth, salinity, etc.) and/or use distinctive habitats throughout their life stages (Gaines et al., 2010). Consequently, ecosystem integrity and species long-term protection could be achieved by capturing an adequate proportion of each habitat across the seascape.

Adequacy

A network that is only representative could still fail at ensuring the long-term persistence of biodiversity in a region. The principle of adequacy deals with this challenge. Accounting for adequacy in conservation planning demands an understanding of how much protection identified biodiversity features require to remain viable. One way of addressing this is through the setting of quantitative conservation targets—the amount of area each biodiversity feature requires for protection. This is typically assessed in conservation planning exercises that use spatial prioritization tools as a key input for decision-making.

Adequacy is increasingly linked to aspects of connectivity (Linke et al., 2011). There is substantial evidence the viability of marine populations over time can be highly dependent on the connectivity of larvae dispersing between protected sites (Gaines et al., 2003; White et al., 2010). However, the incorporation of all aspects of connectivity in marine conservation planning has proved to be a daunting and difficult task. We consider this subject more fully in Chapter 9.

Text Box 8.1. Brief description and explanation of Marxan.

Marxan uses an optimization algorithm (i.e. simulating annealing) that finds multiple "good" solutions to solve a conservation problem known as the minimum set. This problem stems from the fact that biodiversity conservation competes against social, economic, and management constraints. Hence, Marxan was designed to achieve a minimum representation of biodiversity features for the smallest possible cost, here in terms of area. In order to solve this conservation problem, the software requires that:

a. the planning/study region is subdivided into planning units, e.g. grids or hexagons;
b. identified conservation features are mapped;
c. quantitative targets are assigned to each feature;
d. "costs" are assigned to each planning unit; and
e. the number of features within each planning unit is calculated.

Marxan works by developing a selection routine to find spatially efficient solutions/portfolios (i.e. the spatial configuration of selected planning units) and assigning scores to each of them. The score is based on each portfolio's ability to meet conservation targets while minimizing the defined cost. The Marxan objective function is the mathematical formulation from which the score is calculated (Equation 3). In its simplest form, it is a combination of the total cost of the solution (e.g. sum of total area of the system and boundary length) and the penalty for not meeting ecological targets. This objective function is designed so that the lower the value, the better the solution (Game & Grantham 2008).

$$\text{Score} = \sum_{\text{PUs}} \text{Cost} + \text{BLM} \times \text{Boundary Length} + \sum_{\text{Features}} \text{SPF for missing features} \qquad [3]$$

Below we provide a brief description of each of the main components of the objective function.

Cost of the selected conservation system: Sum of costs assigned to each planning unit selected in the solution.

Boundary length of the conservation system: Sum of selected planning units that share a boundary with planning units not selected in the solution.

The boundary length modifier (BLM): Controls the spatial compactness of the solution by increasing the cost of reserves with high boundary length-area ratio. A lower BLM can lead to highly fragmented solutions with considerable boundary length, which can be costly and difficult to manage. A higher BLM makes the solution more compact, lowering the boundary length-area ratio. Hence, the role of the BLM is to provide some flexibility for designing solutions more desirable for management.

Penalty for missing features: Sum of every penalty incurred each time a conservation target is not met. Conservation solutions that fail to meet pre-set targets are penalized. The more unmet targets, the higher the penalty contributing to the total cost of the solution.

Species Penalty Factor (SPF): This parameter is a user-defined penalty cost allowing different weightings to be given to different conservation features.

Marxan outputs are usually expressed through maps showing the "best" solution (the scenario that meets targets, while minimizing cost) and the selection frequency (overlap of all solutions in a Marxan execution).

Some pragmatic approaches have become popular amongst managers searching for effective ways to deal with adequacy requirements. For instance, conservation area size and species/habitat replication are design considerations commonly used to justify an adequate network. The rationale behind increasing the conservation area size is two-fold. First, larger conservation areas increase the likelihood that adult individuals of non-migratory species will remain within an area throughout their lifetime. Second, larger sites provide protection to a variety of ecosystems and associated gradient zones (ecosystem boundary), therefore, maintaining the flow of nutrient, chemicals, energy, and materials (ecosystem connectivity—see

Carr et al., 2017). Replicability can promote persistence by providing insurance against local disturbances, thus greatly reducing the risk of losing an entire conservation feature (Gaines et al., 2010).

Complementarity

SCP relies on methods that can identify a system of conservation areas that are complementary to one another. Complementarity is well-captured when the set of identified areas for protection contain different or complementary portions of the targeted biodiversity features (Watson et al., 2011). The complementarity principle offers a system-based approach to designing protected area networks, in which the whole is more than the sum of its parts (Watts et al., 2017).

Efficiency

Spatial conservation designs that are very large and expensive to manage, and which exclude social and economic uses on which communities or economic pursuits depend, tend to have lower levels of social acceptability and thus fewer chances of being successfully implemented (Kukkala & Moilanen, 2013). Efficiency is increased when conservation plans minimize the impact of conservation action on other competing societal objectives (e.g. livelihoods, economic development, etc.). Therefore, a key goal of SCP is to design conservation systems that can deliver ecological objectives for the least cost. Typical costs of a protected area system include those associated with management and lost opportunity (the costs to other human uses in the region).

Replication/ Redundancy

See below.

MARXAN ANALYSES - BACKGROUND

The planning region for the MECCEA study included four DFO marine bioregions (Hudson Bay Complex, Eastern Arctic, Arctic Archipelago, and Arctic Basin), which have been described in Chapter 3. We subdivided the planning region into 82,174 hexagons of 45 km^2 as the planning units (PUs) for the Marxan analyses. The planning region was extended to two planning units inland (two hexagons) from the coast to account for sea-land connections of key Arctic marine species and habitats. This resulted in a planning region that covered an area of approximately 3,697,830 km^2.

Data used in this study have been described in Chapters 4, 5, and 6, and the process of selecting conservation features (CFs) was described in Chapter 7. We grouped CFs by species or habitat types and according to the conservation objective/criteria for which the feature was identified (see Text Box 2.1). Conservation features were split by marine bioregion, and in some cases, were split again to ensure replicability of the feature in the network design or to reflect different species subpopulations/management units.

Initial Calibration

The standard input files for Marxan were generated using ArcGIS 10.6 (ArcMarxan toolbox) and PyCharm (i.e. IDE, Integrated Development Environment). The calibration of Marxan is a critical step if robust results are to be achieved. We executed numerous experimental runs as part of the calibration process to produce robust and consistent results from Marxan.

We tested the number of iterations—internal program repetitions within a run—by increasing its value until Marxan consistently produced efficient solutions as judged by lower number and larger selected areas. Starting at 10^6 iterations, the number of iterations was gradually increased; the final number chosen for analyses was 10^8. While fewer iterations were less time-demanding, calibration showed that 10^8 iterations produced more efficient solutions than a lower number (Figure 8.2). The number of runs (repeat uses of the program) was set to 10 during this period of testing; however, the final number of runs chosen for analyses was 25.

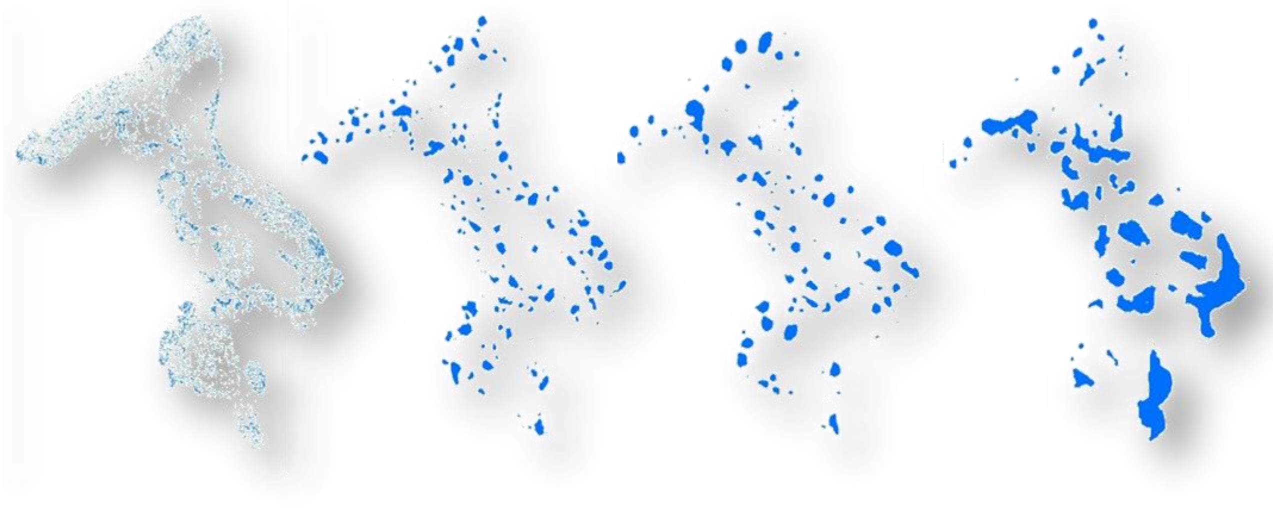

Figure 8.2. Marxan calibration results showing the combined effects of increasing BLM and number of iterations (from left to right) in producing fewer areas of larger size.

The species penalty factor (SPF of 1) was not adjusted given that 99% of CFs were meeting their respective targets.

The BLM was also tested in order to achieve an adequate degree of clumping in the solutions. An appropriate BLM value was determined by comparing the boundary length and the total cost (here defined as area) for each BLM tested during the experimental runs. Changes in the BLM affected the spatial configuration of the resultant "patches"—the individual polygons in the Marxan scenarios (Figure 8.3). When the BLM was increased, the total area of the patches in the solutions also increased while the boundary length decreased (Table 8.1). An ideal BLM is one that balances the cost of area against the cost of boundary length. A BLM of 0.4 complies with this requirement as can be seen in Figure 8.3.

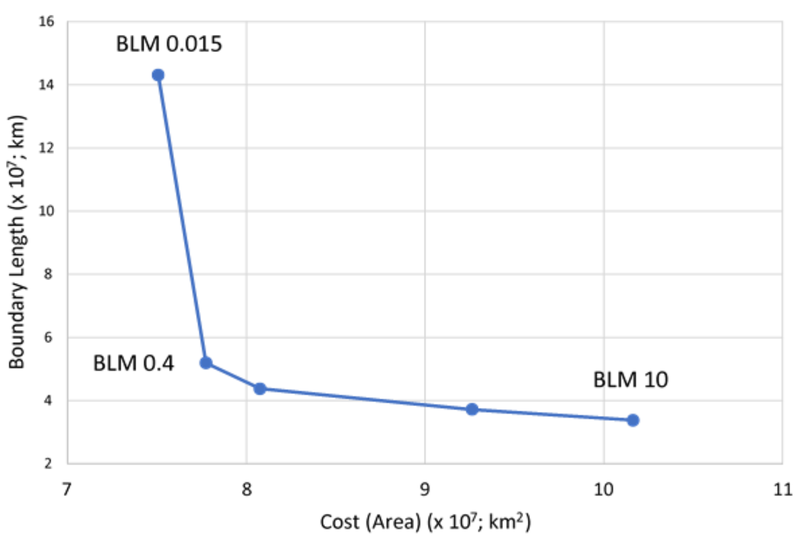

Figure 8.3. BLM and its relation to cost (defined as area in MECCEA).

Table 8.1. Relationship between the BLM, area and other scenario parameters during calibration, including number of planning units (PU), boundary length and penalties applied for missed targets (see Text Box 8.1).

BLM	Area (x10^3 km^2)	# of PUs	Boundary Length (x 10^4 km)	Penalties
10	101,673	22,594	3,373	9
4	92,570	20,571	3,716	10
1	80,757	17,946	4,373	14
0.4	77,742	17,276	5,189	17
0.015	75,065	16,681	14,307	25

In practice, however, decisions about the preferred spatial compactness rely more heavily on what decision-makers deem appropriate for management; this depends on the specific context in which the exercise takes place. The combination of parameters chosen for the final MECCEA Marxan analyses is given in Table 8.2.

Table 8.2. Final parameters chosen for the Marxan analyses.

Parameter	Value
Number of iterations	100 million
Number of runs	25
BLM	0.4 and 10
SPF	1

Marxan Conservation Features, Targets, and Indicators

A series of Marxan scenarios was generated to aid decision making around the selection of PACs. Marxan is designed to meet predefined targets while minimizing costs. A total of 513 conservation features were included for the analysis: 120 layers of marine mammal key habitats, 45 layers of fish habitats, 8 layers of significant benthic areas, 2 layers of benthic family richness, 18 layers of hotspots (i.e. marine mammals, polar bears and seabirds), 9 layers of seabird colony sites, 18 layers of seabird key habitats, 12 layers of Important Bird Areas (IBAs), 31 layers of coastal habitats (i.e. cliffs, wetlands, inlets, intertidal areas), 32 layers of seafloor geomorphic features, 9 layers of areas of high productivity and primary production, 3 layers of polynyas, 1 layer of eelgrass areas, and 205 seascape layers (see Appendix 2). We treated cost as the area of each planning unit, meaning that targets are met with the smallest possible spatial footprint.

We explored several alternative Marxan scenarios at different target levels—minimum and high on each side of the median target range. Henceforth, we refer to the Marxan scenario that uses the bottom end of the target range as “minimum” to describe the lowest acceptable level of protection recommended by WWF-Canada. We also explored different BLMs (0.4 and 10), and spatial restrictions, i.e. inclusion or exclusion of existing or proposed protected areas. A description of the parameters used for each scenario that was run is provided in Text Box 8.2.

Marxan was also used to assess the extent to which established and proposed protected areas provide long-term protection to Arctic marine biodiversity. Overall, indicators were developed to better understand the efficiency of resulting scenarios in meeting conservation targets. Size and area indicators including, but not limited to, total area of the solution, total number of patches, and average size of patches, were measured and compared with indicators of efficiency. A mathematical formulation of efficiency indicators is presented in Text Box 8.3.

Text Box 8.2. A description of each group of MARXAN scenarios.

- S1—Current system of designated MPAs. Marxan was run with zero targets, and, therefore, no planning units or areas were selected. Outputs from this run were only used to calculate indicators and to highlight existing biodiversity gaps. Indicators were calculated for targets at each side of the median target range.
- S2—Represents both the current and proposed MPAs and OEABCMs (Other Effective Area Based Conservation Measures). Marxan was used here only to calculate indicators and highlight biodiversity gaps, but no areas/PUs were selected (i.e. targets were set to zero). Indicators were also calculated for targets at each side of the median target range.
- S3—Marxan was run with targets at the minimum end of the target range. This scenario does not have any spatial restrictions; thus, existing/proposed MPAs were not included at the outset (i.e. no MPAs were locked-in). In this case, all planning units have an equal chance of being part of the final solution, which will depend on how well planning units can reach CF targets while minimizing the overall cost of the solution. A BLM of 10 was used in this scenario.
- S4—Scenarios in which all planning units associated with a designated MPA were locked-in. As such, this is a spatially restricted scenario in which Marxan builds on the existing MPAs to efficiently find new areas that altogether meet CF targets. There were six scenarios under this group that resulted from a combination of different targets (at minimum, median, and high ranges) and BLMs (0.4 and 10).

  Three scenarios from these runs – minimum, median, high - at BLM 10 were selected for further examination of connectivity and networks of PACs, broader ecological and environmental relationships, commercial and socio-cultural relationships, and management relationships in subsequent chapters.
- S5—A group of two spatially restricted scenarios in which planning units associated with both designated <u>and</u> proposed MPAs were locked-in. Therefore, Marxan was run to find solutions that efficiently complement the existing and proposed conservation network. The two scenarios were a combination of minimum and high target ranges, and with a BLM of 0.4.

Note: In August 2019, the status of a new marine protected area, **Tuvaijuittuq,** was changed from "proposed" to "designated", during the course of the Marxan study. Although too late to be included, extensive areas within it were selected by our MARXAN runs (see Figures 8.18, 8.19, 8.20).

DATA DISTRIBUTION AND CONCEPTS

Data richness for the MECCEA planning region is shown in Figure 8.4, where more than 50 layers represents 513 conservation features. Much of the available data are contained within the Nunavut Settlement Area and adjacent offshore waters. More specifically, the Eastern Arctic and Hudson Bay Complex marine bioregions are data-rich compared to the Arctic Archipelago and Arctic Basin. Even within the relatively data-rich marine bioregions, data richness is not spatially evenly distributed. There is a lack of data throughout the center of Hudson Bay and some offshore areas around the center of Baffin Bay. Most data-rich areas appear along the shoreline near Inuit communities, in the Lancaster Sound area, around the southern portion of Baffin Bay, in Davis Strait, and the area along the Hudson Strait. Not surprisingly, the Arctic Basin appears to be the most data poor region, although the southern part holds greater biodiversity compared to the northern part.

Text Box 8.3. Indicators to calculate the efficiency of scenarios in meeting conservation targets.

Let f be a CF belonging to the set $C = \{f_1, f_2, f_3 \ldots f_n\}$ where C represents the total number of CFs considered in a given scenario, s.

Let $K \subset C$; $K = \{f \mid PAh_f > 105\%\}$ where K is the set of $f(C)$ that the proportion of area within is greater than 105% of its target.

Therefore, PAh_f, the proportion of area in f, is given by:

$$PAh_f = \frac{(\mathrm{Ah}f - \mathrm{At}f)}{\mathrm{At}f} * 100$$

where:

Ah_f = area of f held in a scenario, s

At_f = area of target defined for f

We define the following indicators:

- Feature overrepresentation (ORf)

$$ORf_{(s)} = \frac{n}{N} * 100 \qquad \text{and, } 0 \le ORf_{(s)} \le 100$$

where:

n = Total number of overrepresented CFs in scenario, s (*all* $f \in K$)

N = Total number of CFs in scenario, s (*all* $f \in C$)

- Area overrepresentation (ORa)

$$ORa_{(s)} = \frac{(\sum \mathrm{Ah}f - \sum \mathrm{At}f)}{\sum \mathrm{At}f} * 100 \quad \text{and, } 5 < ORa_{(s)} < \infty$$

where:

Ah_f = area of f held in a scenario, s (all $f \in K$)

At_f = area of target defined for f (all $f \in K$)

- Index of overall overrepresentation (OR)

$$OR = \frac{\sum \mathrm{Ah}f - \sum \mathrm{At}f}{n}$$

A summary of conservation objectives, conservation features (CFs), and their targets is shown in Table 8.3. The table also indicates whether replicability or connectivity (two important components for biodiversity persistence—considered further in Chapter 9) were captured in some way within each CF group. Overall, it was important to strike a balance between distinctiveness (Conservation Objective 1, O1B) and representativeness (Conservation Objective 2) in terms of the number of CFs that were included in the analysis, which were 245 and 268 CFs, respectively. Sensitive benthic areas (O1B, Table 8.3) had the lowest number of CFs (8), which speaks to the general lack of available data for biogenic features. Conversely, benthic seascapes had the highest number of CFs (137), the result of the many combinations of oceanographic variables and the fact that they were split by marine bioregion to account for replicability.

Replicability at the marine bioregional level was evident for every CF group. In some cases, CFs were split within a marine bioregion to account for large latitudinal/longitudinal differences in their distribution. Two CF groups, small gorgonian coral concentrations and eelgrass, were not replicated given their limited distributions.

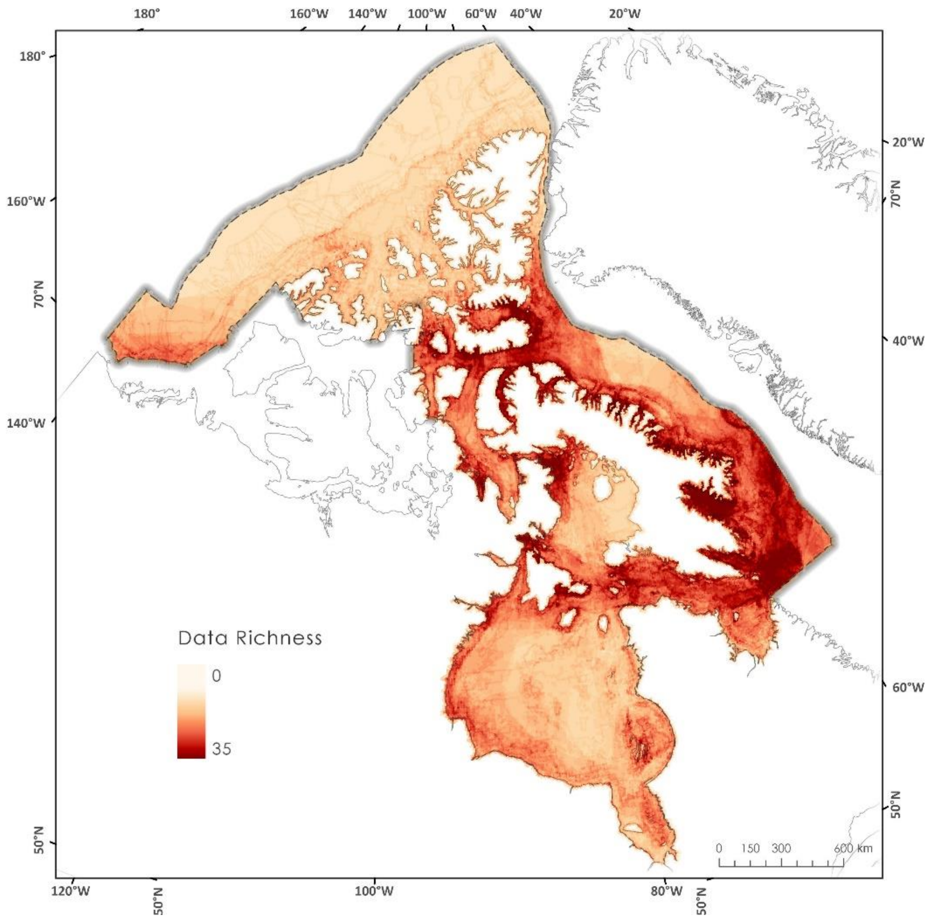

Figure 8.4. Data richness (number of features per planning unit) within the MECCEA planning bioregions.

There were 14 CF groups (all from Conservation Objective 1) that had at least one conservation feature contributing to some aspect of connectivity. Specifically, seasonal migration and habitat connectivity were captured through selected CF key habitats for all identified cetaceans. Patterns of seasonal migration also represented population connectivity across selected CFs. Habitat connectivity was reflected through connected key habitats such as calving areas, foraging areas, and nursery areas identified as CFs under O1A (i.e. species key habitats). Moreover, some aspects of ecosystem connectivity (e.g. as trophic relationships) were captured as highly productive areas, including polynyas and areas of persistent chlor a concentrations. Connectivity among identified the MECCEA PACs is considered further in Chapter 9.

Conservation Feature Gap Analysis

Existing Arctic marine protected areas and proposed conservation areas in the Canadian Eastern Arctic are presented in Figure 8.5. The marine protected areas of the Canadian Eastern Arctic comprised 6.8% of the study area before, and 15.4% after, the designation of Tuvaijuittuq (Table 8.4, S1 and S1-B). While the recent addition of Tuvaijuittuq more than doubles the area of protection, it still does not meet the objectives of marine biodiversity conservation in the study area, with a significant number of CFs still unmet (Table 8.4). If both existing and proposed protected areas are considered together, levels of CF representation improve. Nevertheless, even though marine protection increases from 6.8% to approximately 20.7% under scenario S2, well over 300 CFs would still remain with unmet targets (approximately 25–37% of all CFs).

Table 8.3. Summary of conservation features in the MECCEA Bioregions.

	Conservation Objectives	CF Group	# of CFs	Replicability	Connectivity	Minimum & High target
Distinctive	**O1A – Protect species key habitats**	Polar bear key habitats	29	✓	✓s	5%≤CF-target≤100%
		Beluga key habitats	28	✓	✓s, h	20%≤CF-target≤100%
		Bowhead key habitats	16	✓	✓s, h	20%≤CF-target≤60%
		Narwhal key habitats	22	✓	✓s, h	20%≤CF-target≤80%
		Walrus key habitats	17	✓	✓s	20%≤CF-target≤60%
		Hooded seal key habitats	4	✓	✓h	40%≤CF-target≤60%
		Harp seal key habitats	4	✓	×	40%≤CF-target≤60%
		Bearded seal key habitats	3	✓	×	40%≤CF-target≤60%
		Ringed seal key habitats	4	✓	×	10%≤CF-target≤20%
		Fishes	45	✓	×	10%≤CF-target≤100%
		Seabird colony sites	9	✓	✓s	20%≤CF-target≤100%
	O1B – Protect sensitive benthic areas	Large gorgonian coral concentration	2	✓	×	80%≤CF-target≤100%
		Small gorgonian coral conc.	1	×	×	80%≤CF-target≤100%
		Sea pen concentrations	3	✓	×	40%≤CF-target≤60%
		Sponge concentrations	2	✓	×	60%≤CF-target≤80%
	O1C – Protect areas of high productivity & species diversity/ concentrations	Benthic family richness	2	✓	×	60%≤CF-target≤80%
		Marine mammal hotspots	5	✓	✓s	10%≤CF-target≤35%
		Seabird hotspots	6	✓	✓s	10%≤CF-target≤100%
		Polynyas	3	✓	✓e	5%≤CF-target≤50%
		Key seabird areas	18	✓	✓s, h	40%≤CF-target≤100%
		Important bird areas	12	✓	✓s, h	10%≤CF-target≤80%
		Max. chlor a concentration	4	✓	✓e	15%≤CF-target≤50%
		Primary production	5	✓	✓e	10%≤CF-target≤100%
		Eelgrass	1	×	×	60%≤CF-target≤80%
Representative	**O2 – Protect representative habitats**	Benthic seascapes	137	✓	×	2%≤CF-target≤100%
		Pelagic seascapes	68	✓	×	2%≤CF-target≤100%
		Benthic geomorphology	32	✓	×	2%≤CF-target≤100%
		Intertidal habitats	6	✓	×	2%≤CF-target≤90%
		Inlets	19	✓	×	2%≤CF-target≤100%
		Cliffs	3	✓	×	5%≤CF-target≤50%
		Wetlands	3	✓	×	15%≤CF-target≤60%

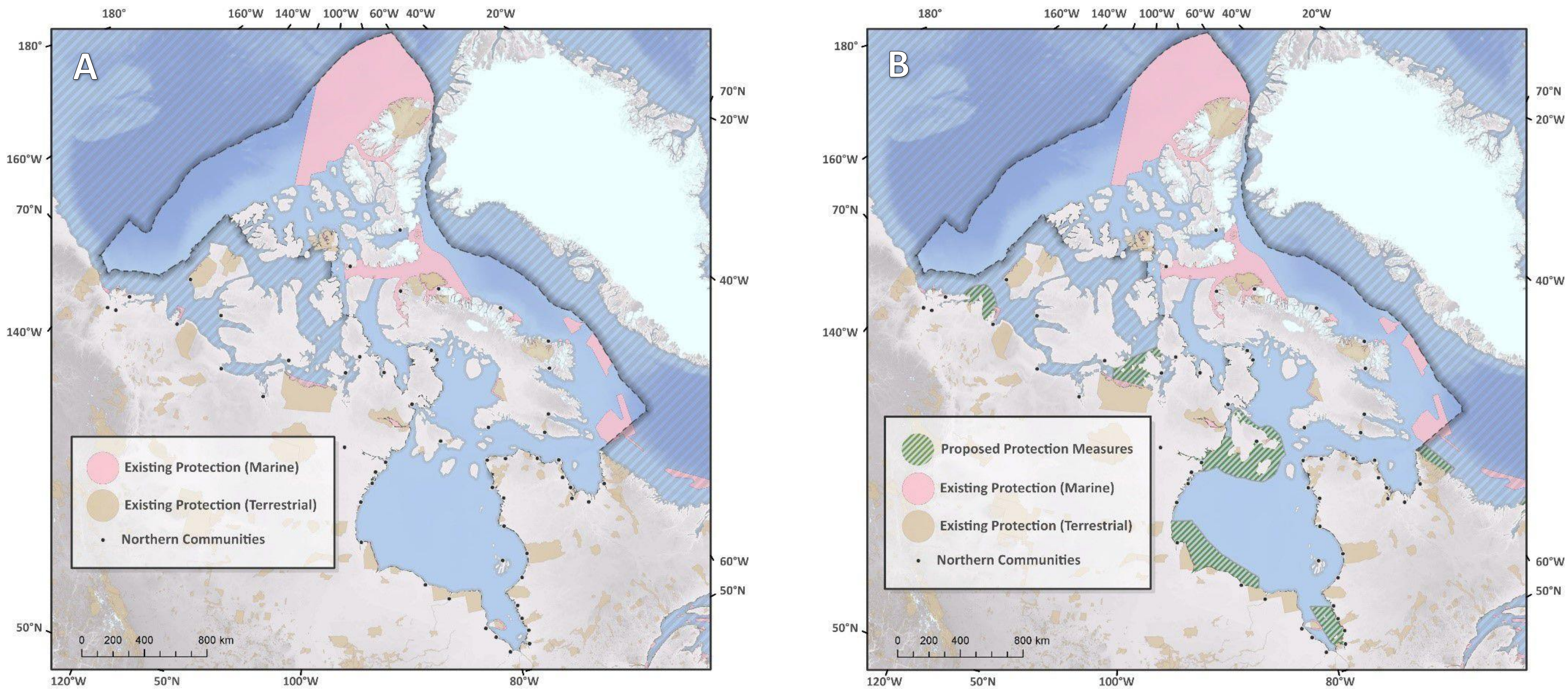

Figure 8.5. A) Existing (S1); and B) proposed (S2) protected areas for the Canadian Eastern Arctic. Note that the shape of the Tuvaijuittuq protected area in the Arctic Basin changed from the time of its proposal (as shown in Figure 8.14 and Figure 8.15) to the time of its designation (as shown in all other figures in this chapter).

Table 8.4. Resulting characteristics of Marxan scenarios.

		S1		S1-B		S2		S3	S4					
		Designed MPAs (excluding Tuvaijuittuq)		Designed MPAs (including Tuvaijuittuq)		Designed MPAs & Proposed Conservation Areas		No MPA restriction	Potential network design scenarios (current MPAs restriction)					
									Min. *Target Range*		*Med. Target Range*		*High Target Range*	
		S1.1 Min. Targets	**S1.2** High Targets	**S1-B.1** Min. Target	**S1-B.2** High Target	**S2.1** Min. Target	**S2.2** High Target	**S3.1** Low BLM High Target	**S4.1** Low BLM Min. Target	**S4.2** HighBLM Min. Target	**S4.3** Low BLM Median Target	**S4.4** High BLM Median Target	**S4.5** Low BLM High Target	***S4.6*** High BLM High Target
Size & Area	Area (km²)	257,257		581,028		781,795		1,310,737	882,110	1,151,626	1,111,280	1,474,866	1,365,136	1,774,924
	Proportion of study area (%)	6.8		15.4		20.7		34.8	23.4	30.6	29.5	39.1	36.2	47.1
	No. of patches	53		54		195		117	141	75	132	45	141	44
	Max. patch size (km²)	108,000		333,127		333,127		397,470	182,556	263,187	220,278	351,393	327,404	460,719
	Average patch size (km²)	4,854		10,759		4,009		11,202	6,256	15,355	8,418	32,774	9,681	40,339
Efficiency in meeting targets†	Proportion of CF targets met* (%)	19.1	12.2	26.8	18.4	36.9	25.4	99.0	98.6	99.0	98.6	99.2	99.4	99.8
	No. of CF targets unmet	415	450	375	418	323	382	5	7	5	7	4	3	1
	ORa* (%)	171.3	94	251.8	139.5	218.7	110.7	108	160	175	124	145	110	121
	ORf** (%)	16.9	8.7	24.6	16	33.8	22.7	52.8	60.4	72.1	60.0	71.0	53.6	70.1
	OR***(km²)	12,476	13,589	15,397	15,809	16,491	14,886	14,521	12,155	13,098	13,372	18,709	15,950	17,774

† Efficiency metrics were calculated using the same projection system in which MARXAN was run (EPSG:3347) which results in a slight areal distortion of ~1.8% across the study area.
* Indicator of area overrepresentation
** Indicator of conservation feature overrepresentation
*** Index of overall overrepresentation

A gap analysis conducted using the CFs and targets of the MECCEA study, shows that all groups of Arctic marine species are variously under-represented (Figure 8.6A). Thus, levels of protection in the Canadian Arctic provided by the existing set of protected areas, fall short in meeting conservation targets and fail to provide long-term persistence for several features of Arctic marine biodiversity. Benthos was the group with the highest level of CF representation. More specifically, 91% of the minimum area required for long-term protection of selected benthic CFs is covered by recently established marine refuges of southern Baffin Bay (which were purposely established to protect biogenic habitats). Fish, pinnipeds, birds, polar bear, and cetaceans have levels of CF representation that range between 55% and 30% of the total number of CFs analysed. Eelgrass was the only CF presently with zero representativity and is, therefore, unrepresented.

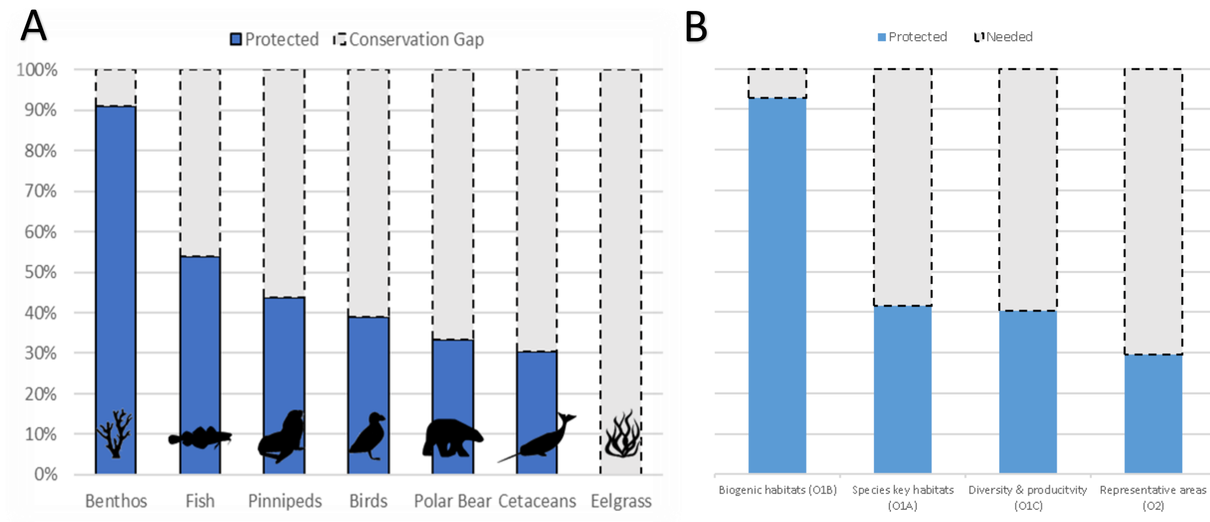

Figure 8.6. Biodiversity conservation gap analysis based on current protection coverage. A) Arctic species groups. B) MECCEA's conservation objectives. Blue: Area under existing protection. Grey: Area needed to meet minimum area conservation requirements.

A gap analysis was also conducted to assess current protection levels for CFs falling under MECCEA's conservation objectives (see Figure 8.6B). Results show that current conservation measures in the Canadian Eastern Arctic are biased towards the protection of biogenic habitats (MECCEA Conservation Objective 1B, O1B) where more than 90% of their assigned targets are protected. Conversely, only some 40% of the minimum required area for species key habitats and areas of high productivity/diversity is currently under protection. Representative areas are presently the most under-represented feature in the Canadian Eastern Arctic, with more than 70% of minimum conservation area requirements missing.

MARXAN SCENARIOS

The best solution (see Text Box 8.1) from Marxan scenario (S3) without spatial restriction (i.e. without locking in pre-existing protected areas), with high targets, and a BLM of 0.4, is shown in Figure 8.7. The 117 sites identified (S3.1, Table 8.4) cover approximately 35% of the MECCEA planning area. Patch size ranges from 45 km² (i.e. the area of a single planning unit) to a maximum of 397,470 km². The maximum patch size extends along the east coast of Baffin Island, covering most of the offshore areas of southern Baffin Bay, and parts of Hudson Strait and Ungava Bay. Under this scenario, 99% of all CFs met their targets, but 5 CFs did not (Table 8.4). Also, 271 CF targets exceeded >105%. Therefore, this scenario occupied more area than was required to meet the targets for all CFs. Overall, the area was overrepresented by 108%, or on average by 14,521 km² per CF.

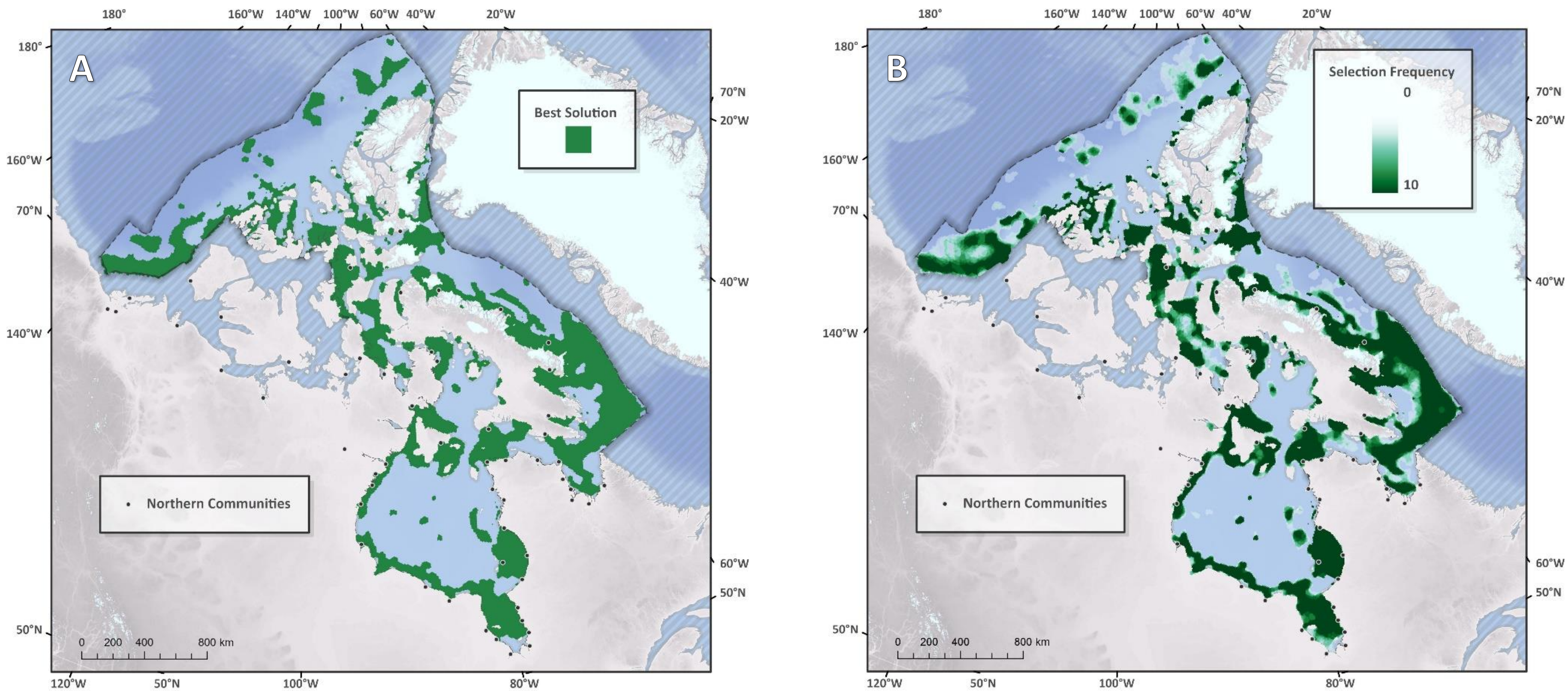

Figure 8.7. Marxan scenarios with no spatial restriction, S3 (no spatial restrictions; high targets; BLM 0.4). A) Best solution. B) Selection frequency.

Marxan was also executed with existing marine protected areas and OEABCMs (other effective area-based conservation measures) locked-in, but excluding the newly established Tuvaijuittuq (Group S4, Table 8.4 and Figure 8.8–Figure 8.13). ***Note that the status of Tuvaijuittuq changed from "proposed" to "designated" during the course of the MECCEA study.*** Within this group, scenarios with minimum targets covered 23.4% of the planning area when BLM was set to 0.4 (S4.1, Figure 8.8), and 30.6% when the BLM was set to 10 (S4.2, Figure 8.9). With a higher BLM of 10, Marxan solutions resulted in more clumped, less fragmented areas, and with a reduced number of patches; 75 compared to 141 in S4.1. S4.2 more than doubled the average patch size to 15,355 km^2 compared to 6,256 km^2 in S4.1. Both scenarios reached high levels of CF target representation, with 98.6% (S4.1) and 99% (S4.2) of CF targets met. However, more than 300 CFs had their targets surpassed in each scenario (310 CFs in S4.1 and 370 CFs in S4.2). Also, the area selected in each of these scenarios exceeded the total area of CF targets assigned by more than 150% (Table 8.4).

The percentage of area occupied for scenarios at the median target range was 29.5% (S4.3, BLM = 0.4) and 39.1% (S4.4, BLM= 10) of the total planning area (Figure 8.10 and Figure 8.11). The number of patches was reduced from 132 in S4.3 to only 45 in S4.4 in which the BLM was set to 10, but this produced a three-fold increase in the average patch size, from 8,418 km^2 (S4.3) to 32,774 km^2 (S4.4). Scenarios S4.3 and S4.4 had a CF target achievement of 98.6% and 99.2%, respectively. CFs for which targets were unmet are shown in Table 8.4. However, both scenarios had targets surpassed for 60% of CFs (308 out of 513) in S4.3 and 71% (367 out of 513) of CFs in S4.4. The areas selected in these scenarios exceeded the total area of CF targets assigned by 124% (S4.3) and 145% (S4.4). There was a target overachievement of 13,372 km^2 per CF in S4.3 and 18,709 km^2 per CF in S4.4.

Marxan scenarios with high targets achieved the largest areal coverage among this group of scenarios. Specifically, S4.5 and S4.6 (Figure 8.12 and Figure 8.13) covered 36.2% and 47.1%, respectively, of the MECCEA planning region (Table 8.4). The scenario with high BLM (S4.6) resulted in a smaller number of patches (44) but produced the largest average patch size among all scenarios (40,339 km^2) including one of the largest patches covering an area of 460,719 km^2. Likewise, S4.5, with BLM 0.4 resulted in a greater number of patches (141) of smaller size on average (9,681 km^2). This group had the best level of target achievement with 99.4% (S4.5), and 99.8% (S4.6) of CF targets met. Overrepresentation was also characteristic of the two scenarios. CF targets were overachieved by 110% and 121% for 275 CFs in S4.5 and 360 CFs in S4.6 (see Table 8.4). For these CFs, targets were surpassed on average by 15,950 km^2 and 17,774 km^2 per CF in each scenario.

A further alternative for a spatial conservation network design for the Canadian Eastern Arctic was considered (Group S5, Figure 8.14 and Figure 8.15). For this group, there was greater spatial restriction, both existing and proposed conservation areas were locked in, including Tuvaijuittuq). The Marxan spatial solutions yielded the largest areal coverage of all scenarios, exposing a lack of spatial efficiency in current conservation planning for the Canadian Eastern Arctic. Even though a lower BLM was used in this group (BLM 0.4), the maximum patch size was above 400,000 km^2 for both the minimum and high target scenarios. In addition, the number of patches was prohibitively high—119 and 94 for minimum and high targets respectively. Accordingly, this solution was not pursued further.

SCENARIO COMPARISON AND EVALUATION

A comparison and evaluation of Marxan scenarios can help understand the influence of different parameters in the spatial configuration of solutions and can facilitate decision making around the selection of PACs.

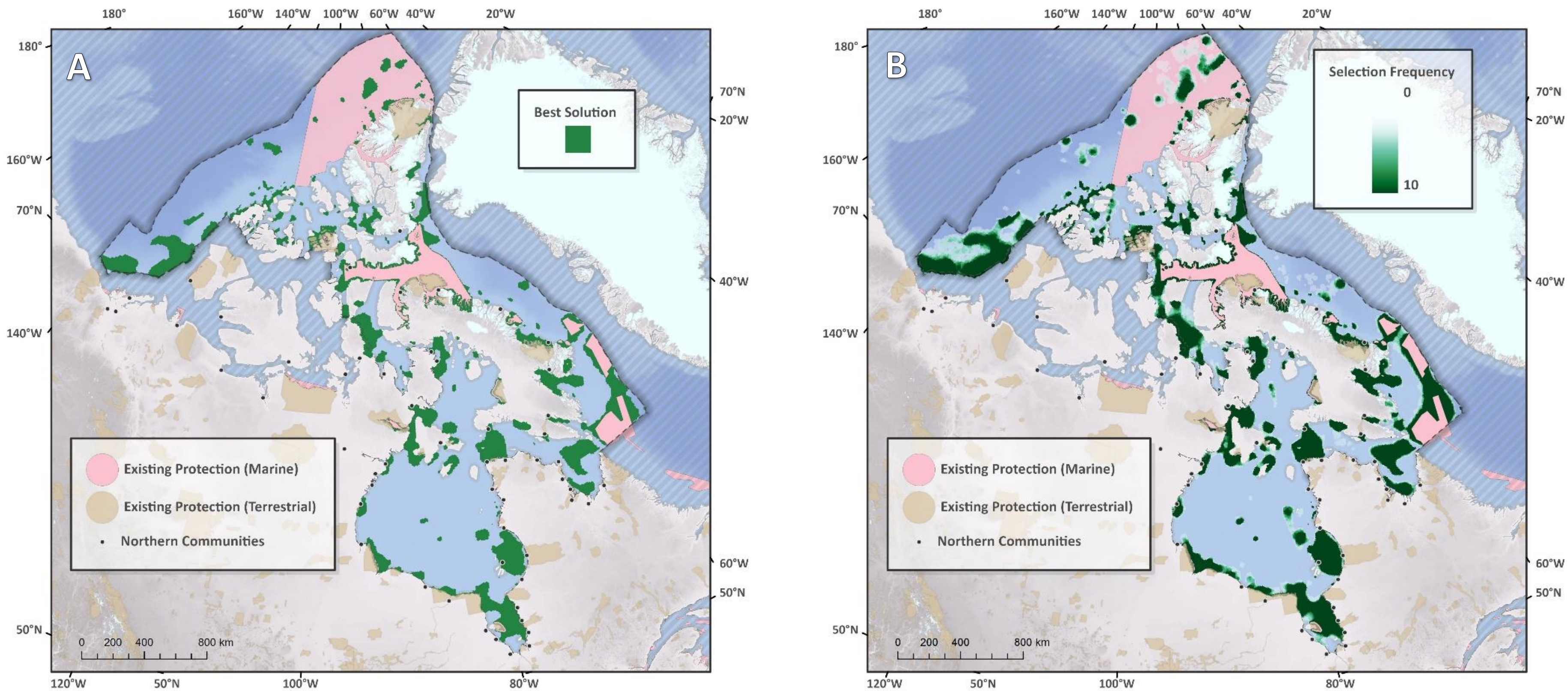

Figure 8.8. Potential network design scenario, S4.1 (existing MPAs locked in; minimum targets; BLM 0.4). A) Best solution. B) Selection frequency.

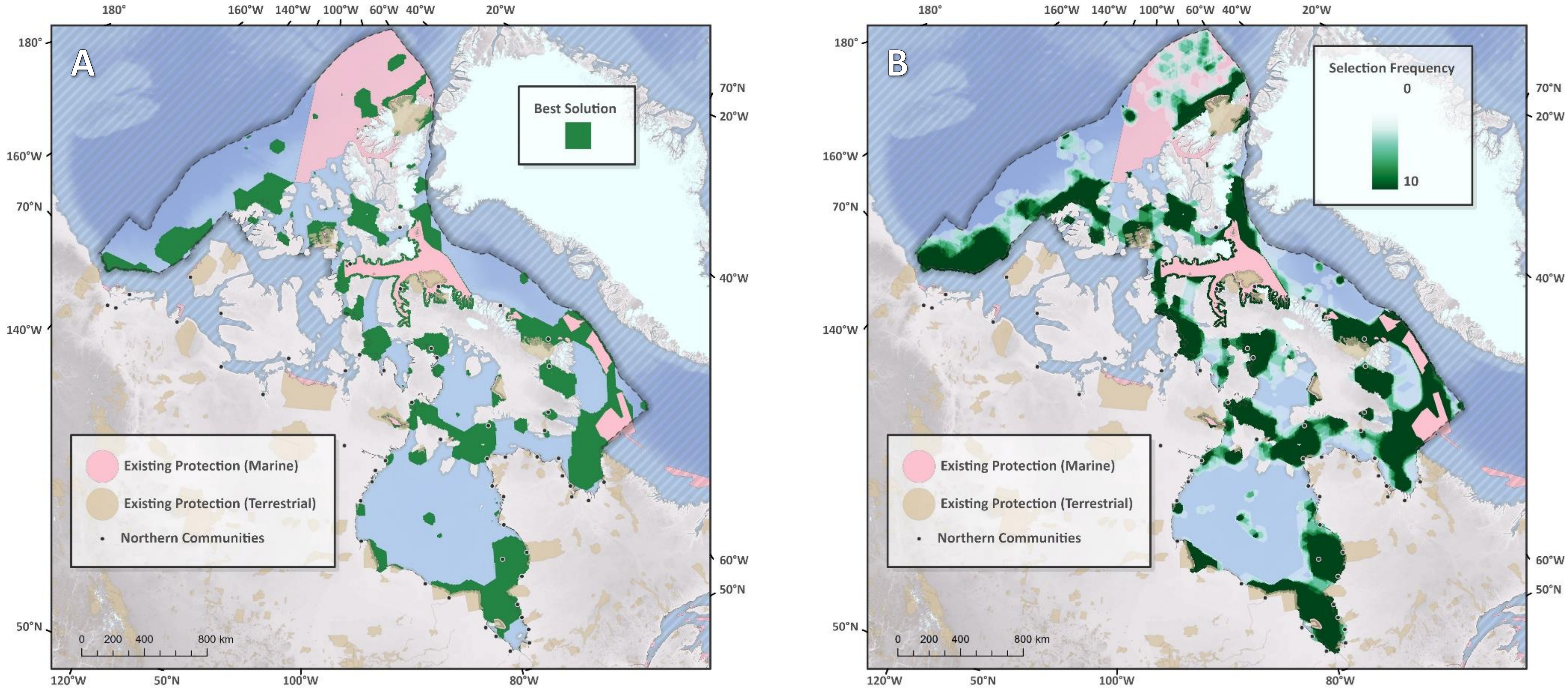

Figure 8.9. Potential network design scenario, S4.2 (existing MPAs locked in; minimum targets; BLM 10). A) Best solution. B) Selection frequency.

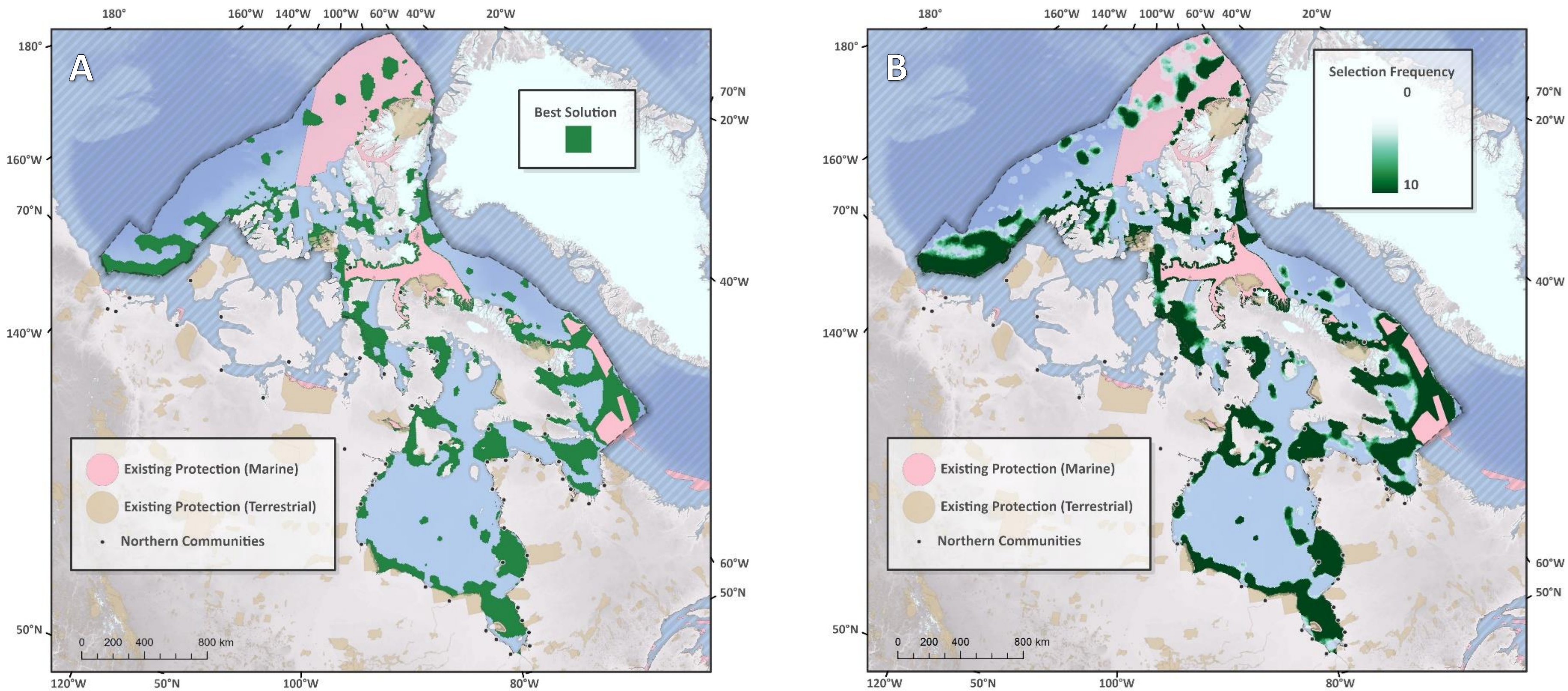

Figure 8.10. Potential network design scenario, S4.3 (existing MPAs locked in; median targets; BLM 0.4). A) Best solution. B) Selection frequency.

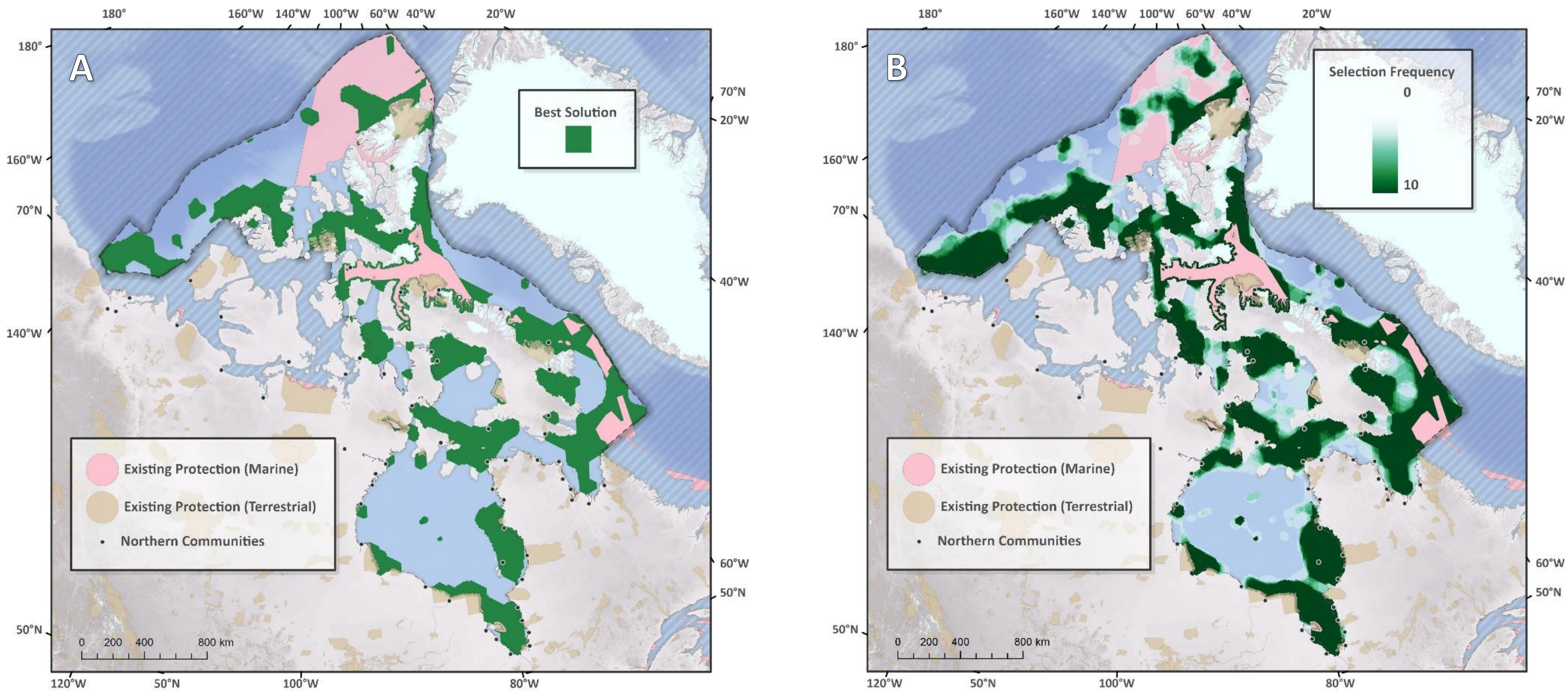

Figure 8.11. Potential network design scenario, S4.4 (existing MPAs locked in; median targets; BLM 10). A) Best solution. B) Selection frequency.

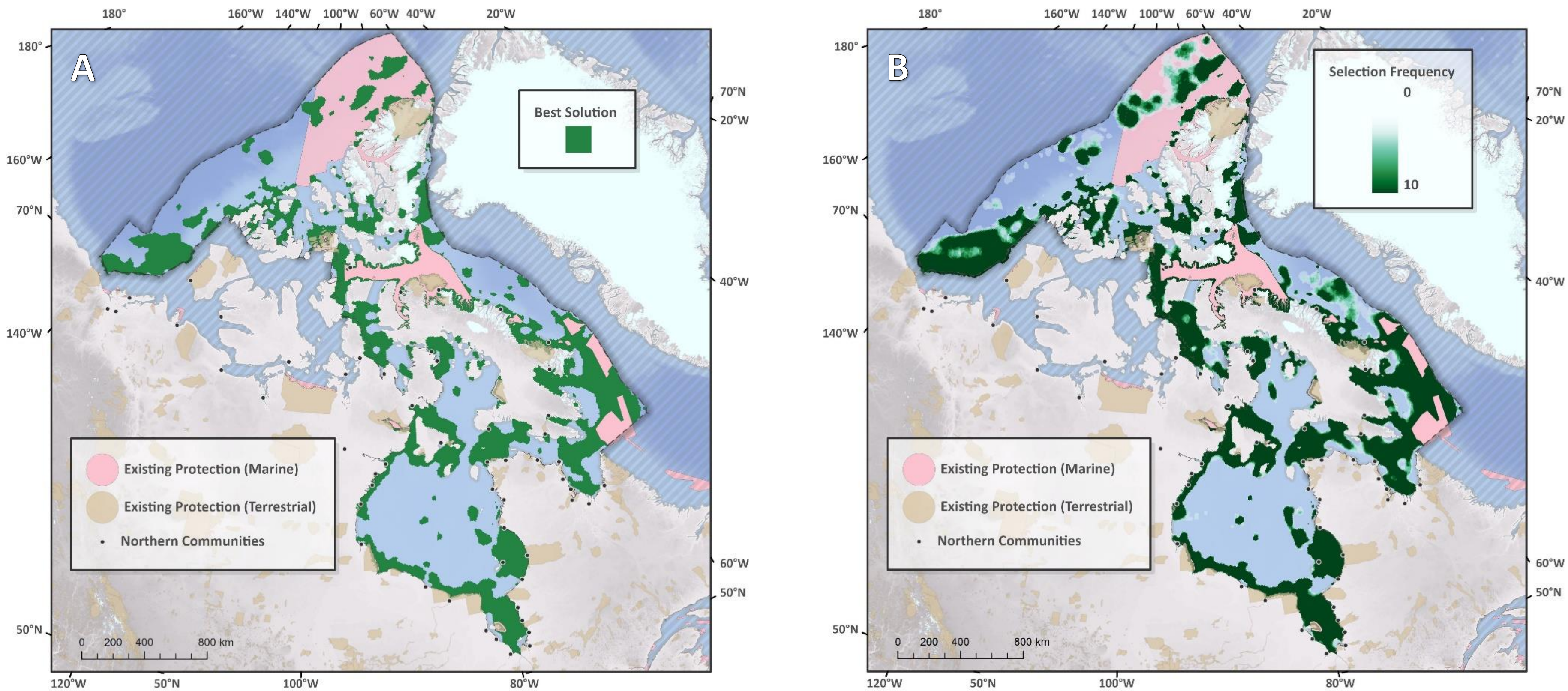

Figure 8.12. Potential network design scenario, S4.5 (existing MPAs locked in; high targets; BLM 0.4). A) Best solution. B) Selection frequency.

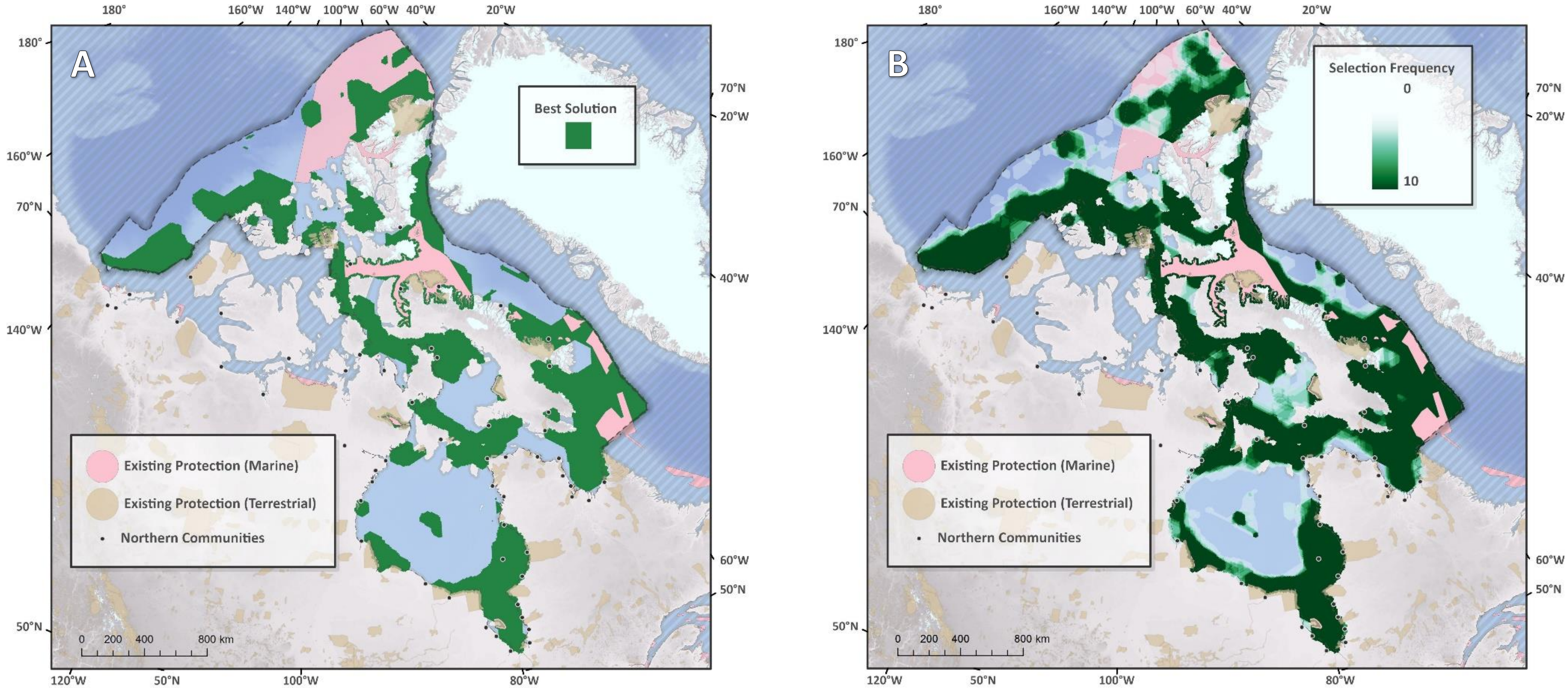

Figure 8.13. Potential network design scenario, S4.6 (existing MPAs locked in; high targets; BLM 10). A) Best solution. B) Selection frequency.

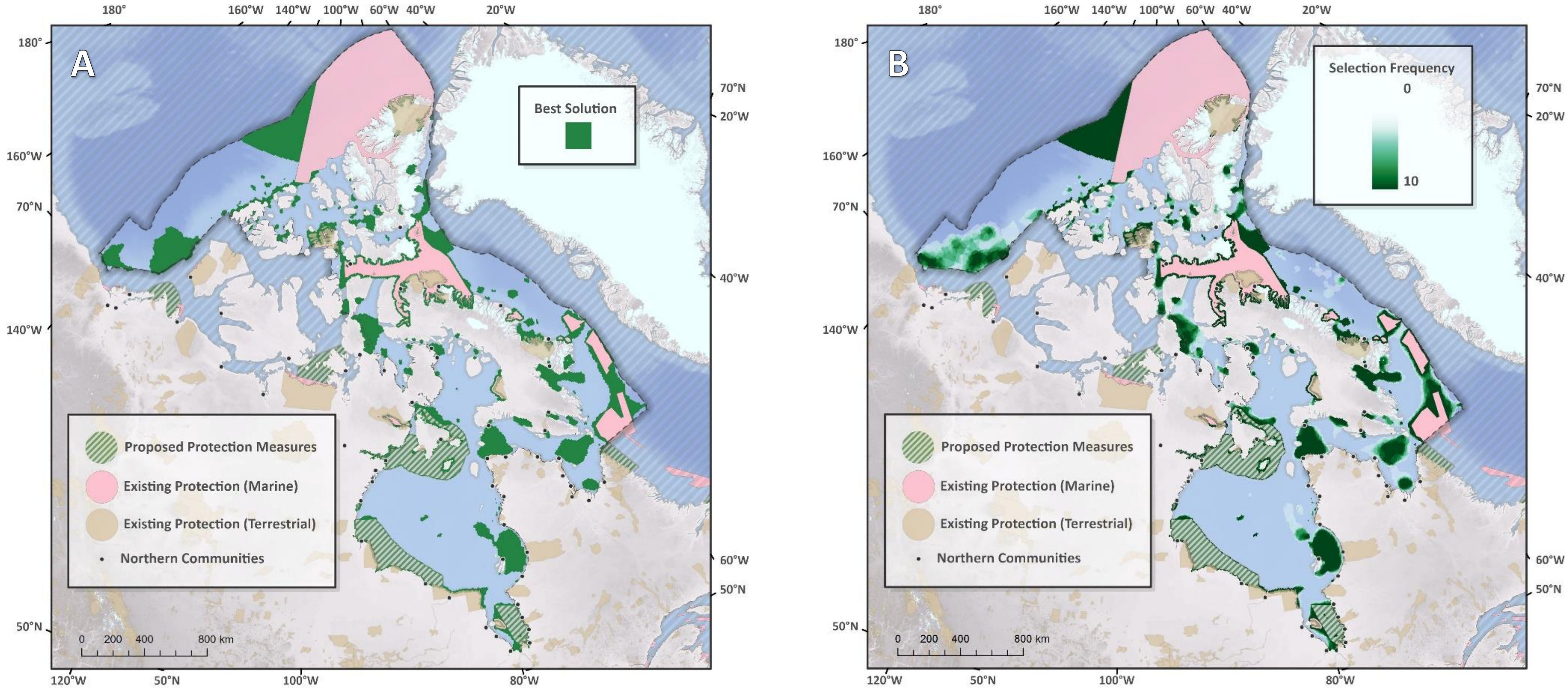

Figure 8.14. Potential network design scenario, S5.1 (existing and proposed MPAs locked in; minimum targets; BLM 0.4). A) Best solution. B) Selection frequency. Note that at the time of this study, the Tuvaijuittuq MPA was only proposed, and its boundary has changed since designation. This figure displays the proposed boundary that was used in Marxan.

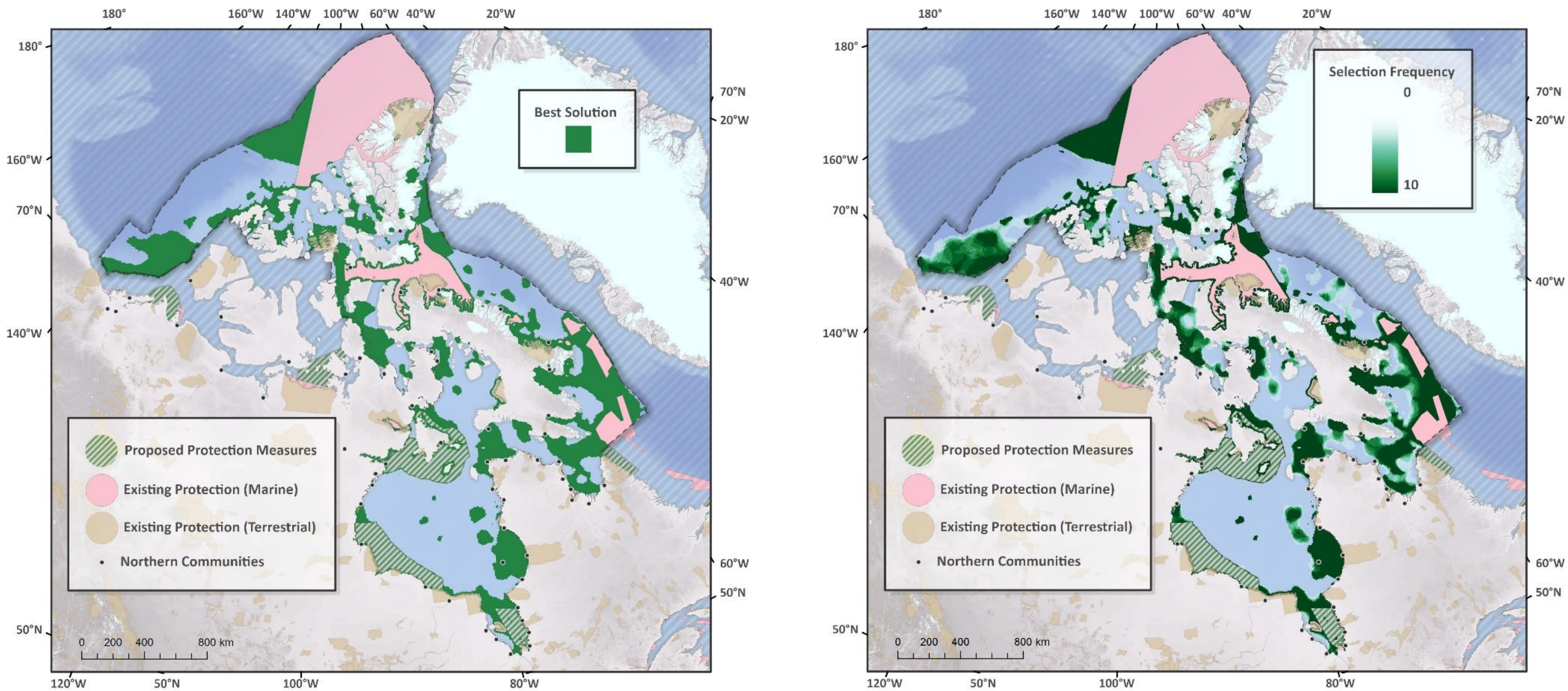

Figure 8.15. Potential network design scenario, S5.2 (existing and proposed MPAs locked in; high targets; BLM 0.4). A) Best solution. B) Selection frequency. Note, at the time of this study, the Tuvaijuittuq MPA was only proposed, and its boundary has changed since designation. This figure displays the proposed boundary that was used in Marxan.

Present Biodiversity Conservation Gaps

Results from the Marxan gap analysis indicate significant biodiversity conservation gaps in the Canadian Eastern Arctic. Overall, none of the species groups analyzed had their biodiversity requirements (i.e. targets) met. The lack of spatial conservation measures for endemic Arctic species such as polar bear and cetaceans is worrisome given the current and future development of human uses in the Arctic (e.g. marine shipping). Among the MECCEA objectives, only biogenic habitats currently had adequate protection levels (Figure 8.6). Known distributions for this group are biased towards the southern areas of the Eastern Arctic marine bioregion where three recently established marine refuges provide coverage. More data for biogenic habitat distributions will be needed to fully account for their protection.

Effects of Targets and BLM

The spatial configuration of Marxan solutions was more affected by a change in the BLM than by an increase in the targets (from minimum to median to high target ranges). The spatial outputs of S4.1, S4.3, and S4.5 (Figure 8.8, Figure 8.10, and Figure 8.12), all with a BLM value of 0.4, maintained the same pattern. Only an increase in area is observed among these scenarios as targets are increased from minimum in S4.1 to high in S.4.5. The same occurs when comparing the solutions of scenarios with a BLM value of 10—small changes in the spatial pattern.

A BLM value of 0.4 produced a more fragmented pattern with a higher number of smaller patches than with a higher BLM. A BLM value of 10 yielded a more clumped configuration, with a smaller number of patches, each larger in size. This inverse relationship between size and number of patches that result from altering BLM values is seen in Figure 8.16.

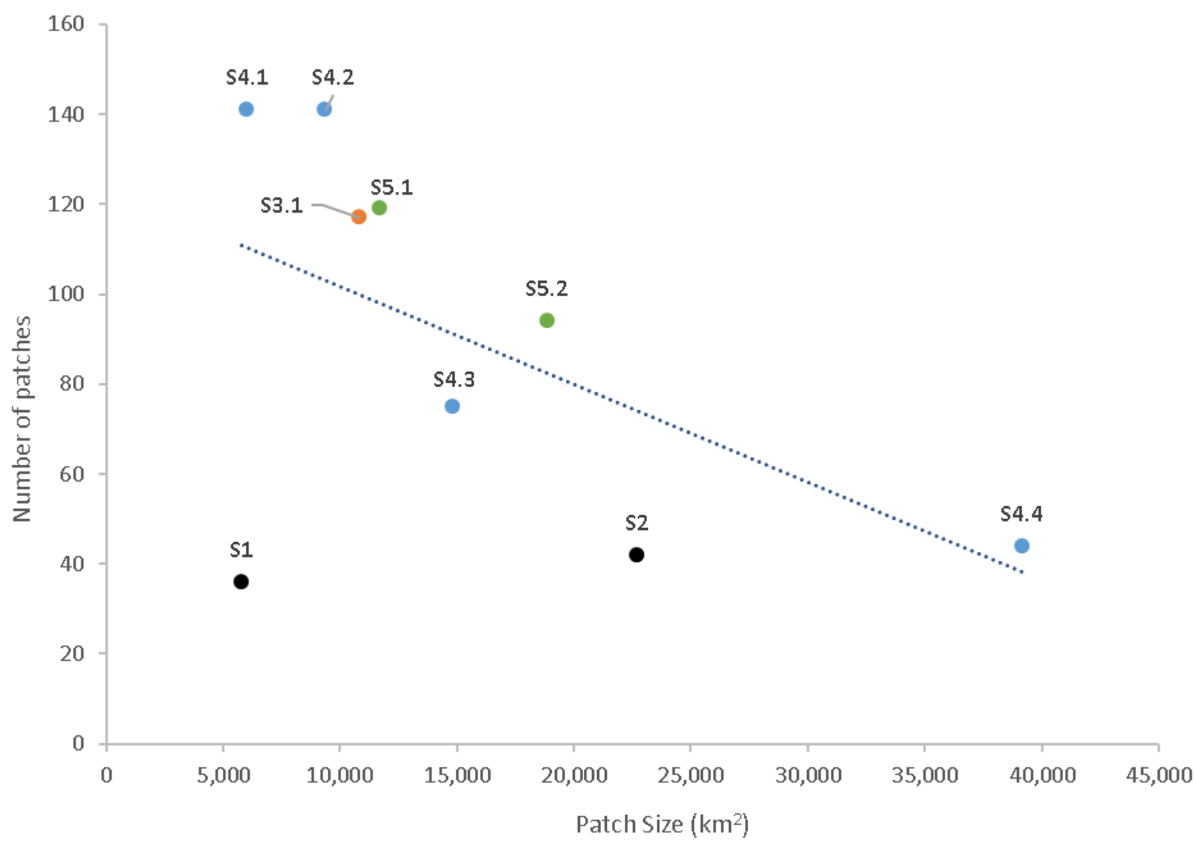

Figure 8.16. Relationship between size and number of patches in Marxan scenarios.

Therefore, decisions about choosing the BLM could matter more for the selection of PACs than any decision about having targets at the bottom, middle, or top of the range. Further, while there is a lack of evidence concerning a minimum number for conservation areas to be effective, it has been argued that larger conservation are more effective in meeting multiple conservation goals/objectives (Green et al., 2009). Thus, choosing a scenario with larger areas may be better for the persistence of Arctic marine biodiversity.

Selection Frequency

Selection frequency maps (indicating the number of times areas were selected in Marxan runs) were also produced along with the best solution for each scenario. Areas with high selection frequency indicate irreplaceability of planning units for meeting conservation targets. Some commonalities can be highlighted. For example, Marxan scenarios consistently selected areas around the Sanikiluaq and James Bay area in the Hudson Bay marine bioregion despite differences in BLM values and targets. Likewise, a section of the Hudson Strait (including Ungava Bay) as well as southern areas of the Baffin Bay, such as Cumberland Sound, were always selected across scenarios. The selection frequency maps (Figure 8.7B to Figure 8.15B) validate the recurrence of these areas across scenarios.

However, while selection frequency maps can be a useful guide for conservation area selection, they should not be decisive since focusing only on frequently selected areas does not guarantee CF target achievement. Best solutions maps offer a complete network design because they ensure all CF targets are met. Ideally, a combination of best solution maps and selection frequency maps should guide experts and mangers/planners in the identification of PACs for the Canadian Eastern Arctic.

Target Achievement

All Marxan scenarios of the S3 and S4 series attained nearly 100% of CF target achievement.

Target Efficiency

All scenarios (S3 and S4 series) had CFs for which targets were exceeded. In fact, all scenarios showed levels of overachievement, meaning that more area than that required to meet targets was necessary to form a complementary network. Factors contributing to this result include the scale of the planning region and the scale and distribution pattern of the conservation features.

Indicators of target efficiency were plotted to show the level of spatial inefficiency across Marxan scenarios (Figure 8.17). Some scenarios achieved targets more efficiently than others. Notably, scenarios falling under quadrant III (lower left) reached the lowest levels in terms of both area of target and the number of CF targets that were overachieved. Interestingly, S4.5, S4.3, and Sc4.1, in which a BLM value of 0.4 was used, fell in this quadrant. This is consistent with the calibration analysis that showed a BLM of 0.4 as the best balance between area and boundary length. Target efficiency increased from S4.1 to S4.5, and from S4.2 to S4.6, showing that scenarios with higher targets were more efficient in meeting conservation targets. In contrast, S5.1 (not shown in Table 8.4) was the most target-inefficient amongst all scenarios examined.

The level of spatial inefficiency found among Marxan scenarios should not be viewed as an obstacle for promoting or implementing conservation action. However, it can be a consideration when making decisions about the final conservation targets for the selection of PACs. For example, scenarios with minimum targets could be achieving the targets of a median target scenario.

Replication/Redundancy

Having CFs replicated across MECCEA marine bioregions helps to attain an even distribution of patches, despite the lack of data in areas of the Arctic Basin and Arctic Archipelago.

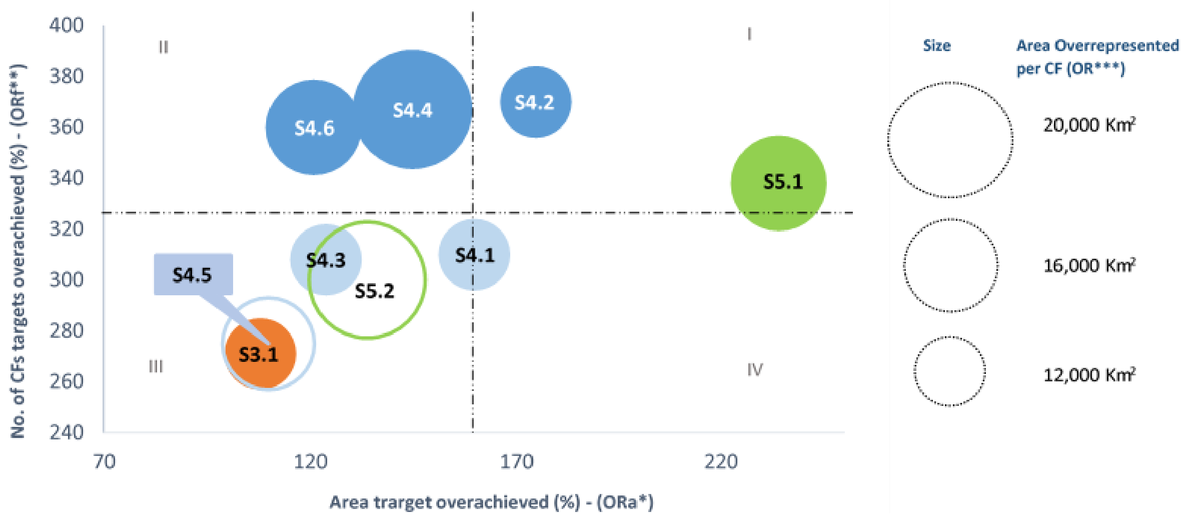

Figure 8.17. Relationship between number of conservation targets that were over-achieved and the area that was over-represented.

FINAL SCENARIO SELECTIONS

As is evident from the preceding comparisons of scenarios, there were inevitable trade-offs when selecting sets of PACs, which depended on several Marxan parameters, including conservation targets and area requirements.

Based on the analyses, three Marxan scenarios were selected for further evaluation. These three scenarios used the minimum, median and high targets all with a BLM of 10 (Figure 8.9, Figure 8.11, and Figure 8.13.). For comparison, these three scenarios are provided again in Figure 8.18, Figure 8.19, and Figure 8.20, but plotted with the other proposed marine protection measures. Note that the boundaries of the Tuvaijuittuq marine protected area changed between when it was proposed and after it was officially designated in August 2019. The figures in this chapter depict Tuvaijuittuq after its designation, except for Figure 8.14 and Figure 8.15, which display the boundary of Tuvaijuittuq as it was proposed and as it was used in Marxan.

Each of the selected Marxan scenarios meets its targets for CFs as defined in Chapter 7. The higher BLM value was selected because of the lower number of PACs, at the expense of a larger total area. It would be unrealistic to select PACs without consideration of the contribution by already established marine conservation areas. For this reason, our three selected Marxan scenarios also take into consideration the contribution of existing marine protected areas/OEABCMs towards the MECCEA conservation targets in the Canadian Eastern Arctic, except for Tuvaijuittuq, as explained above, and further below.

As an example of the conservation features included within each PAC, the CFs in the James Bay PACs for the median and high conservation target scenarios are shown in Figures 8.21 and 8.22, and listed in Tables 8.5 and 8.6. Such listings provide not only a complete accounting of replication (redundancy) for all conservation features, but also provide a means of comparing the appropriateness of conservation targets (minimum, median, or high) within a geographic region or within complete marine bioregions. A complete list of all conservation features within each PAC has been produced from Marxan. These data and the original shapefiles are available by request to WWF-Canada.

Further evaluation and implications of the selected PACs and Marxan scenarios (referenced to Figure 8.18, Figure 8.19, and Figure 8.20), are considered in the post-Marxan analyses, including: connectivity and networks of PACs and, broader ecological and environmental relationships (Chapter 9); commercial and socio-cultural relationships (Chapter 10); and management relationships (Chapter 11).

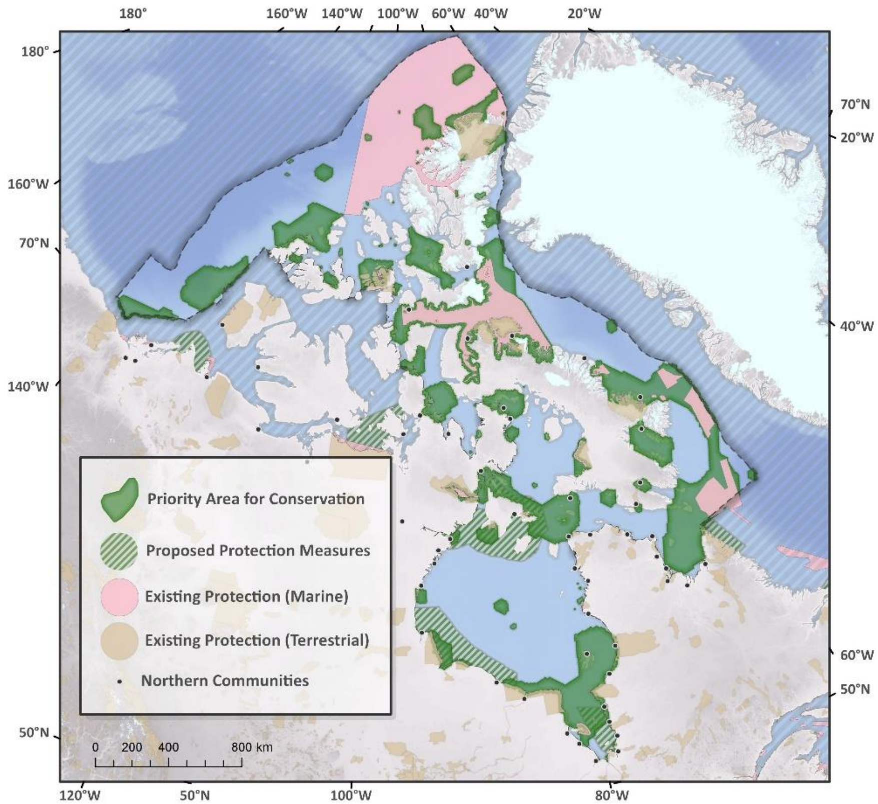

Figure 8.18. As in Figure 8.9A but including proposed protection measures. Potential network design scenario, S4.2 (existing MPAs locked in; minimum targets; BLM 10).

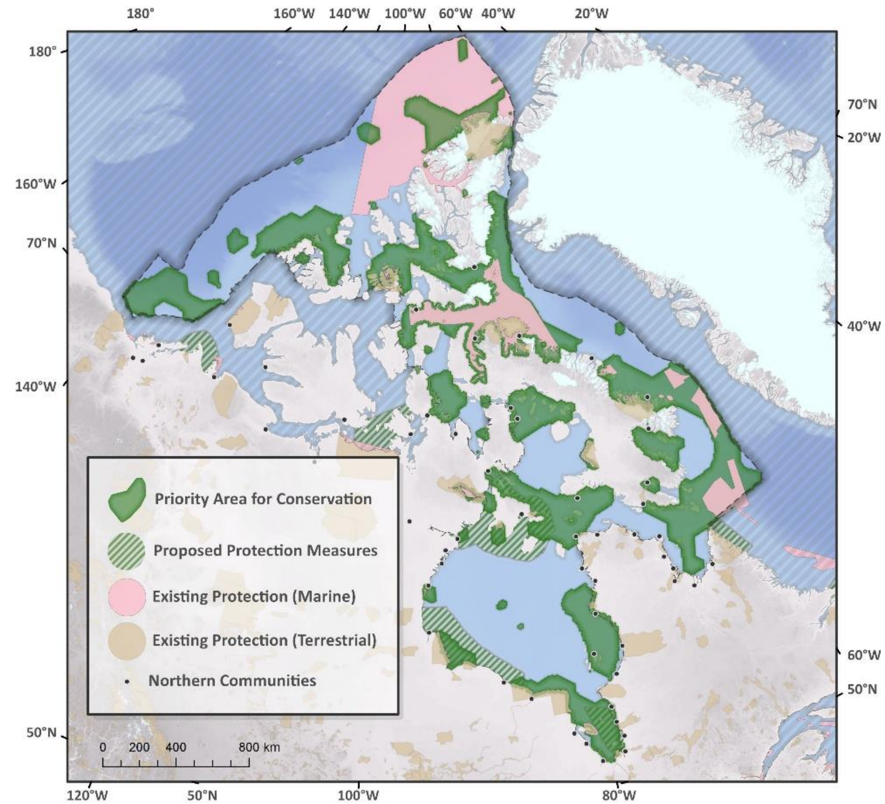

Figure 8.19. As in Figure 8.11A but including proposed protection measures. Potential network design scenario, S4.4 (existing MPAs locked in; median targets; BLM 10).

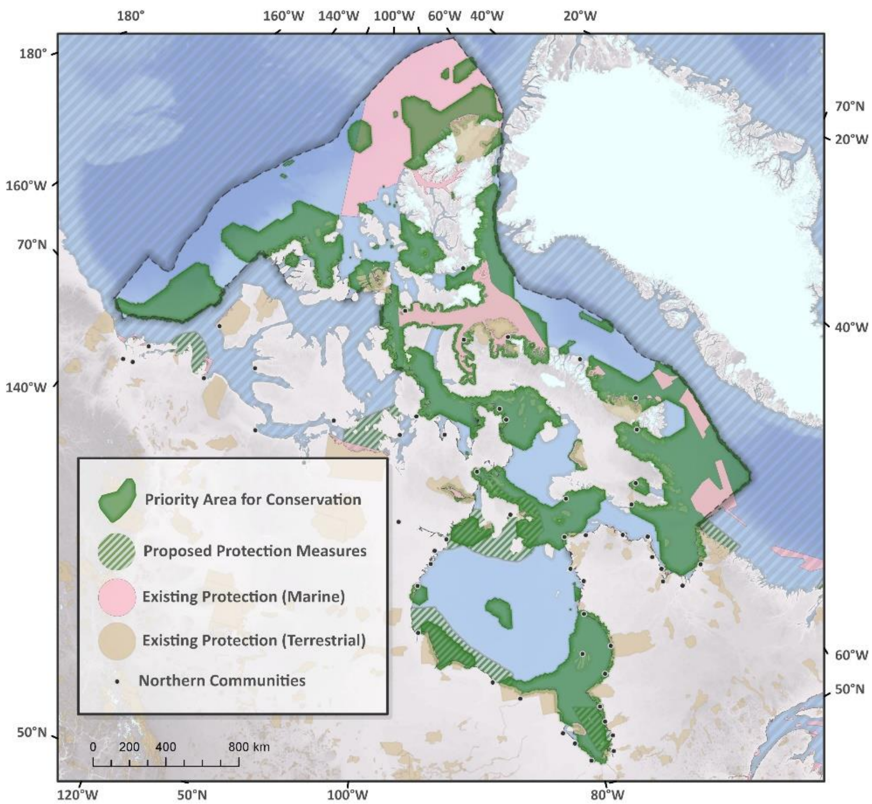

Figure 8.20. As in Figure 8.13A but including proposed protection measures. Potential network design scenario, S4.6 (existing MPAs locked in; high targets; BLM 10).

TUVAIJUITTUQ

Other current marine protected areas were locked in to our Marxan scenarios S4.1 to S4.6 (Table 8.4), but the marine protected area Tuvaijuittuq was not considered due to its very recent designation (August 2019). This large area (covering nearly 320,000 km^2 in the Arctic Basin) makes some significant additions to Canada's existing Arctic marine protected areas. In our study region, it more than doubles the existing protected area, and reduces our assessment of the number of unmet CFs. Furthermore, Tuvaijuittuq overlays the most diverse geomorphic habitats in the MECCEA study area—a region identified as significant at the Pan-Arctic Level (Fernandez-Arcaya et al., 2017).

We reran spatial analyses of the three scenarios, selected from Marxan, this time to include the new Tuvaijuittuq marine conservation area (see Figures 8.18, 8.19, and 8.20). However, the MECCEA conservation targets are already almost completely met in the three selected scenarios (S4.1 to S4.6, see Table 8.4). Therefore, the addition of the entire area of Tuvaijuittuq, which significantly overlaps the MECCEA PACs in the Arctic Basin, would not increase the number of conservation targets met in our study, but would significantly increase the proportion of the study area and the average patch size (Table 8.7).

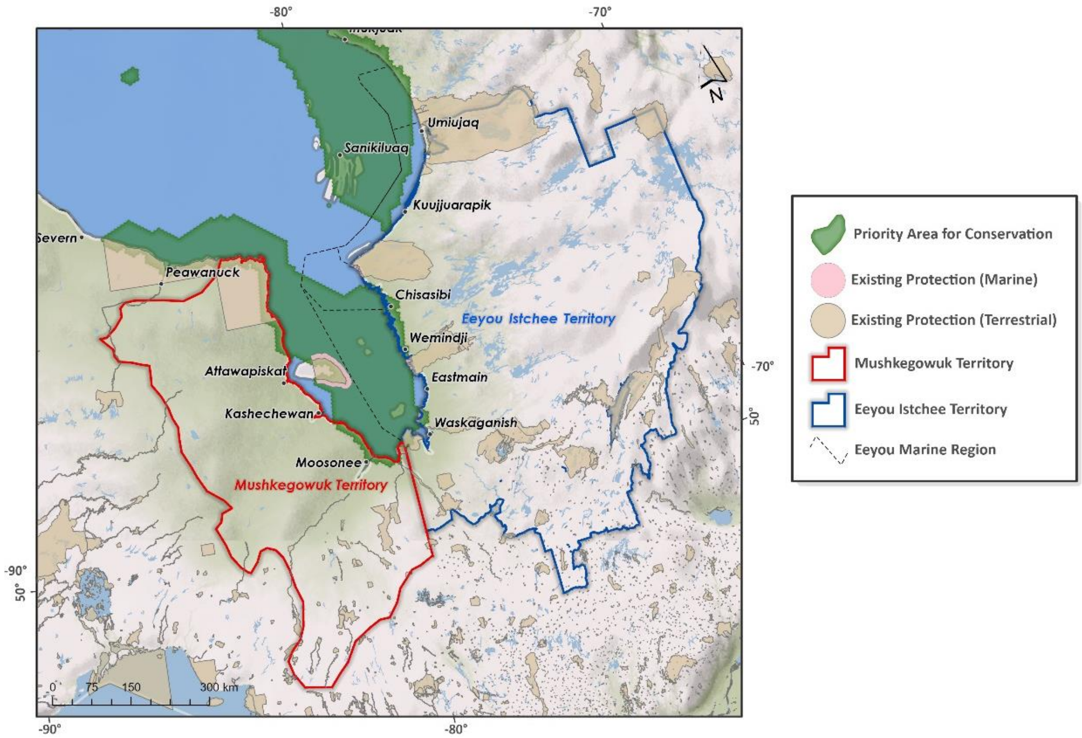

Figure 8.21. James Bay PACs from the S4.4 (median targets) scenario in Figure 8.19. Conservation features within are listed in Table 8.5.

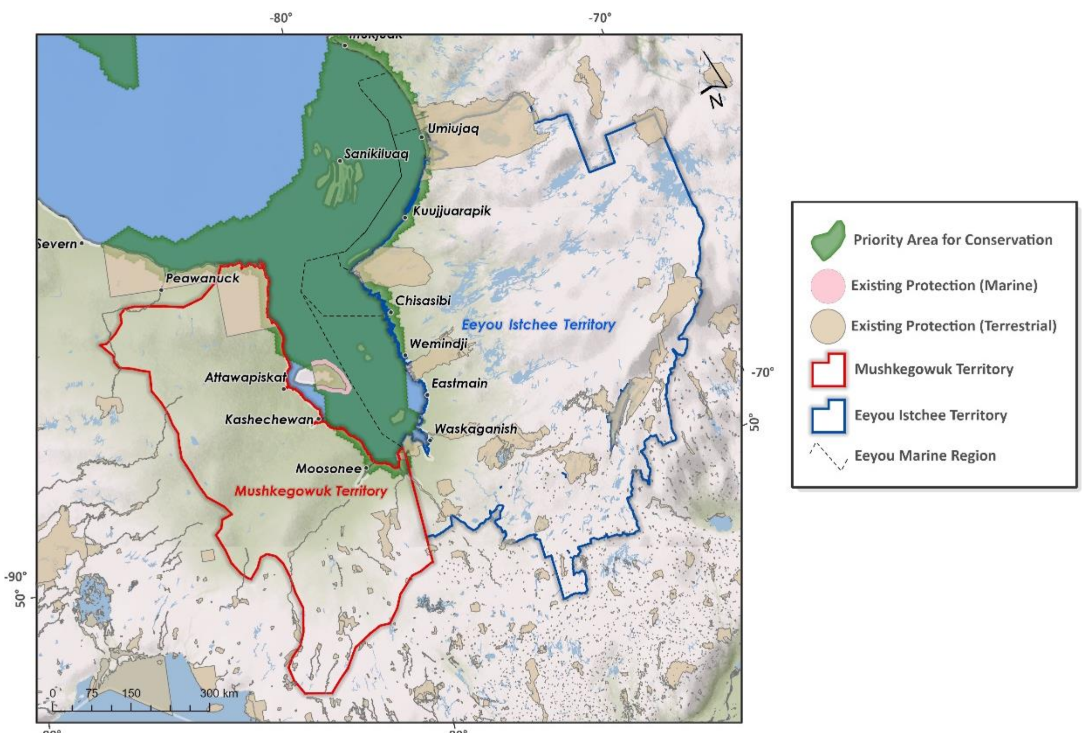

Figure 8.22. James Bay PACs from the S4.6 (high targets) scenario in Figure 8.20. Conservation features within are listed in Table 8.6.

Table 8.5. List of conservation features within the James Bay PACs for the S4.4 (median targets) scenario shown in Figure 8.21.

MEDIAN TARGET Conservation Features			
Species	**Locally Identified**	**Geomorphic**	**Seascapes**
• Arctic charr habitat • Beluga calving ground • Coregonus habitat • Four-horned sculpin habitat • Key migratory bird habitat Sites (x2) • Lumpfish habitat • Marine mammal summer hotspot • Marine mammal winter hotspot • Polar near winter hotspot • Polar bear denning • Walrus range • Walrus wintering areas • Walrus haulout sites	• Arctic charr habitat • Arctic cod habitat • Bearded seal habitat • Beluga habitat • Ringed seal habitat • Walrus habitat	• Coastal cliff habitat • Coastal inlet habitat • Coastal intertidal habitat • Coastal wetland habitat • 3 types of unique seafloor geomorphic features	• Chlorophyll hotspot • Primary productivity hotspot • Polynya habitat • 14 unique classes of benthic seascapes • 1 class of pelagic seascape

Table 8.6. List of conservation features within the James Bay PACs for the S4.6 (high targets) scenario shown in Figure 8.22.

HIGH TARGET Conservation Features			
Species	**Locally Identified**	**Geomorphic**	**Seascapes**
• Arctic charr habitat • Arctic cod habitat • Beluga calving ground • Beluga summer high-density area • Beluga year-round high-density area • Beluga summer range • Coregonus habitat • Eel grass habitat • Eider year-round habitat • Four-horned sculpin habitat • Key migratory bird habitat sites (x4) • Lumpfish habitat • Marine mammal summer hotspot • Marine mammal winter hotspot • Polar bear winter hotspot • Polar bear denning • Walrus range • Walrus wintering areas • Walrus haulout sites	• Arctic charr habitat • Arctic cod habitat • Ringed seal habitat • Bearded seal habitat • Walrus habitat • Beluga habitat	• Coastal cliff habitat • Coastal inlet habitat • Coastal intertidal habitat • Coastal wetland habitat • 3 types of unique seafloor geomorphic features	• Chlorophyll hotspot • Primary productivity hotspot • 15 unique classes of benthic seascapes • 3 unique classes of pelagic seascapes

Table 8.7. Resulting characteristics of Marxan scenarios with Tuvaijuittuq included.

		S4 Potential network design scenarios (current MPAs restriction & Tuvaijuittuq MPA)		
		S4.2 High BLM Min. Target	**S4.4** High BLM Median Target	**S4.6** High BLM High Target
Size & Area	Area (km²)	1,439,046	1,736,518	2,003,785
	Proportion of study area (%)	38.2	46.1	53.2
	No. of patches	64	36	35
	Min. patch size (km²)	45	45	45
	Max. patch size (km²)	336,453	351,393	460,720
	Average patch size (km²)	22,485	48,236	57,251

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CHAPTER 9: DOCUMENTING CONNECTIVITY AMONG PRIORITY AREAS FOR CONSERVATION

INTRODUCTION

An important goal for MECCEA has been: "to identify a network of priority areas for conservation (PACs) in Canada's Arctic marine environment" (Text Box 2.1). Because the oceans are fluid and continuous, there are limitations on the ecological integrity of an isolated protected area. Only a connected network can achieve substantial ecological integrity since any one site depends to varying degrees on its connectivity with other similar sites, in terms of resources and organism recruitment. Connectivity is especially significant in the Arctic, where differential habitat productivity and use, and seasonal migrations dominate annual trophodynamics.

Defining Connectivity and Network in MECCEA

"Connectivity" has several meanings and implications in the marine environment, and those that are addressed by MECCEA are summarised in Text Box 9.1. Studies of connectivity have generally concentrated on **migrations** (active, "purposeful" movements of organisms, or seasonal transpositions) and **dispersal** (passive dissemination from a source), and thus on the patterns of oceanographic connectivity.

The term "Network" in the context of the marine environment, although now frequently used, is often misused, poorly defined, or not defined at all, Therefore, we clarify our usage of this term here.

Text Box 9.1. Types of connectivity addressed in the MECCEA analysis.

The following characteristics and process are considered as features of the MECCEA network and as types of connectivity among the PACs. They are described in this chapter.

1. Summer and winter use areas by species of birds.
2. Summer and winter use areas by marine mammals.
3. Dis-connectivity and the existence of discrete populations of organisms based on morphological and/or genetic studies.
4. Recognition of migration corridors for marine animals. In the Arctic this would include marine mammals and larger fish species.
5. Narrow Passages—Betweenness. An analysis of critical pathways, potential bottlenecks and important thoroughfares for organisms, water, nutrients, and energy.
6. Connections from the marine environment to freshwaters via rivers and estuaries, especially in terms of diadromous migrations.
7. Connections to and from the land (in terms of reproduction, inputs of energy, and nutrients). This would include nesting/denning sites for birds and polar bears, and ice crossing sites for caribou.
8. Trophic connectivity within the marine environment, including definition of marine food-webs and their important components.
9. Oceanographic connectivity and models of organism dispersal based on analysis of ocean current patterns.
10. Socio-economic connectivity
11. Connections beyond MECCEA, to other bioregions, other potential networks, and to ArcNet.

Canada has adopted the IUCN definition (IUCN-WCPA, 2008) of a network of marine protected areas, namely:

> "An MPA network can be defined as a collection of individual MPAs or reserves operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve."

Therefore, while connectivity is not inherent in this definition of network, the Government of Canada (2011) does specify "additional design properties", which include connectivity as well as replication and adequacy/viability; and "culturally important areas", including areas important for cultural heritage, public use and enjoyment, and education.

The MECCEA Network of PACs

In MECCEA, we have developed a coherent series of PACs through a robust conservation analysis, that has produced a network congruent with the IUCN (2008) definition. Although it is preferable to iteratively examine patterns of connectivity until an optimal solution is found (see Roff, 2009), the Marxan analyses themselves did not explicitly incorporate any metrics of marine ecological connectivity.

In this chapter we examine the elements of connectivity in our post-Marxan analyses that describe the characteristics of the MECCEA network of PACs. Unless otherwise specified, the PACs considered here are those in the minimum, median and high scenarios, selected at the conclusion of Chapter 8.

The elements of connectivity we address below include:

- species seasonal use differences;
- population genetic differences;
- migration routes;
- land-water connections;
- oceanographic connectivity as patterns of dispersal; and
- connections beyond the MECCEA study bioregions.

SUMMER AND WINTER USE AREAS BY MARINE BIRDS

Connectivity for marine birds has been addressed in part through the inclusion of seabird hotspots for summer and winter use areas. Many bird species found in the Canadian Arctic during spring, summer and fall, spend the winters further south, outside of the MECCEA study area (Mallory et al., 2018). This is the case for all the seabird species selected for the MECCEA analysis. Summer areas (colonies and other key habitat sites) are included as conservation features, but wintering areas have either not been identified or fall outside of the study region (Richards and Gaston, 2018), with the exception of some overwintering sites included in the key seabird habitat and Important Bird Areas conservation feature groups. Thus, essentially all the bird habitat included in MECCEA is used between April to October. The MECCEA study includes colony-specific location for the species listed in Table 9.1. Other types of seasonal habitat are noted in Table 9.2 and Table 9.3.

For bird species that do overwinter in the Arctic (and within the MECCEA study area), polynyas, shore leads, and the ice edge represent important habitats for winter and during seasonal migrations. Polynyas were captured as a conservation feature in MECCEA for this reason, as well as for their significance for other Arctic species and ecosystem processes. The dataset used for key marine habitat sites for seabirds has also integrated sites that are significant during each season for the bird species included in MECCEA, ensuring that a range of seasonal habitats for seabirds is at least partially included.

Table 9.1. Seabird populations that use different seasonal habitats.

Group	Species	Summer Habitat Included	Winter habitat
Seabirds	Common eider King eider Ivory gull Long-tailed duck Dovekie Northern fulmar Parasitic jaeger Ross's gull Thick-billed murre Sabine's gull Herring gull	Summer Hotspots (all species)	Winter hotspots (all species)
	Black guillemot	Known summer colony sites	Some remain in Arctic waters over the winter near polynyas, others migrate further south.
	Black-legged kittiwake	Known summer colony sites	Evidence suggests they spend winters near Newfoundland and Labrador or further south.
	Dovekie	Known summer colony sites	Migrate to waters near Newfoundland in the fall for the winter.
	Thick-billed murre	Known summer colony sites	Spend winter in open-water areas in southern Davis Strait, the Labrador Sea, and offshore Newfoundland.
	Ivory gull	Only one summer colony site identified within MECCEA study area	Rare in the Canadian Arctic but thought to overwinter in southern Davis Strait and the Labrador Sea.
	Ross's gull	Known summer colony sites	Rare species in the Canadian Arctic, and overwintering areas are unknown.

SUMMER AND WINTER USE AREAS BY MARINE MAMMALS

Connectivity for marine mammals has been partially addressed in the MECCEA network by the inclusion of conservation features associated with seasonal habitat use by most of the included marine mammal species. For example, polar bear and marine mammal (cetacean and pinniped) key habitats include both summer and winter hotspots. For beluga, bowhead, and narwhal, there were additional key habitat conservation features linked to seasonal uses. The populations/subpopulations with seasonally important habitats for multiple seasons, which are represented as conservation features in our analyses, are given in Table 9.4.

DIS-CONNECTIVITY AND DISCRETE POPULATIONS—GENETIC DISCONTINUITIES

Populations of species for which separate populations, subpopulations or management units have been identified within the MECCEA study area, were each considered as individual conservation features. The vulnerability assessments used in the target setting process also treated separate populations or management units as distinct. Different populations, subpopulations, and management units of conservation features are noted in the conservation feature names in the conservation features tables (see Chapter 7 and Appendix 2).

Here, we summarize the conservation feature categories, and provide information about the populations, subpopulations, and management units that have been identified for species in Arctic Canada.

Table 9.2. Key seabird areas and their seasonal uses.

MECCEA Conservation Feature	Key Seabird Areas Included	Seasonal Association
Foraging/breeding areas, Barrow Strait/Prince Regent Inlet	Cape Liddon Prince Leopold Island Batty Bay Hobhouse Inlet	Overwintering (black guillemots) Migratory habitat (ivory gull, dovekie) Summer habitat (northern fulmar) Summer habitat (thick-billed murre, black-legged kittiwake)
Wintering site, Central Davis Strait	Central Davis Strait	Winter habitat (ivory gull)
Foraging/breeding areas, Cornwallis Island	Queens Channel Browne Island Hell Gate and Cardigan Strait	Overwintering (black guillemot) Summer habitat (northern fulmar) Summer habitat (17 species) Summer habitat (black-legged kittiwake, northern fulmar, black guillemot)
Breeding areas, East Baffin Island	Buchan Gulf Scott Inlet	Spring habitat (eider) Summer habitat (northern fulmar, glaucous gull) Migratory habitat (black guillemot, eider)
Foraging/breeding areas, Frobisher Bay	Frobisher Bay	Summer habitat (7+ species) Winter habitat (ivory gull)
Foraging/breeding areas, Lancaster Sound	Eastern Lancaster Sound Cape Hay Baillarge Bay Cape Graham Moore	Early summer habitat (murre, fulmar, guillemot, kittiwake, dovekie) Spring habitat (fulmar, black guillemot)
Foraging/breeding areas, north Baffin Bay	North Water Polynya Eastern Jones Sound	
Breeding areas, northern Hudson Bay/Hudson Strait	East Bay Markham Bay Coats Island Digges Sound	Summer/fall habitat (6 species)
Foraging/molting areas, northern Ontario coastline	Northern Ontario Coastline	Moulting/migratory habitat (black scoter)
Foraging/breeding areas, Qaqulluit and Akpait	Qaqulluit and Akpait	Summer habitat (fulmar, thick-billed murre, black-legged kittiwake)
Foraging/breeding areas, Seymour Island	Seymour Island	Summer habitat (ivory gull)
Year-round eider habitat, Sleeper Islands	Sleeper Islands	Year-round (eider)
Staging/breeding areas, Ungava Bay	Akpatok Island Ungava Bay Archipelagoes	Summer habitat (thick-billed murre) Migratory habitat (multiple species) Summer/fall habitat (eiders)
Seaducks staging/foraging areas, Western Arctic	Amundsen Gulf Bathurst Polynya	Summer habitat (long-tailed duck)

Table 9.3. Important bird areas and seasonal uses (seabirds, shorebirds, and waterfowl).

MECCEA Conservation Feature	Important Bird Areas Included*	Identified Seasonal Association
Eastern Prince Patrick Island IBAs	NT044	
Hudson Bay West Coast IBAs	MB003, MB006, MB008, MB013, NU020	Summer habitat (95+ species) Migratory habitat (6+ species)
Barrow Strait IBAs	NU006, NU059, NU060, NU062, NU065	Summer habitat (10+ species)
Eastern Baffin Island IBAs	NU069, NU070	Summer habitat (northern fulmar)
Foxe Basin IBAs	NU021	
Jones Sound IBAs	NU052, NU053, NU054, NU055	Summer habitat (black guillemot, ivory gull)
Lancaster Sound IBAs	NU004, NU013, NU068	Summer/fall habitat (dovekie, ivory gull)
North Baffin Bay IBAs	NU010, NU014, NU057	Summer/fall habitat (black-legged kittiwake, dovekie, thick-billed murre, ivory gull)
Northern Hudson Bay IBAs	NU001, NU005, NU022, NU023, NU024	Summer/fall habitat (black guillemot, thick-billed murre, Iceland gull, Ross's gull, snow goose)
Northern Ontario Coastline IBAs	NU036, ON123, ON124, ON125, ON127, ON129, ON130, ON133, ON134, ON135, ON137, ON138, ON139, ON140, ON141, ON142, ON143, ON147	Spring/summer/fall habitat (10+ species)
Ungava/Frobisher Bay IBAs	NU007	Summer/fall habitat (thick-billed murre)
Western Quebec Coastline & Belcher Islands IBAs	NU030, NU031, NU032, NU034, QC143, QC145, QC146, QC147, QC148	Year-round habitat (eider) Summer habitat (semi-palmated plover, black scoter, harlequin duck) Migratory habitat (black guillemot)

*Abbreviations are from the IBA website.

Polar bear

There are 13 identified subpopulations of polar bears in Canada, of which 11 occur within or overlap with the MECCEA study area (Text Box 9.2). These subpopulations were originally identified based on patterns of sea ice formation and have been further assessed through telemetry, genetic surveys, capture surveys, and through harvest monitoring (Peacock et al., 2015).

Although there are genetic differences between subpopulations, they are not sufficient to designate subspecies. These 13 subpopulations are also used as harvest management units and are the basis for structuring monitoring programs in the region (COSEWIC, 2008). For the MECCEA analysis, polar bear key habitat conservation features were split by subpopulations into denning areas, and locally identified habitat (associated subpopulations are indicated in the Conservation Features List, Appendix 2).

Table 9.4. Populations of species where data are available on different seasonal habitats.

Species*	Population	Summer Habitat Included	Winter Habitat Included	Notes
Polar Bear	All†	Summer hotspots	Winter hotspots	
	Baffin Bay		Denning areas	
	Davis Strait		Denning areas	
	Foxe Basin		Denning areas	
	Gulf of Boothia		Denning areas	
	Kane Basin		Denning areas	
	Lancaster Sound		Denning areas	
	M'Clintock Channel		Denning areas	
	Norwegian Bay		Denning areas	
	Southern Hudson Bay		Denning areas	
	Viscount Melville Sound		Denning areas	
	Western Hudson Bay		Denning areas	
Beluga	Cumberland Sound	Calving	Overwintering areas	
	Eastern Beaufort Sea	Summer range		
	Western Hudson Bay	Summer range, summer high density areas, calving	Winter range	
	East. High Arctic-Baffin Bay	Summer range, calving	Winter range	
	Ungava Bay	Summer range		
	Eastern Hudson Bay	Calving		
Bowhead	East Canada-West Greenland	Summer foraging, distribution, and calving, and spring foraging areas	Overwintering areas, winter distribution	
	Bering-Chukchi-Beaufort	Summer distribution		
Narwhal	Somerset Island	Summer foraging/calving areas	Winter high density areas	
	Admiralty Inlet	Summer foraging/calving areas	Winter high density areas	
	East Baffin Island	Summer foraging/calving areas	Winter high density areas	
	Eclipse Sound	Summer foraging/calving areas	Winter high density areas	
	Northern Hudson Bay	Summer foraging/calving areas, summer range	Winter range	
	Jones Sound	Summer calving, summer range		
Walrus	Canadian Central Arctic	Haulout sites	Wintering areas	
	Canadian High Arctic	Haulout sites	Wintering areas	
	Canadian Low Arctic	Haulout sites	Wintering areas	
Hooded Seal	N/A		Whelping patch, spring	
Harp seal	N/A		Whelping patch, spring	
Bearded seal	N/A			Locally identified habitat included, no seasonal associations identified
Ringed seal	N/A			Locally identified habitat included, no seasonal associations identified

*For additional conservation features for species listed above but not associated with a specific season, see the conservations features list in Appendix 2.
†Organized by bioregion, not subpopulation for hotspots data.

Text Box 9.2. Subpopulations of polar bear found in the bioregions of the MECCEA study area.

- Baffin Bay
- Davis Strait
- Foxe Basin
- Gulf of Boothia
- Kane Basin
- Lancaster Sound
- M'Clintock Channel
- Norwegian Bay
- Southern Hudson Bay
- Viscount-Melville Sound
- Western Hudson Bay

Beluga

There are seven distinct beluga management stocks identified in Canada, six of which overlap with the MECCEA study area: the Eastern High Arctic-Baffin Bay; Ungava Bay; Cumberland Sound; Eastern Hudson Bay, Western Hudson Bay, and Eastern Beaufort Sea populations (COSEWIC, 2004). The Ungava Bay, Eastern Hudson Bay, and Western Hudson Bay stocks are named for their distinct summering areas and may interact during their annual migrations through Hudson Strait to their wintering areas. They show differentiation in mitochondrial DNA but are not otherwise genetically distinct (Colbeck et al., 2012; Turgeon et al., 2011). Recent surveys of belugas in James Bay support the separation of a distinct stock of James Bay belugas, separate from the Eastern and Western Hudson Bay populations, as the James Bay belugas appear to remain in James Bay year-round (Postma et al., 2012). In MECCEA, a separate population for James Bay is not identified specifically but there is a distinct conservation feature for identified year-round beluga habitat in the James Bay area. Beluga key habitat conservation features and populations are summarized in Text Box 9.3.

Bowhead

There are currently two genetically distinct populations of bowhead whales recognized in Canada: the East Canada-West Greenland population in the Eastern Arctic, and the Bering-Chukchi-Beaufort population in the Western Arctic (COSEWIC, 2009). The East Canada-West Greenland population, once thought to be two separate populations (Hudson Bay-Foxe Basin and Baffin Bay-Davis Strait) based on sea ice barriers in Fury and Hecla Strait, was determined to be one single population based on telemetry data in 2010 (Heide-Jorgensen et al., 2006; Wiig et al., 2011). Further genetic sampling has supported this designation as a single population (Alter et al., 2012). Otherwise, geographic discontinuity due to sea ice may be the key factor determining genetic distinctions between groups of bowhead whales. With changes in sea ice due to climate change, reduced physical barriers between the two populations (Bering-Chukchi-Beaufort and East Canada-West Greenland) in the Northwest Passage may lead to increased genetic interchange (Heide-Jorgensen et al., 2012).

The MECCEA seasonal habitat conservation features include features for both populations, but all other bowhead key habitat conservation features only capture habitat associated with the East Canada-West Greenland population.

Narwhal

There are currently two identified distinct narwhal populations in Canada: the Northern Hudson Bay population, and the Baffin Bay population. The Baffin Bay population is further separated into four management units, based on divided summer aggregations, after which they all share similar wintering areas. Narwhals are also known to occur in Smith Sound, Jones Sound, and Parry Channel but the population structure of these narwhals is not well studied. This group comprises a sixth management unit, but it is unknown whether it forms part of the Baffin Bay population or is separate (Fisheries and Oceans Canada, 2013). Narwhal management units and key habitats are listed in Text Box 9.4.

Text Box 9.3. The following beluga key habitat conservation features were split according to the associated population.

- Foraging
    - Eastern High Arctic-Baffin Bay
    - Eastern Hudson Bay
    - Western Hudson Bay
- Calving
    - Cumberland Sound
    - Eastern High Arctic-Baffin Bay
    - Eastern Hudson Bay
    - Western Hudson Bay
- Seasonal habitats
    - Eastern Beaufort Sea
    - Western Hudson Bay
    - Ungava Bay
    - Eastern High Arctic-Baffin Bay
- Locally identified habitat
    - Cumberland Sound
    - Eastern High Arctic-Baffin Bay
    - Eastern Hudson Bay
    - Western Hudson Bay

Walrus

Two populations have been identified in the MECCEA study area: the Canadian High Arctic population, and the Canadian Central-Low Arctic population. For harvest management, the two populations are further divided into six stocks. There is some evidence to suggest that the Central-Low Arctic population may be two separate populations, but there are not enough data to verify this. However, in a management context, the walrus found in the South and East Hudson Bay stock are not associated with either population (COSEWIC, 2017). For the MECCEA analysis, walrus key habitats are divided into three to match the two identified populations in the study area and to capture the possibly separate low Arctic population/South and East Hudson Bay stock (see Text Box 9.5).

Other species

Apart from those listed above, separate populations have not been identified for any of the other species included in the MECCEA analysis. Hooded seals and harp seals are both associated with the Northwest Atlantic stock throughout the MECCEA study area, and separate units have not been identified for bearded seals or ringed seals. For fish and seabird species in the MECCEA study area, no data are available on genetically delineated populations.

Caribou

Dolphin and Union caribou (*Rangifer tarandus groenlandicus*) are a morphologically and genetically distinct group of caribou that migrate annually between Victoria Island and the mainland of Nunavut in the western Canadian Arctic (Figure 9.1.). This migration is dependent on reliable sea ice conditions to facilitate movement of thousands of animals to and from their calving area on Victoria Island, and their wintering grounds on the mainland. Dolphin and Union caribou have been listed as Special Concern under the federal *Species at Risk Act* (2002) since 2011, and have recently been assessed as Endangered by COSEWIC due to recent population declines and the threats posed to the population. The main threat they face is a reduction in sea ice connectivity that results both from ice-breaking activities and from sea ice loss due to climate change (Environment and Climate Change Canada, 2018).

Text Box 9.4. The six management units for Narwhal and their key habitats.

- Northern Hudson Bay population
- Somerset Island (Baffin Bay population)
- East Baffin Island (Baffin Bay population)
- Eclipse Sound (Baffin Bay population)
- Admiralty Inlet (Baffin Bay population)
- Smith Sound/Jones Sound/Parry Channel (population unknown)

The population and management units associated with specific narwhal key habitat are as follows:

- Summer calving
    - Jones Sound
    - Somerset Island
- Summer calving/foraging
    - Admiralty Inlet
    - East Baffin Island
    - Eclipse Sound
    - Northern Hudson Bay
    - Somerset Island
- Seasonal habitats
    - Baffin Bay stocks (grouped)
    - Northern Hudson Bay
- Locally identified habitat
    - Baffin Bay stocks
    - Northern Hudson Bay

Text Box 9.5. Walrus data groupings.

The walrus data for MECCEA was associated with three groupings. In the Conservation Features list (Appendix 2) these are labelled as “Canadian High Arctic”, “Canadian Central Arctic”, and “Canadian Low Arctic”, for each of the following walrus conservation features:

- Haulout sites
- Distribution
- Wintering areas
- Locally identified habitat

Peary caribou (*Rangifer tarandus pearyi*) are a subspecies of caribou that inhabit the Canadian archipelago, moving between the islands in annual migrations and making regular movements between islands across home ranges. Peary caribou were listed as Endangered under the federal *Species at Risk Act* (2002) since 2011 and were more recently assessed as Threatened by COSEWIC in 2015. Living in relatively remote areas, the biggest threats facing Peary caribou involve the negative effects of climate change, including decreased extent and thickness of sea ice impacting migration and movement patterns (COSEWIC, 2015).

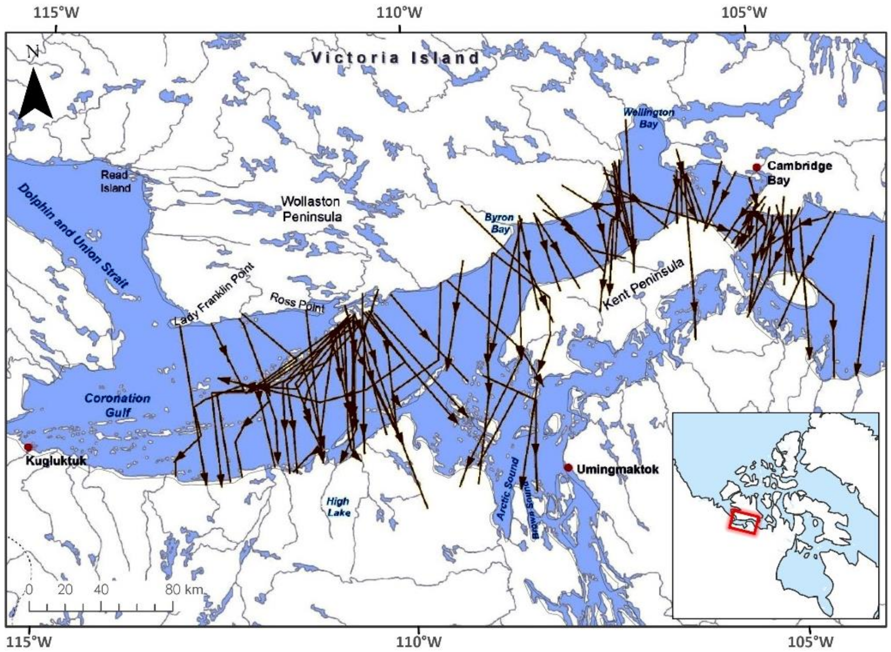

Figure 9.1. Dolphin and union caribou fall migration routes between Victoria Island and the mainland, modified from Poole et al. (2010), as seen in Environment and Climate Change Canada (2018).

MIGRATION CORRIDORS FOR MARINE MAMMALS

Migration routes for caribou species are reported above. Migration routes for marine mammals in the Arctic are variable but generally occur within "corridors".

Static protected areas have shortcomings as instruments for protection of migratory species. Protected areas can afford protection at the "ends" of migration routes, in regions of hotspots, and high resource use, but they do not protect the migration routes or corridors themselves, unless specifically designed to include them. Since migrations are movements between areas, it could be argued that they would be hard to include in a spatial network. However, they do not lie outside the limits of our network study, and there should be ways to incorporate them in efficient and effective networks.

Three possible options present themselves, but we have no present basis to prefer any one of them:

1. We could simply accept that marine mammal migrations lie outside our MECCEA remit, and that they should be dealt with as a management issue under other provisions, such as possibly Arctic EBSAs.
2. We could examine the most significant migration corridors, documented by DFO (2011) as EBSAs within our bioregions, and then extend the boundaries of contiguous PACs to meet and encompass these corridors. This approach has been adopted by Solovyev et al. (2017) in the Russian Arctic. It has not been adopted here, but it could be a feasible option.
3. Finally, we could take into account the degree of overlap between our PACs and corridors for marine mammals recognized in the Arctic EBSAs as identified by DFO (2011) (Figures 9.2, 9.3 and 9.4). See Table 9.5 for numerical listings and descriptions of these areas. For this option, we examined overlays which indicate that for MECCEA minimum targets, our PACs already encompass 42.2% of marine mammal migratory corridors. For the MECCEA high target scenario, our PACs would afford protection to 57.2% of these migratory corridors. Thus, our identified PACs (although static) already contain areas that contribute significantly to the protection of migratory species, but still leave several important areas vulnerable.

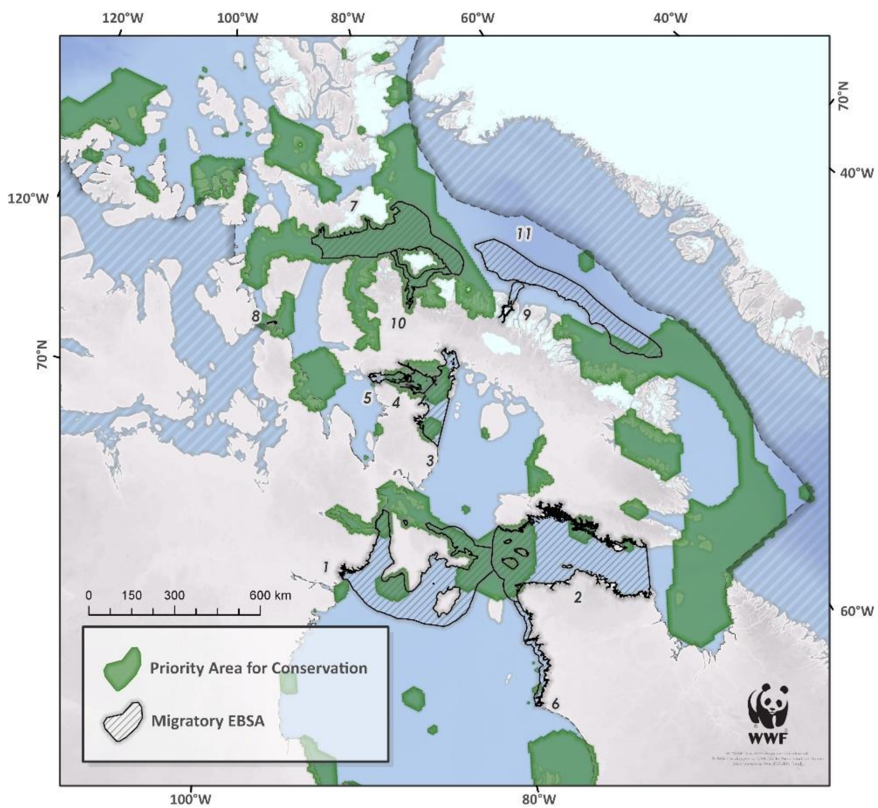

Figure 9.2. Spatial relationships between minimum target PACs and EBSAs identified as important for marine mammal migrations. For area identification by number see Table 9.5.

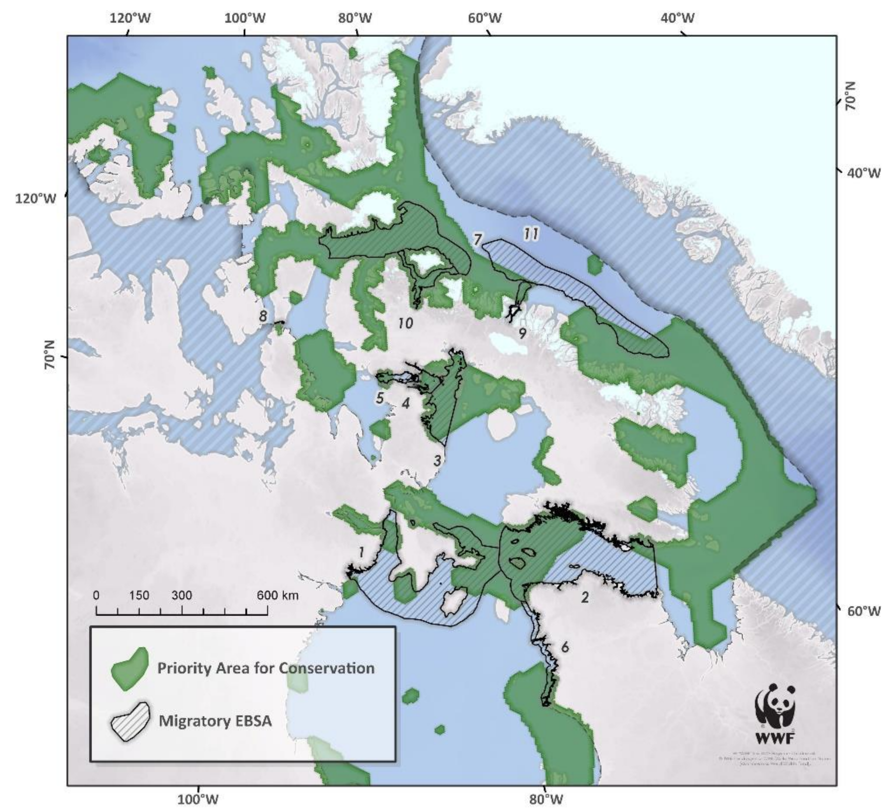

Figure 9.3. Spatial relationships between median target PACs and EBSAs identified as important for marine mammal migrations. For area identification by number see Table 9.5.

Table 9.5. Listing of DFO EBSAs, identified as important for marine mammal migration, that overlap significantly with MECCEA PACs. See also Figure 9.2, Figure 9.3, and Figure 9.4 for EBSA locations.

ID # in Figures	EBSA Name	Bioregion	Migratory Information
1	Southampton Island	Hudson Bay Complex, Hudson Bay	Waters around the island are important spring and fall migration routes for beluga and eastern Arctic bowhead (COSEWIC Special Concern).
2	Western Hudson Strait	Hudson Bay Complex, Hudson Strait	Major seasonal migration route for all marine mammals that spend the summer in Hudson Bay, Foxe Basin and beyond, and winter in either Hudson Strait, and/or Davis Bay, including beluga, narwhal, and bowhead.
3	Rowley Island	Hudson Bay Complex, Foxe Basin	Serves as a migratory corridor for several species of marine mammals, including belugas and narwhals.
4	Igloolik Island	Hudson Bay Complex, Foxe Basin	Serves as a migratory corridor for several species of marine mammals, such as narwhal and beluga, and supports several species of seabirds.
5	Fury and Hecla Strait	Hudson Bay Complex, Foxe Basin	Important migratory route for several species of marine mammals, including bowhead whales, belugas and narwhals, providing access to feeding areas.
6	Eastern Hudson Bay Coastline	Hudson Bay Complex, Hudson Bay	Eastern coastline from the Belcher Islands to Digges Sound is an important migratory corridor for the Endangered Eastern Hudson Bay beluga population.
7	Lancaster Sound	Eastern Arctic, Lancaster Sound/Barrow Strait Complex	High importance as a migratory corridor for several species of marine mammals including beluga, narwhal, bowhead whale, Atlantic walrus, and harp seal.
8	Bellot Strait	Eastern Arctic, Lancaster Sound/Barrow Strait Complex	The Somerset Island stock of the Baffin Bay narwhal population and Eastern High Arctic–Baffin Bay beluga use the area as a migration corridor between Prince Regent Inlet and Peel Sound. The strait is considered a choke point funneling migrating whales through a relatively narrow passage
9	Scott Inlet	Eastern Arctic, Davis Strait/Baffin Bay	The extension out to the Baffin Bay shelf break captures a cross section of the Baffin Bay Narwhal migration corridor.
10	Eclipse Sound	Eastern Arctic, Lancaster Sound/Barrow Strait Complex	The area is used as a migration corridor in the spring and fall by the Eclipse Sound stock of the Baffin Bay narwhal population.
11	Baffin Bay Shelf Break	Eastern Arctic, Davis Strait/Baffin Bay	Indigenous Knowledge identifies this area as an important migration route for bowhead whale as well as harp seal, hooded seal, ringed seal, and bearded seal.

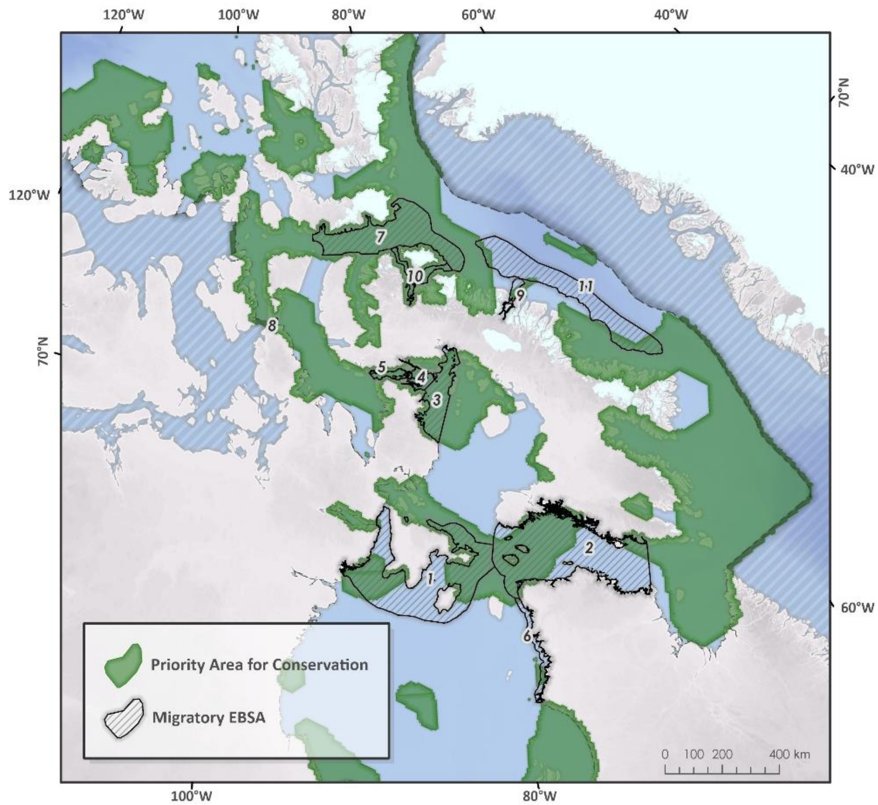

Figure 9.4. Spatial relationships between high target PACs and EBSAs identified as important for marine mammal migrations. For area identification by number see Table 9.5.

NARROW PASSAGES AND BETWEENNESS CENTRALITY

From an ecological perspective, a spatially heterogeneous environment is generally considered more "valuable" than a homogenous one, and it is likely to show greater biodiversity and species richness (Roff and Zacharias, 2011). However, the borders among the heterogeneous components can create ecological challenges, depending upon the scale of features.

The Canadian Arctic is replete with narrow channels and passages among the various islands. These may now, and will in the future, represent important bottlenecks to animal movements. Many of these areas are presently ice covered in the Archipelago, but given climate change, within decades may become ice-free during the summer months. These should be considered as distinctive geographic/geomorphic areas.

These narrow passages may be the complete antithesis of resilient areas; they are in fact potentially highly vulnerable, yet our knowledge is particularly incomplete about them. However, it is relatively easy to predict that interactions between major priority species that may use such areas (e.g. by exploring new migration routes) and marine traffic, could become serious.

In the marine environment, explicit knowledge of the movements of motile organisms is often lacking. For species with passive dispersal, movements can be modeled using information on organism sources and ocean currents (see section on connectivity models below). However, in the case of active swimmers, modeling general patterns of locomotion can require a different approach (Putman et al., 2016).

One such approach that allows estimation of broad inter-species movements is *betweenness centrality* (Costa et al., 2017). This concept originates in graph theory and is a measure of the importance of linkages or areas in contributing to the overall connectivity of a network. Areas ranking high in the metric of betweenness centrality indicate locations through which pass a large portion of the shortest paths connecting different parts of the network pass (Freeman, 1977). Simply put, areas with high betweenness represent theoretical key transit corridors and, therefore, potential bottlenecks for species movements.

The application of graph theory to movement ecology is still developing, and limitations exist (Moilanen, 2011), but the underlying logic is well-grounded. Organisms will seek to conserve energy resources as they move through the landscape by showing preference for more direct routes. Identification of these direct routes (i.e. least-cost paths) in a systematic and objective manner can aid in understanding where disturbances that impede movements could have greater fitness consequences for organisms (Etherington, 2016).

With this in mind, we modeled potential movement corridors across our entire study area using the ArcGIS NetworkX wrapper (ESRI, 2018) to score each portion of the region in terms of betweenness centrality. The marine portion of the study area was input as a spatial network graph of edges and nodes with a consistent lattice grid structure (resolution 10 km^2). Two versions of this grid were produced: one considering year-round ice as a barrier to movement, and one without this constraint.

The results of this analysis highlight several areas with a disproportionate importance in contributing to the network as a whole (Figure 9.5 and Figure 9.6). These are areas where the coastal topography may act to direct marine species along a route in order to reduce the overall distance travelled as they traverse the landscape of corridors and bottlenecks. Unsurprisingly, many of these areas correspond with the locations of known importance for species migration. For example, Bellot Straight, Fury and Hecla Strait, Roes Welcome Sound, Lancaster Sound, and Hudson Strait, which have been designated as EBSAs due to their importance for migration (DFO, 2011; DFO, 2015), are all in the top 95th percentile of betweenness centrality scores. Furthermore, if we compare these results with those generated considering multiyear ice as a barrier to movement, we see new corridors emerge through the Sverdrup Basin. This result could have interesting implications for a future Arctic where the extent of sea ice is increasingly confined.

In general, the areas highlighted in Figure 9.5 and Figure 9.6, should be given special consideration due to their potential importance as a corridor for the movement of active swimmer species.

HOTSPOTS – ARCTIC TRAILS STUDY

The study by Yurkowski et al. (2019) is the largest dataset of telemetry for Arctic marine predators, consisting of 1,282 individuals from 21 species. Their results for cetaceans and pinnipeds, seabirds, and polar bears were incorporated into the MECCEA Marxan analyses. These areas of particular importance within the MECCEA bioregions (called "hotspots" in this report) were identified during summer-autumn and winter-spring, in Baffin Bay, Davis Strait, Hudson Bay, and Hudson Strait. They occurred nearshore and within the continental slope in summer-autumn, and offshore in areas of moving pack-ice in winter-spring—both areas with oceanographic features that enhance productivity and foraging opportunities. This study, therefore, describes aspects of trophic connectivity (see below).

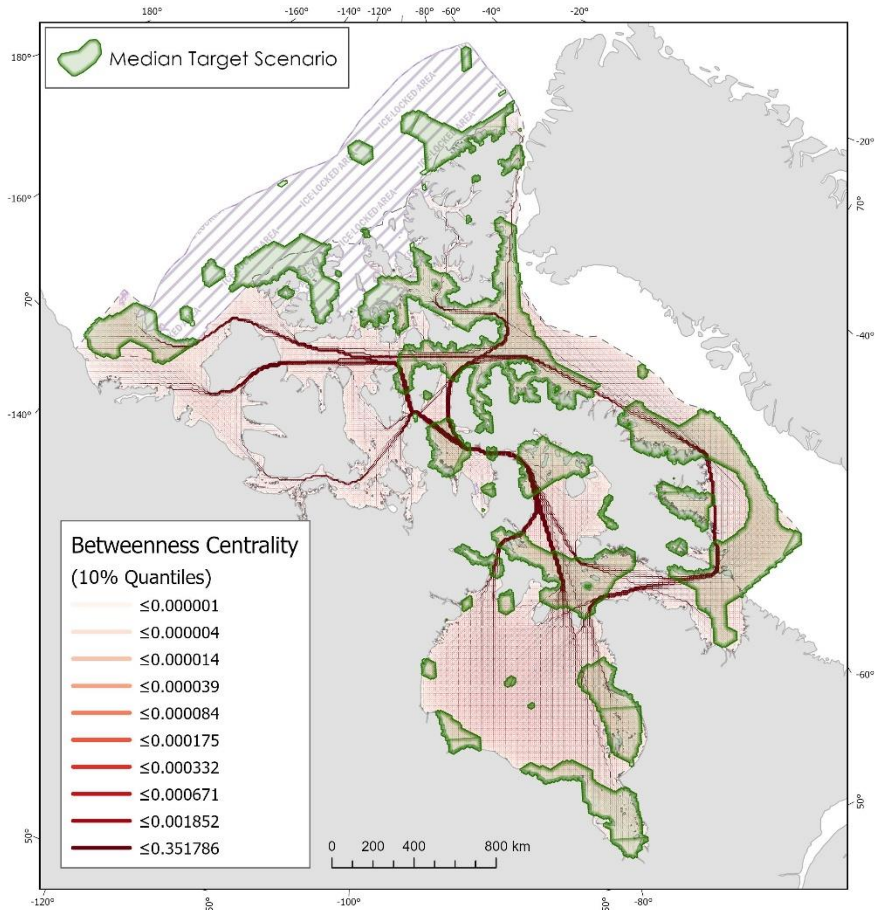

Figure 9.5. Betweenness centrality analysis indicating significant pathways of connectivity during present summer ice cover periods.

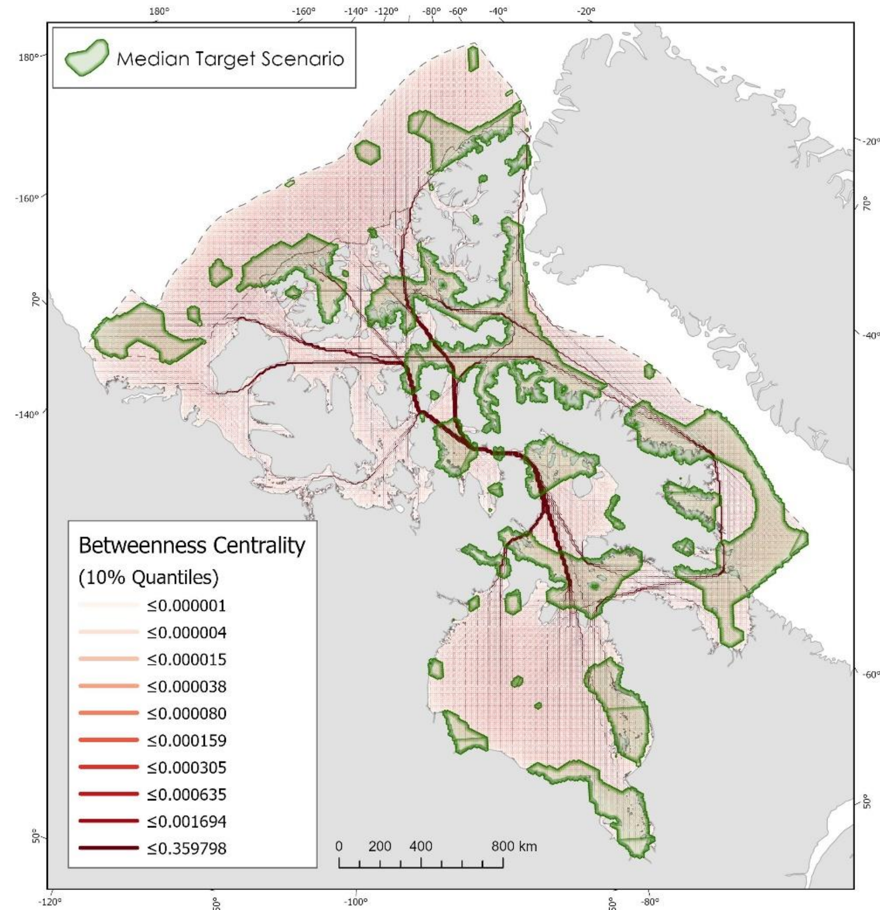

Figure 9.6. Betweenness centrality analysis indicating significant pathways of connectivity during projected annual ice-free periods.

CONNECTIONS FROM OCEAN TO FRESHWATER AND VICE-VERSA

In MECCEA, for fish populations, we have considered only existing fishing and spawning areas as known from IK and scientific knowledge (see Chapter 6), and these areas have been incorporated into our Marxan models. However, anadromous salmonids and coregonines are widespread in the study area, and they are harvested as an important food resource by most communities. This is done despite the lack of data and information for those areas. The estuarine habitats they traverse during migrations are included in our inlets category where they are presently not distinguished from bays. Given the significance and widespread distributions of these taxa, their significance in conservation is perhaps best evaluated as management plans are developed for individual PACs.

CONNECTIONS TO AND FROM THE LAND

Connectivity between land and ocean is significant for a variety of reasons. Several species such as polar bears and seabirds use terrestrial locations for breeding, while exploiting the marine environment for resources. These aspects of species biology are incorporated in our Marxan analyses.

Of greater concern, due to changing ice conditions and marine ice-breaker activity, is the status of Arctic caribou populations that depend on stable sea ice for annual shore-to-shore migrations (see above).

Of even greater concern are the massive contemporary rates of coastal erosion, due to melting of permafrost. Rates of coastal recession up to 40 m per year in the Beaufort Sea area and rates of up to a metre in a single day have been recorded (Cunliffe et al., 2019), which may result in serious disruption to both natural ecological processes and to local Indigenous communities. A combination of increased shoreline erosion and changing sea levels, both consequences of climate change, could dramatically alter the geography and patterns of connectivity in the future Canadian Arctic.

Of presently minor concern, are the adverse effects of pollution inputs from local communities. However, pollution from humans via cruise ships is becoming a growing local issue.

On a more positive note, in MECCEA we document the potential synergistic relationships between our identified PACs and nearby existing terrestrial protected areas (Figure 9.7 and Figure 9.8, for median and high PAC scenarios, respectively). Such proximity between land and sea protected areas could support enhanced monitoring protocols and co-development of management regimes. We found that many of our PACs fall within 1 km of existing terrestrial protected areas. For the minimum target scenario, 22 of 75 PACs are within this range of terrestrial protected areas. For the median and high target scenarios, the numbers are 17 of 45 PACs and 15 of 44 PACs, respectively. Note that the numbers decrease in the higher target scenarios because PACs coalesce.

Although we have not carried out any detailed examination of actual or potential relationship between terrestrial sites and marine sites, this undertaking could produce valuable results. Here, we document a single example in Figure 9.9. One of the main conservation features within the Eastern Hudson Bay PAC is a beluga calving area (Eastern Hudson Bay beluga are listed as endangered by COSEWIC). This calving area is connected to the Nastapoka estuary and river within the Tursujuq National Park. The calving area is currently not protected either by the national park or by any other type of protected area. This example illustrates an opportunity for collaboration among federal, provincial, and territorial governments and rightsholders when setting conservation objectives for protected areas adjacent to national parks. See also MELCC (2019) for more detail on this Quebec shoreline.

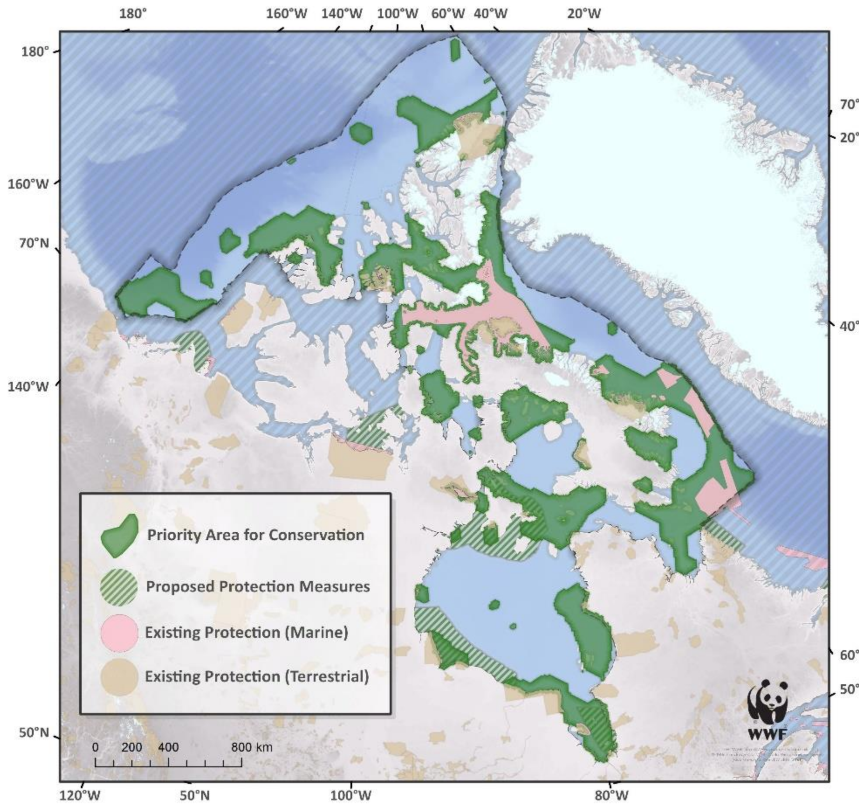

Figure 9.7. Spatial relationship between median target PACs, other marine proposed and protected areas, and existing terrestrial protected areas.

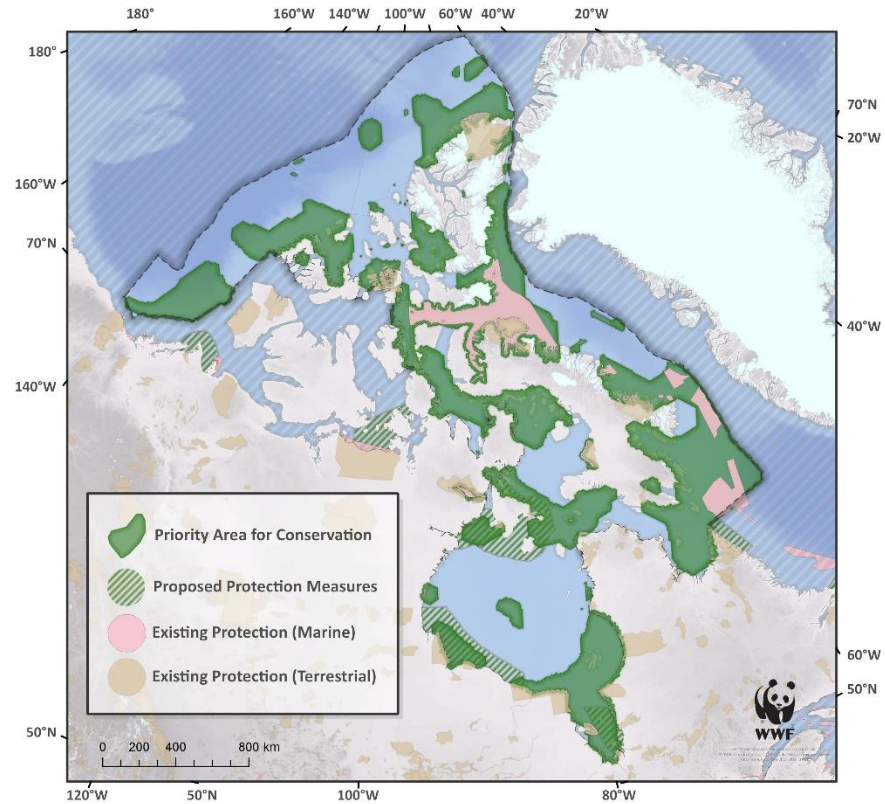

Figure 9.8. Spatial relationship between high target PACs, other marine proposed and protected areas, and existing terrestrial protected areas.

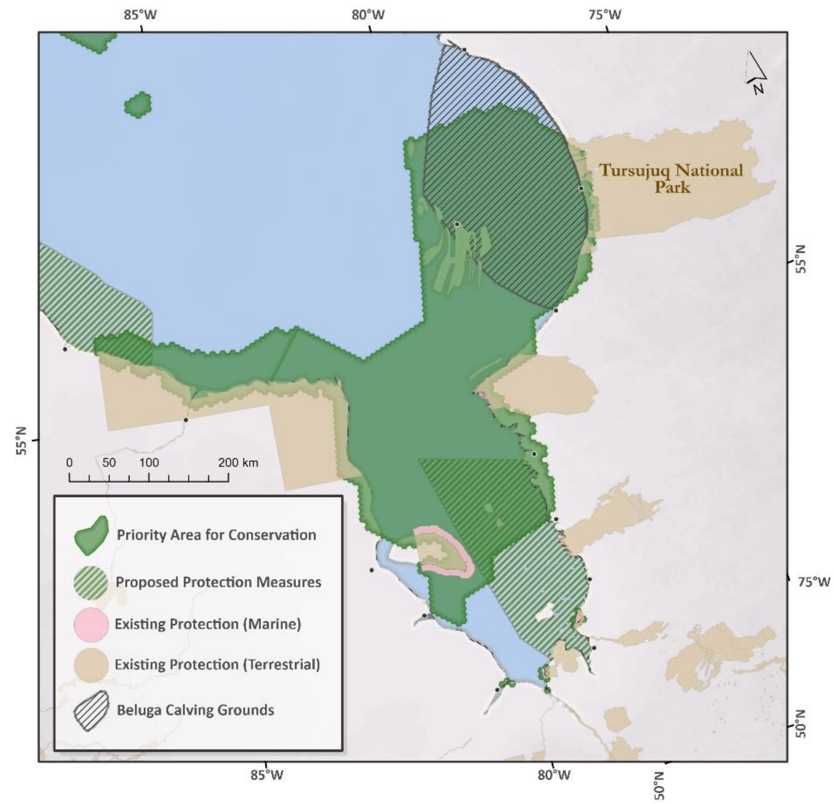

Figure 9.9. Detailed spatial relationship in the Southern Hudson Bay and James Bay areas between the minimum target PACs, other marine proposed and protected areas, existing terrestrial protected areas, and beluga calving ground.

TROPHIC CONNECTIVITY

Although we have reviewed available data for many components of Arctic bioregion food webs (in Chapters 5 and 6), data are generally sparse. Despite this, generalized food webs for the four bioregions could be valuable as management plans are developed for the various PACs.

Unfortunately, such an analysis is beyond the scope of the present MECCEA study. However, any Arctic food webs would need to take into considerations some major factors. These would include:

1. Biogeographic differences among and within bioregions;
2. Ongoing and potential changes in Arctic marine food webs, largely as a result of range extensions of temperate species;
3. Seasonal migrations of marine mammals and birds, which involve massive regional use and export of resources;
4. Differences among pelagic and benthic food webs; and
5. Differences among coastal, shelf and deeper waters.

OCEANOGRAPHIC CONNECTIVITY AND MODELS OF DISPERSAL AMONG PACS

Patterns of Ocean Circulation in the Canadian Arctic

Ocean circulation and tidal currents in the Arctic are essential to the transport and dispersal of organisms and are therefore fundamental to connectivity among marine protected areas. Defining these patterns of connectivity is a valuable addition to the designation of a true network of PACs and effective biodiversity conservation (Kenchington et al., 2016).

Circulation of marine waters within the four MECCEA bioregions is driven by several processes. Inputs to the region come primarily from the Beaufort Sea, from the Arctic Ocean via Nares Strait between Ellesmere Island and Greenland, and from the Atlantic Ocean in the East Greenland Current. Additionally, currents are generated by tidal excursions that reach extreme levels in Ungava Bay. Added to this again, are surface currents driven by freshwater runoff that dominate in Hudson Bay whose drainage basin occupies some 38% of the entire continental land mass of Canada.

Various aspects of circulation and biology in the Canadian Arctic have been investigated in recent years (e.g. Jones et al., 2003; Canada's Arctic Marine Atlas, 2018), but their significance for marine conservation has never been fully evaluated. Here, we make a **first attempt** to describe the patterns of connectivity among the MECCEA PACs, in order to stimulate further research into network design in the Canadian Arctic.

Dispersal of Propagules

Connectivity among protected areas depends on the interaction of geophysical, oceanographic and hydrodynamic parameters on one hand, with the biological characteristics and behaviours of organisms on the other. These important aspects of connectivity are summarised in Text Box 9.6.

Marine connectivity studies may reveal initially very opposing findings. A recent survey of marine connectivity studies concluded that nearly 50% underestimated true connectivity (Manel et al., 2019). Dispersal distances can range 10-fold further than previously thought (Carr et al., 2011; Mora et al., 2006). Conversely, larval retention and recruitment may be very local with low dispersal (e.g. Swearer et al., 1999).

Previous Canadian studies of connectivity and networks include those by Roff and Zacharias (2011) on the Scotian Shelf and Kenchington et al. (2019) in the northwest Atlantic. There is as yet little experience of biological connectivity in complex regions of archipelagos, islands, bays, and inlets. The present modelling study—the first of its kind in the Canadian Arctic—should be considered as a structural connectivity analysis (see Text Box 9.6). It has not explored all the additional complicating factors affecting larval development in Arctic waters (Table 9.6). A full report on this study is available from WWF-Canada.

Table 9.6. Complications and some apparent contradictions concerning the meroplanktonic phase in Arctic organisms and consequences for MPA network design.

Factors affecting larval development in Arctic waters.
There exists a great taxonomic and anatomical diversity of larval forms.
There is no such thing as an "average" larval development time.
There is a decrease in the proportion of benthic species with meroplanktonic larvae at higher latitudes.
There is an increase in the proportion of benthic species with direct development at higher latitudes.
There is an increase in the proportion of benthic species with direct development with increasing depth.
Smaller larvae have shorter meroplanktonic durations and are transported for shorter distances.
Larval development time increases with decreasing temperature.
Recruitment of larvae is highest at the time of spring bloom.
Larvae may be preferentially associated with the under-ice sympagic community.
Meroplanktonic larvae may be present year-round.
Spacing of marine protected areas should be further apart at higher latitudes.
Marine protected areas should be larger at higher latitudes.
Dispersal distances may be greatly under-estimated or over-estimated.
Dispersal may be reduced by retention mechanisms

Text Box 9.6. Important concepts in connectivity and dispersal.

Definition and significance of Connectivity

According to IUCN (2008), connectivity is defined as, "the extent to which populations in different parts of a species' range are linked by the exchange of eggs, larvae recruits or other propagules, juveniles or adults."

Connectivity is important because its rate, scale, and spatial structure drive population replenishment with important ramifications on population dynamics and genetics (Cowen et al., 2006). From a management perspective, connectivity can drive the replenishment of biodiversity in areas damaged by natural or human-related drivers (Kenchington et al., 2016), influence the spread of invasive species (Lubchenco et al., 2003), and help safeguard species by resilience to climate change (Costello and Connor, 2019).

Functional Connectivity

Connectivity among protected areas depends on the interaction of geophysical, oceanographic, and hydrodynamic parameters on one hand (structural), with the characteristics and behaviours of organisms on the other (biological).

Structural Connectivity

Structural connectivity can only represent actual physical connections in the ocean that are driven by coastal geomorphology, bathymetry, and ocean currents. Two areas may be structurally connected but functionally disconnected. Random velocity perturbations, water column stratification, and extreme events can have a significant effect on connectivity (Kenchington et al., 2019; Manel et al., 2019). This study is one of structural connectivity.

Biological Connectivity

Biological Connectivity is affected by a suite of factors including:

- Inter-annual variability;
- Non- passive swimming ability and behaviour (Currie et al. 1998) of adults and meroplankton (larvae or other propagules) including diurnal vertical migration;
- Dispersal duration (pelagic larval duration); and
- Characteristics of competency period and settlement behaviour.

See also Roff and Zacharias (2011) for further factors and Table 9.5 for further complications in arctic waters.

Model Sources and Features

Sources and characteristics of the drift and oceanographic models used are summarised in Text Box 9.7.

Experimental Design

The experimental design for our particle drift simulations was based on Kenchington et al. (2019), where a picture of annual three-dimensional connectivity was achieved in all four seasons covering various time spans and depths. Simulations were run for 74 scenarios, at varying durations, times of the year, and depths, with models of a temporal and spatial resolution sufficient in the shorter simulations to resolve the currents of the complex coast and bathymetry of the Canadian Eastern Arctic. The details of our connectivity analyses and supporting rationale are presented in Text Box 9.8.

Simulations were run for three MECCEA scenarios including: S4.2 (HL here), S4.4 (HM here), and S4.6 (HH here) (see Chapter 8 and Figure 8.9, Figure 8.11, and Figure 8.13). The following abbreviations are used below for the MECCEA marine bioregions: Arctic Archipelago (AA), Arctic Basin (AB), Eastern Arctic (EA) and Hudson Bay (HBC).

Text Box 9.7. Summary of models used for the connectivity study and caveats.

The Drift Model

Based on Treml et al. (2008; 2012), the drift model generates spatially explicit predictions of population connectivity by simulating hydrodynamic dispersal of propagules from user-defined 'patches' (akin to MECCEA's PACs). It was developed by Duke University's Marine Geospatial Ecology Lab (MGET).

Spatial extent and grid resolution were set by 3 project rasters:

1. a water mask—a binary image differentiating water and land;
2. a definition of patch (PAC) locations; and
3. a float raster that specifies how each patch is seeded with drift particles.

MGET is computationally intensive and recommends a maximum of 200,000 pixels in any simulation.

Model output comes in two parts: a) a series of raster images showing snapshots of particle dispersal at user-defined timesteps; and b) a geodatabase summarizing how particles have redistributed by the end of the simulation.

Rather than producing true dispersal tracks of drifted particles, the simulation provides information about the quantity and proportion of particles that:

1. remained within the original patch;
2. connected to other patches; and
3. were lost from the patch network.

These geodatabases are used here to provide the baseline framework of connectivity among the MECCEA PACs.

Importantly, MGET results are expressed both in terms of the absolute quantity and the probability of particles drifting from one patch to patch another.

The Ocean Model

The ocean model chosen for use by MECCEA needed to be suitable for our large, oceanographically complex, and high latitude study area.

Our study was based on the GLORYS12V1 model, from the Copernicus Marine Environment Monitoring Service (CMEMS). It is a global high-resolution ocean reanalysis product with 1/12° horizontal resolution (6.0 and 1.6 km at 50°N and 80°N, respectively) and 50 levels in the vertical.

It uses daily observations of changing ocean properties and combines these with output from a numerical ocean general circulation model that simulates this evolution of ocean physical properties. The observations incorporate altimeter data, sea surface temperatures, sea ice concentrations, and in situ temperature and salinity vertical profiles.

The model component uses the Nucleus for European Modelling of the Ocean (NEMO; nemo-ocean.eu) platform with its ocean dynamics (NEMO-OCE), sea ice (NEMO-ICE), and biochemistry (NEMO-TOP) physical core engines. The NEMO platform was also used by Kenchington et al. (2019)'s connectivity analysis in the North Atlantic.

Together these elements provide a synthesized estimate of the state of the ocean and important variables like temperature, salinity, sea level, sea ice extent/concentration/thickness, and current speed/direction, the last of which was used for this analysis.

The ocean current data used in simulations was limited to just one calendar year, 2016. A simulation based on daily mean current data averaged over a multiyear period or averaging the connectivity output over several years would have been preferable. These approaches should be considered in future analyses.

The Western Arctic bioregion was not included in MECCEA's study, but its waters were included in the domain of the connectivity analysis.

(*Continued next page*).

Text Box 9.7 (cont.). Summary of models used for the connectivity study and caveats.

Some Caveats

This analysis provides an annual picture of connectivity while avoiding computationally intensive, long-duration simulations.

Ocean current resolution maybe have been insufficient to describe some of the connections between narrow channels. This reduced resolution was required for the 90-day simulations (i.e. 45 km) in order to overcome the memory limitations of MGET.

Ideally this memory limitation must be overcome in order to conduct analyses using higher resolution ocean data. This may be possible either by using a smaller study area to focus on narrow channels, or by initializing fewer cells for seeding the drift simulation.

Without PACs being defined in the Western Arctic (which was not part of the MECCEA study area), it was difficult assess connectivity through this region.

Text Box 9.8. Summary of models used for the connectivity study and caveats.

Undertaking a connectivity analyses based on planktonic larval duration (PLD) was impractical because of the large number of species, variability of durations, and paucity of information in the Arctic. We instead chose to provide a framework of structural connectivity in Canada's Arctic by simulating connectivity over three different durations: 14, 30 and 90 days.

While longer PLDs may be important, for example, as in multigenerational (steppingstone) connectivity, by drifting with sea ice (David et al., 2015), and enhanced dispersal by ice rafting (Macfarlane et al., 2013), this was not practical given the computational intensity of modelling, over a large study area with a high-resolution ocean model.

Particle drift was initiated from all cells in the PACs, so as to provide a full picture of connectivity.

Simulations were run in all four "seasons"; the calendar year was arbitrarily divided into four quarters: January–March (Winter); April–June (Spring); July–September (Summer); and October–December (Autumn). These seasons corresponded to the 90-day simulations. The 30- and 14-day simulations were run for the middle month of each season.

The model was run at two depths: near surface at 5 m depth; and the midpoint of the shelf at 110 m. The bottom depth was not available in this model output.

The connectivity of all three MECCEA scenarios was considered, i.e. the minimum, median and high target scenarios. All three used the highest BLM setting (10) that favoured larger and fewer over more and smaller PACs.

These three scenarios, referred to herein as HL (high BLM – minimum target), HM (high BLM – median target) and HH (high BLM – high target), correspond to scenarios S4.2, S4.4 and S4.6, respectively, in Chapter 8 of this report.

Results and Interpretation

Connectivity Changes with Time

Observing the drift simulations of the three durations in sequence, 14, 30 and 90 days, reveals the progression of connectivity in the Canadian Arctic over time and provides an indication of the planktonic larval duration (PLD) that might be required for the biological consequences of the connections to develop between PACs. As previously in this chapter, although all three time periods represent potentially realistic larval durations in the Canadian Arctic, the 90-day simulation is particularly important for providing an indication of longer-term trends and multigenerational (or steppingstone) connectivity. For this analysis, a common start date of 1 July was used for all three simulations.

A comparison of the three simulations, 14, 30 and 90 days, during the summer for the HM scenario at 5 m is given in Figure 9.10. This quarter was chosen as a representative example of a strong period of connectivity. Over the shorter 14-day simulation, the strongest connections emerge between the closest PACs, with connections forming within the HBC, in the vicinity of the large Lancaster/Jones Sound PAC, and on the northwest side of the AA. After 30 days, these links have strengthened and new connections emerge off the northeast coast of Ellesmere Island, around the Lancaster/Jones Sound PAC, and in the southwest AB. At this time scale, connectivity is constrained to within the scale of the marine bioregions. By 90 days, connectivity within and between bioregions has become more extensive. Connections have formed in the southern and northern AB, throughout the HBC, and between Lancaster Sound and the Gulf of Boothia.

At 110 m depth (Figure 9.11), the progression of connectivity is similar but involving different PACs. Connections after 14 days are limited to neighbouring PACs and after 30 days, connections are largely confined to the bioregion scale. After 90 days, connectivity has extended, particularly around the large Lancaster/Jones Sound NMCA, and with links between the AA and EA. Links have developed along the east side of HBC, and throughout the southern AB. Analysis for the HH and HL scenarios (not shown) showed similar results.

Thus, distant links between MECCEA's PACs are not quick to form, but strong connections do develop over the 90-day simulation across some but not all marine bioregion boundaries.

Seasonal Variability in Connectivity

Seasonal variations in connectivity over 90-day simulations were run for all four seasons at 5 m and 110 m (Figure 9.12 and Figure 9.13, respectively).

At 5 m, winter sees the weakest connectivity while summer and autumn months show the strongest. From winter to spring, connectivity changes little except for a local increase among the PACs of the southwest AB, those of western HBC, and around Southampton Island. Moving into summer, connectivity begins to increase from Lancaster Sound into the Gulf of Boothia, in a southward direction along the east coast of Ellesmere Island, within HBC, and from Foxe Basin into HBC. Into autumn, connectivity weakens in the HBC with reversals in connectivity direction throughout the study area. Persistent throughout the year are the southward connections to the west of Ellesmere Island and through Hall and Kane Basins as well as those in the vicinity of the Lancaster/Jones Sound PAC.

At depth (110 m), connectivity throughout the year differs considerably to that at the surface. Winter is still the season with weakest connections. However, some connections exist at depth in winter that do not exist at the surface, such as Lancaster Sound to the Gulf of Boothia and to southern Baffin Island. Other connections are seasonally variable in occurrence, strength, and direction. Connectivity in HBC remains low all year and in no season is there a connection to or from Foxe Basin.

In summary: unsurprisingly, results show that summer and autumn—the widely ice-free period—have the strongest connections. More surprising is the total lack of connections at one depth that are present at the other, likely due to the strong stratification of the water column. This highlights the importance of a multi-depth approach to connectivity assessment.

Annual Maximum Connectivity

To provide an overall synthesis of the results of MECCEA's connectivity analyses, the strongest connections that occurred throughout the 2016 calendar year were identified and tallied from the four 90-day simulations for each of the three Marxan scenarios. These results are presented in Figure 9.14, Figure 9.15, and Figure 9.16 for the HM, HH, and HL scenarios, respectively.

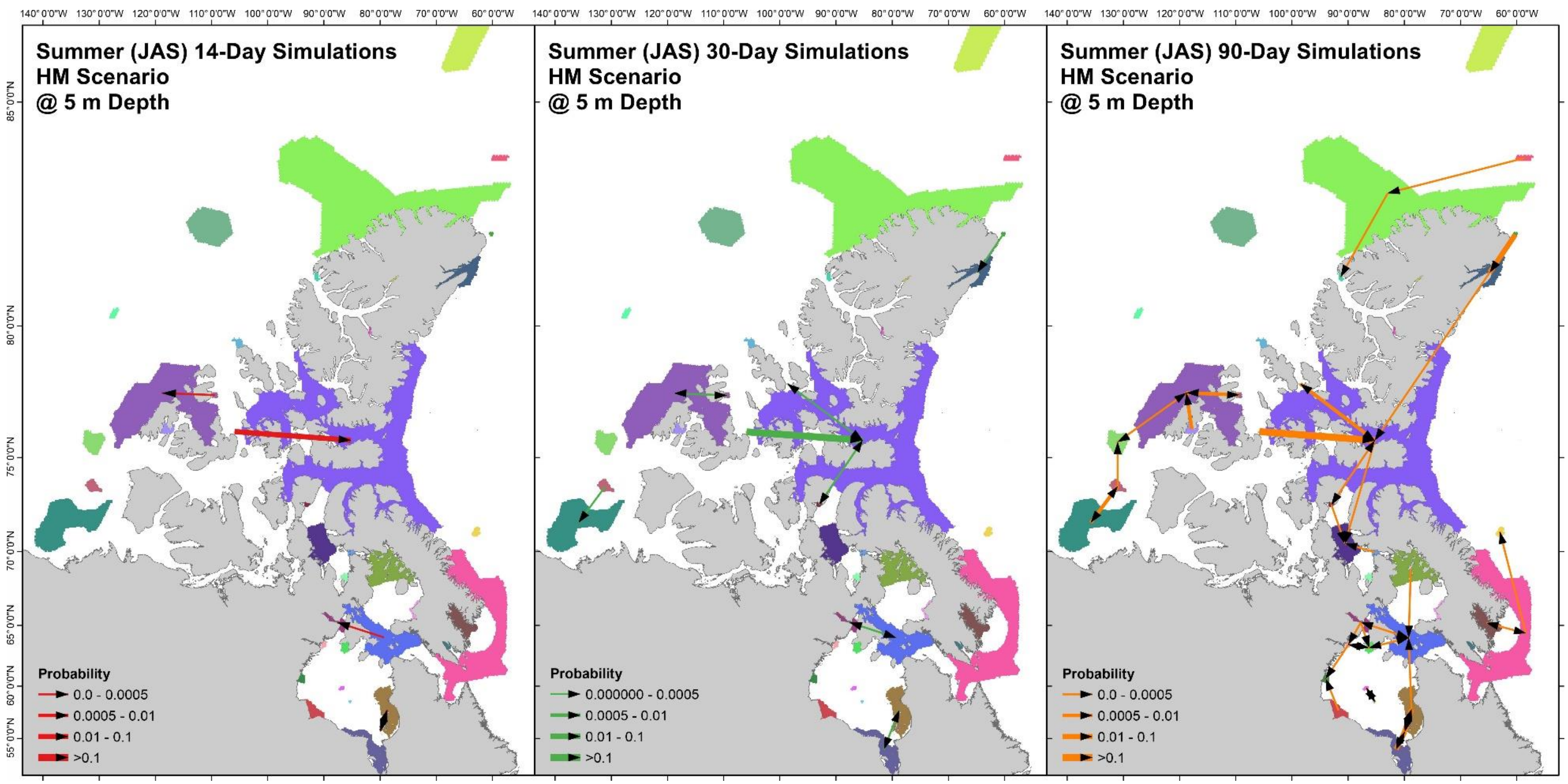

Figure 9.10. Comparison of HM (high BLM, median target PACs) connectivity scenarios within the four MECCEA bioregions for increasing duration (14, 30, 90 days) in the summer months (July, August, September) at 5 m depth. Connections between PACs are shown as red lines, with thickness proportional to the probability (0.0-1.0) that "larvae" seeded from one PAC will connect to another PAC. Black arrow heads indicate direction of connections, which can be bidirectional. Path and length of lines indicate connection between PACs, not the actual trajectory followed.

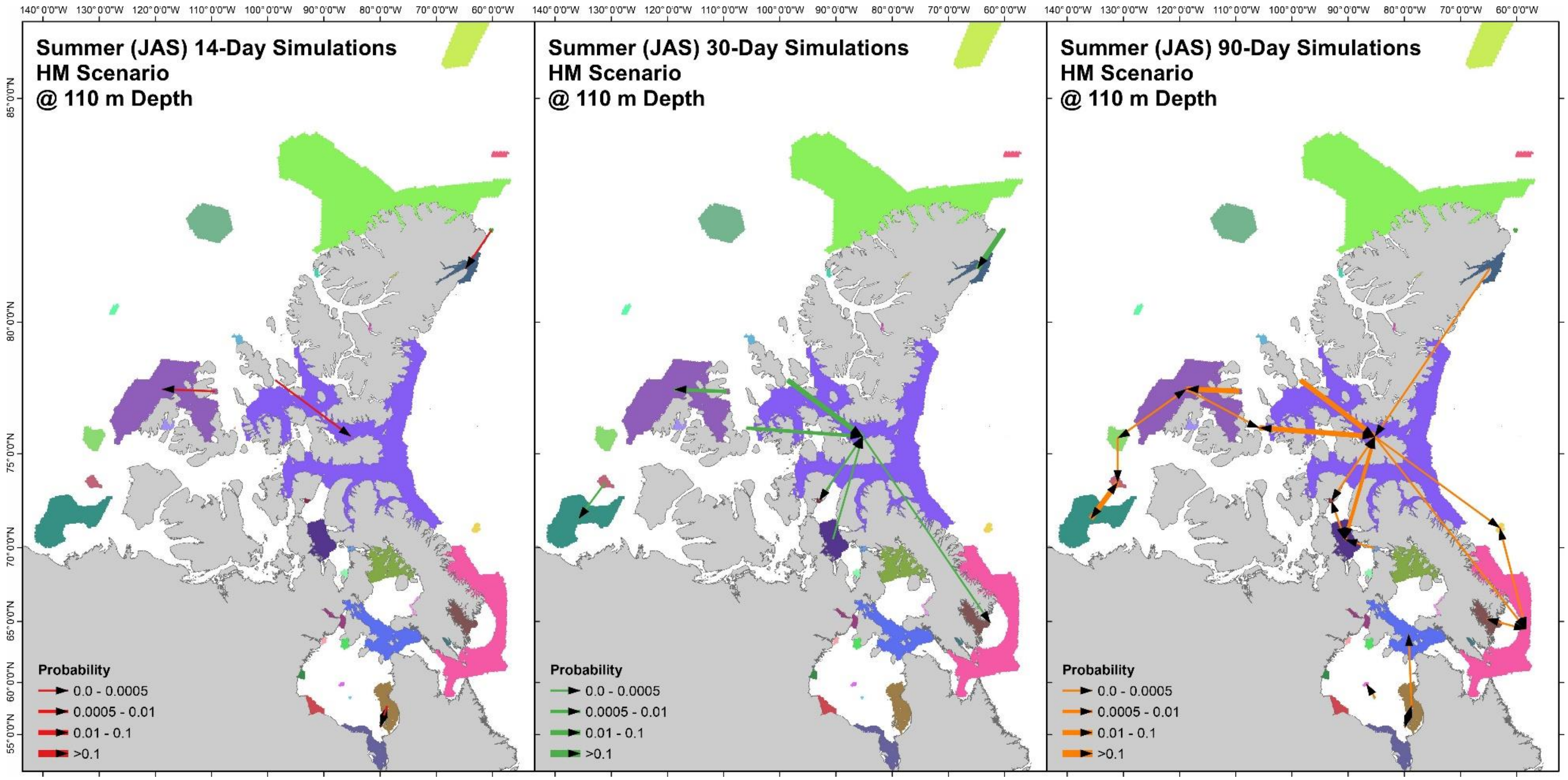

Figure 9.11. Comparison of HM connectivity scenarios within the four MECCEA bioregions for increasing duration (14, 30, 90 days) in the summer months at 110 m depth. Other notation and interpretation as in Figure 9.10.

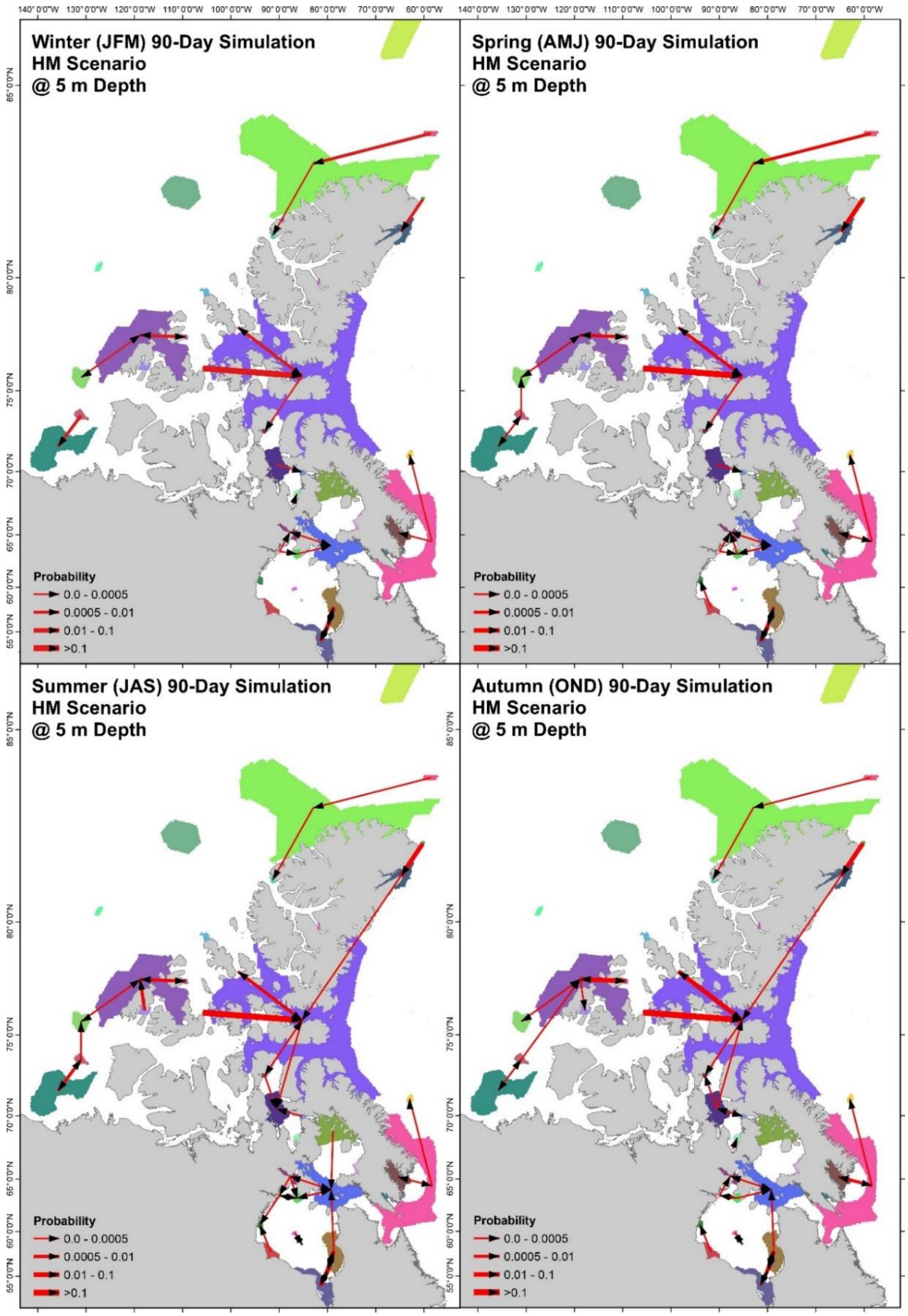

Figure 9.12. Seasonal variations in connectivity for the HM scenario at 5 m depth. Other notation and interpretation as in Figure 9.10.

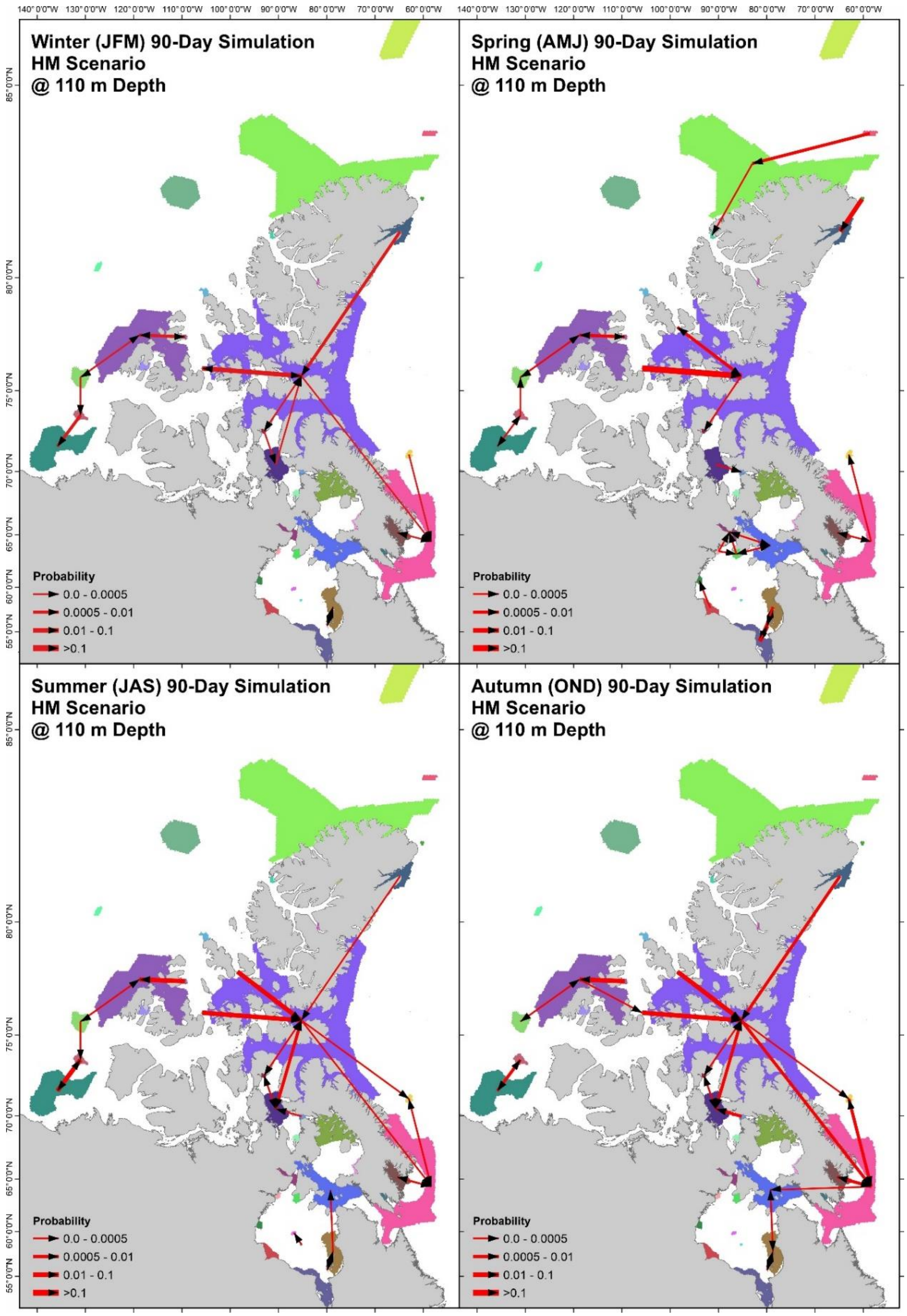

Figure 9.13. Seasonal variations in connectivity for the HM scenario at 110 m depth. Other notation and interpretation as in Figure 9.10.

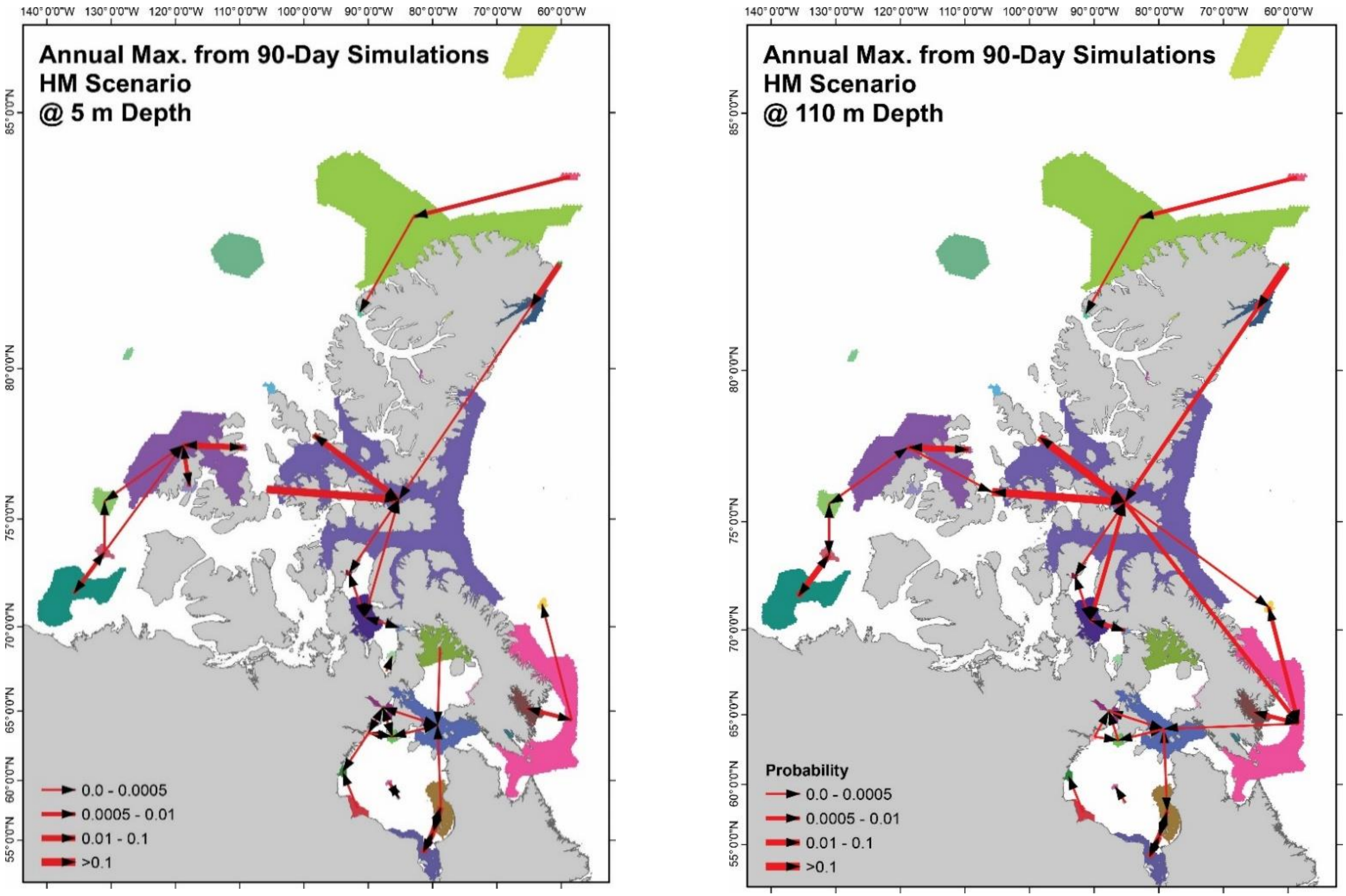

Figure 9.14. Maximum connectivity for the HM scenario at 5 m and 110 m depths from the four 90-day simulations, indicating the full annual connectivity. Other notation and interpretation as in Figure 9.10.

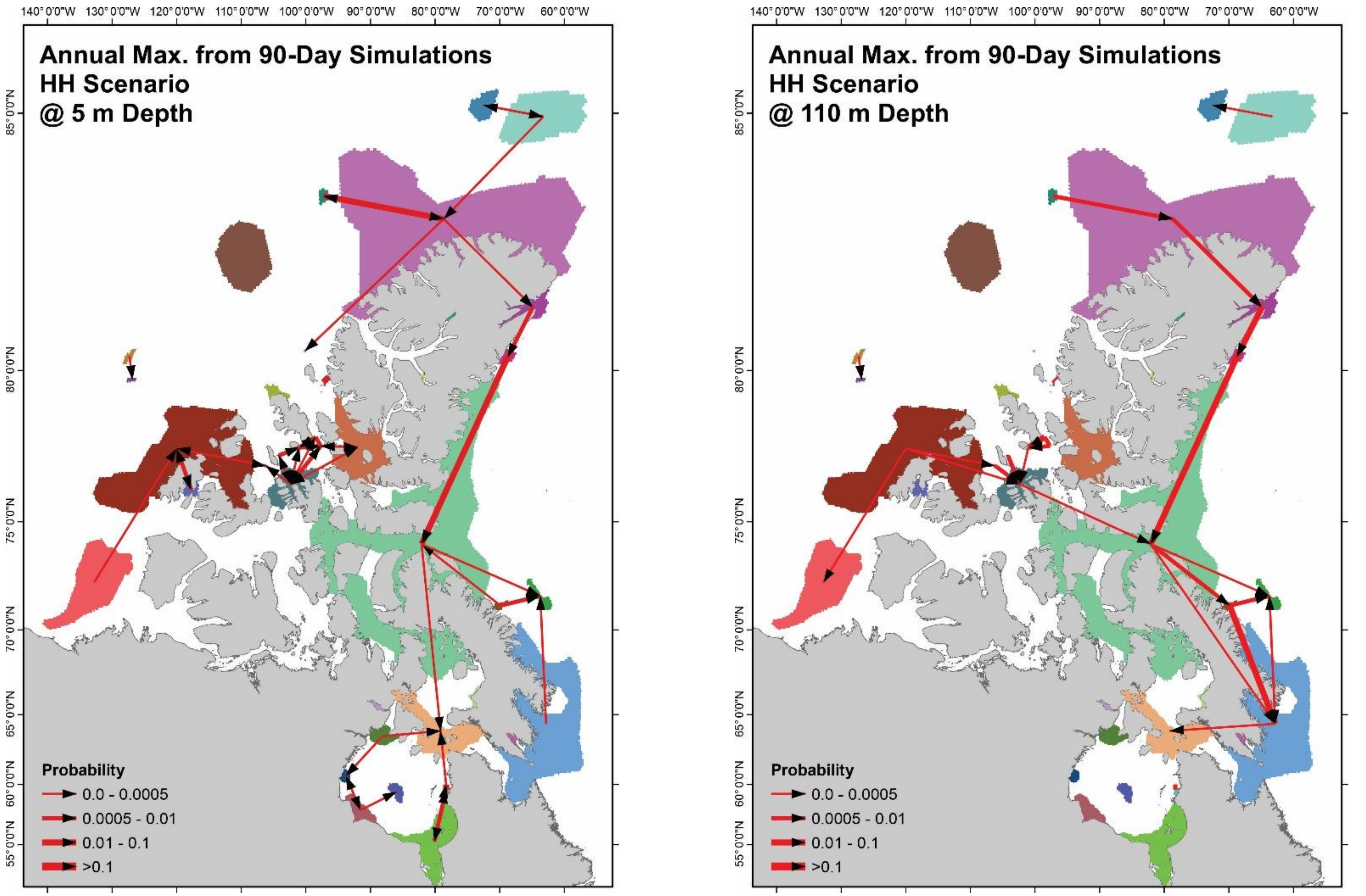

Figure 9.15. Maximum connectivity for the HH scenario (high target PACs) at 5 m and 110 m depths from the four 90-day simulations indicating the full annual connectivity. Other notation and interpretation as in Figure 9.10.

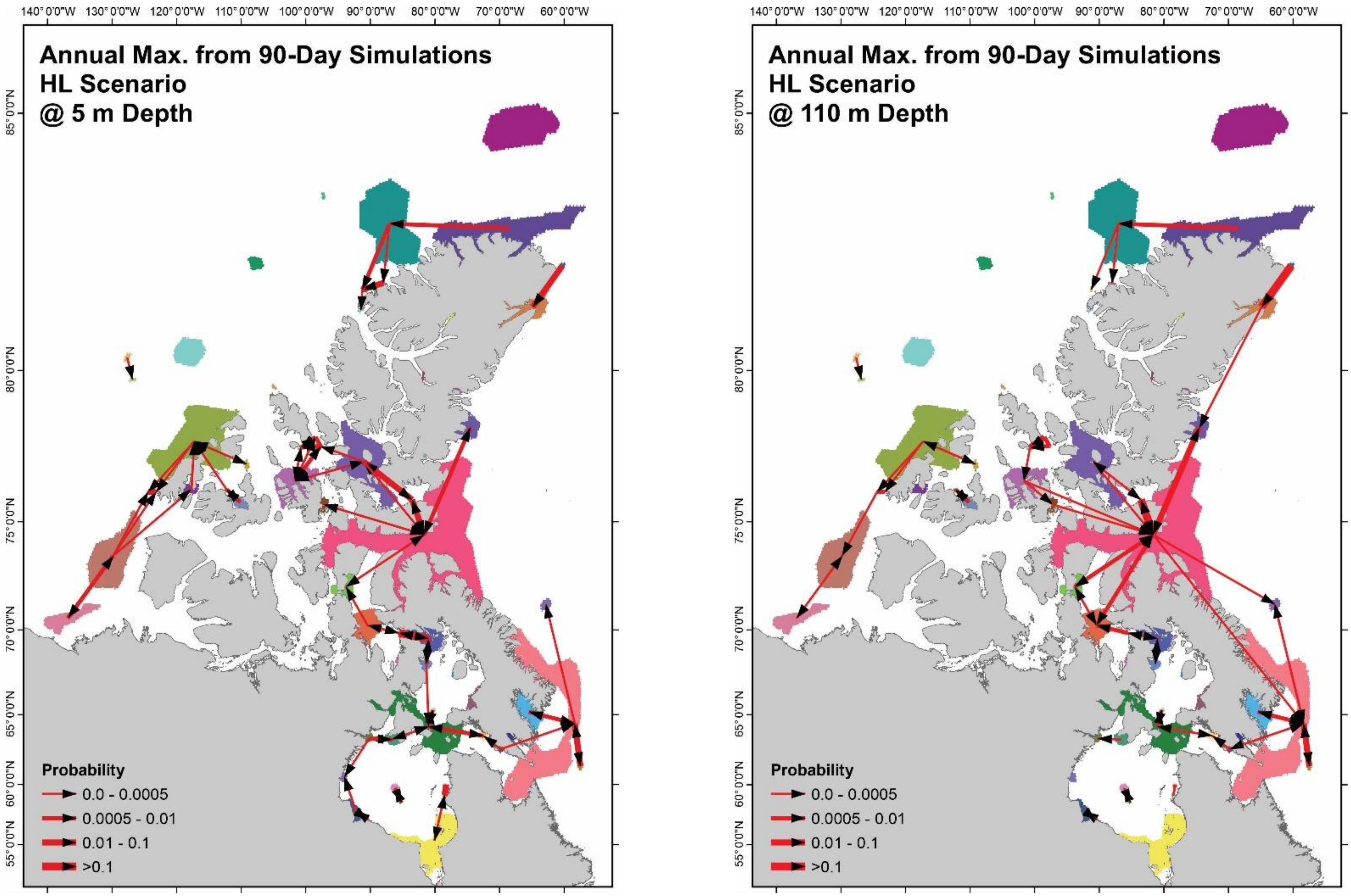

Figure 9.16. Maximum connectivity for the HL scenario (minimum target PACs) at 5 m and 110 m depths from the four 90-day simulations indicating the full annual connectivity. Other notation and interpretation as in Figure 9.10.

These figures reveal strongly connected regions as well as PACs more prone to isolation. Direct comparison among the three scenarios is complicated by the fact that their PACs differ in size, number and distribution. However, the number and proportion of connected versus isolated PACs is provided in Table 9.7. This table provides the number of isolated PACs (red), the number of PACs with only one connection (yellow), and PACs with good connections (green)—defined as those with two or more connections.

Table 9.7. Summary statistics of the maximum connectivity analysis of MECCEA's PAC networks (green, well-connected; yellow, only 1 connection; red, no connection).

	HL 5 m	HL 110 m	HM 5 m	HM 110 m	HH 5 m	HH 110 m
Total # PACs	71	71	42	42	42	42
# of well-connected PACs	44	38	24	18	23	17
% of well-connected PACs	62	54	57	43	55	40
# PACs with one-way cxn	2	1	1	1	3	2
# PACs with 1 cxn	7	8	10	9	9	4
% of connected PACs	75	66	83	67	83	55
# of isolated PACs	20	25	8	15	10	21
% of isolated PACs	28	35	19	36	24	50

As expected, the surface is more connected than at depth for all scenarios. Interestingly, although the higher number of PACs in the HL scenario leads to more well-connected PACs, it also results in substantially more isolated PACs.

For the HM scenario (Figure 9.14), several regions show good connectivity including the southwest part of the AB, the areas adjacent to the large Lancaster/Jones Sound PAC, and from Cumberland Sound to the waters of the Labrador Sea. Although it is clear that northern and southern AB do not connect, there also seems to be an east-west disconnect through the centre of AA. In the HBC, waters around the perimeter are well connected but there appear to be no connections between east and west. Of the isolated PACs, most occur in the offshore waters of AB and in the western inlets of Ellesmere Island.

For the HH scenario (Figure 9.15), the southern portion of the AB is again well-connected, as now is the northern portion, but again there are no connections between them. The small PACs of the central AA are well-connected in this scenario but there is no eastward connection to the Lancaster Sound PAC except at depth, probably via Parry Channel. The isolated PACs in this scenario occur again in the central AB and in the fjords of western Ellesmere Island. The PACs of the HBC are also isolated at depth; there is better connectivity at the surface but with a persistent east-west divide.

The HL scenario (Figure 9.16) paints a more complex picture due to the large number of smaller PACs. However, elements like the (dis)connectivity of the AB and HBC, the east-west divide down the centre of the AA and the locations of isolated PACs are similar. There is good connection at both depths between the Lancaster Sound PAC and the AA, as well as between Foxe Basin and the Gulf of Boothia and through Hudson Strait. The reduced apparent connectivity among the larger PACs of the HM and HL scenarios suggests that the connections here are occurring over short distances and require a small number of distributed PACs to be evident.

Although the connectivity patterns of the three scenarios are different, a number of common characteristics are important for marine connectivity in the Canadian Arctic. First, common to all scenarios was the isolation of a number of PACs in the AB as well as the separation of its northern and southern regions. Also, in common was the east-west disconnect of Hudson Bay, which was otherwise inter-connected along the shore at the surface, but only at depth in the HM scenario. Finally, the large PAC that includes Lancaster Sound is consistently a hub of connectivity for all scenarios. Without PACs being defined in the Western Arctic (which was not part of the MECCEA study area), it was difficult assess connectivity through this region. However, over the 90-day simulations, no connection reached through this region from the Arctic Basin to the Eastern Arctic.

SOCIO-ECONOMIC CONNECTIVITY

Aspects of socio-economic connectivity and implications of the MECCEA PACs are considered in Chapter 10.

CONNECTIONS BEYOND THE MECCEA PACS AND TO ARCNET

The study of connectivity is not completed until ecological connections to contiguous regions have been defined and analyzed, ideally comprising a network of networks.

The four MECCEA study bioregions are bordered to the north by the Arctic Ocean proper (beyond the Canadian EEZ), to the west by the Western Arctic bioregion, to the east by the EEZ waters of Greenland in Baffin Bay and Davis Strait, and to the south-east by the Newfoundland and Labrador Shelves bioregion. Ecological and environmental relations between the MECCEA Network proposed here and these regions has not yet been undertaken and would require additional studies.

Contemporaneous with the MECCEA study, there has also been ongoing planning by the WWF Arctic Programme for an Arctic Ocean network of PACs—ArcNet. Its primary goal is to identify and map an ecologically representative and well-connected pan-Arctic network of marine areas, specially-managed for the conservation and protection of biodiversity, ecological processes, and associated ecosystem services and cultural values, which is integrated in an ecosystem-approach to the wider seascape (Arctic Council, 2015). The ArcNet initiative is not meant to replace smaller regional analysis, but rather to highlight regions across the Arctic which are important to maintaining its collective diversity.

While the ArcNet and MECCEA initiatives share a similar methodology (e.g. Marxan), differences in scale and other technical details mean that alignment in terms of the areas identified by these projects is not guaranteed. Beyond some differences in data and target setting, it is important to understand that aspects of biodiversity deemed crucial at one scale, may be less so at another. With this in mind, a comparison between the draft ArcNet scenarios and the appropriate comparable MECCEA scenario (i.e. the median target scenario) indicates a 61% overlap between the areas identified (Figure 9.17). Although some differences in spatial arrangement exist, these results show a significantly greater proportion of coincidence than would be expected by chance alone (Cohen's k = 0.34), indicating that areas identified within Canada maintain their importance when considered at a pan-Arctic scale.

Some "structural" differences between the two projects likely explain the majority of mismatch. For instance, at the time the MECCEA results were produced, the new Tuvaijuittuq MPA was not yet designated and so was not locked into the Marxan analysis as it was in ArcNet. This resulted in a very different configuration of selected areas in the northern Arctic Basin. Additionally, exclusion of the Western Arctic marine bioregion for MECCEA likely resulted in the differences in configurations along the boundary of this region and the Arctic Archipelago, relative to what is seen in ArcNet.

The pan-Arctic focus of ArcNet is important because of its holistic attention to the biome scale at a time when the ranges of populations, habitats and ecosystems are affected by a rapidly changing environment. A pan-Arctic focus also addresses representation and connectivity from a global rather than a national perspective. This provides a critical wider perspective than any one nation has, though it cannot be expected to provide the level of detail provided by national and sub-national analyses.

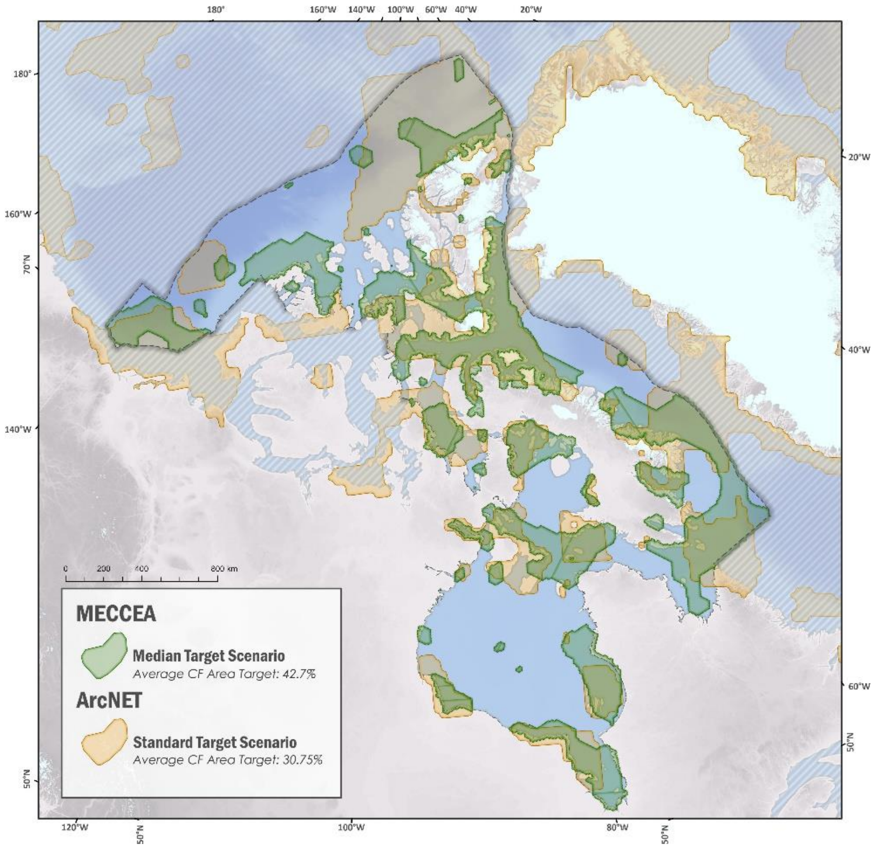

Figure 9.17. Correspondence between the PACs selected by the MECCEA median protection target scenario and areas selected by the ArcNet study. The associated Marxan parameters used by ArcNet are as follows: SPF = 1.2; BLM = 0.3; Protected Areas locked in; Conservation Feature Targets = mid-level. Comparison with this ArcNet scenario was selected as it is conceptually similar and has technical specifications most similar to the MECCEA scenarios. Note that the MECCEA study does not include the Western Arctic.

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CHAPTER 10: COMMERCIAL ACTIVITIES AND INUIT USE AREAS: OVERLAP WITH THE PROPOSED NETWORK OF PRIORITY AREAS FOR CONSERVATION

INTRODUCTION

The MECCEA Marxan analyses (Chapter 8) focused on designing an ecologically connected network (Chapter 9) of PACs; social, economic, and cultural elements in the study area were not incorporated. In order to understand the potential interactions between the ecologically identified PACs and other marine activities (e.g. commercial activities, and local uses), we sourced other spatial data in the study area to overlay with the MECCEA PAC scenarios. The Marxan analyses compared with other marine activities in this chapter are the minimum, median and high target scenarios, with a BLM of 10, selected at the conclusion of Chapter 8.

Three key activities taking place within the MECCEA marine bioregions are: marine shipping, mining, and commercial fisheries. There is currently no oil and gas exploration or extraction within the MECCEA project boundaries or indeed anywhere in the Canadian Arctic. Although there are existing licenses that overlap with the MECCEA's minimum, median and high target scenarios (Figure 10.1, Figure 10.2, and Figure 10.3, respectively), a moratorium on new oil and gas activities in the Arctic is in place until 2021 (United States-Canada Joint Arctic Leaders' Statement, 2016). A report released in August 2019 by the Nunavut Impact Review Board recommends that the 2016 moratorium should remain in place "for at least a decade" (NIRB, 2019).

Inuit culture and livelihoods are also directly linked to the marine environment and the overlaps between areas identified as local use areas in the Nunavut Coastal Resources Inventory and the MECCEA results are also presented in this chapter.

POTENTIAL CONFLICTS BETWEEN COMMERCIAL ACTIVITIES AND THE MECCEA PACS

Marine Shipping - Commercial and Tourism

The remote communities in the Canadian Arctic rely on shipping to provide many of the supplies needed throughout the year. Shipping is also required for the operation of several of the mines in the Canadian Arctic, as well as the growing tourism sector.

Marine shipping in Nunavut almost tripled between 1990–2015. Distance traveled by all vessels grew from around 350,000 km to over 900,000 km, with the majority of the increase occurring over the past decade. Cargo ships as well as government vessels, including icebreakers, account for the largest share of traffic, while pleasure craft (primarily private yachts) represent the fastest growing type of craft, increasing by a factor of 20 over the 25-year period of 1990 to 2015 (Dawson et al., 2018).

The Government of Canada (2016, unpublished), in an unclassified *Marine Security Operations Centre East* report, noted the following—within the MECCEA marine bioregions in 2016:

- 157 different vessels made 329 voyages, a 26% increase from 2015;
- Merchant vessels (bulkers, tankers, general cargo, and tugs) made up 41% of total voyages;
- The Mary River mine accounted for 11%, fishing vessels accounted for 36%, and cruise ships accounted for 8% of total voyages; and
- The Northwest West Passage saw 26 transits (mainly pleasure craft), a 30% increase from 20 transits in 2015.

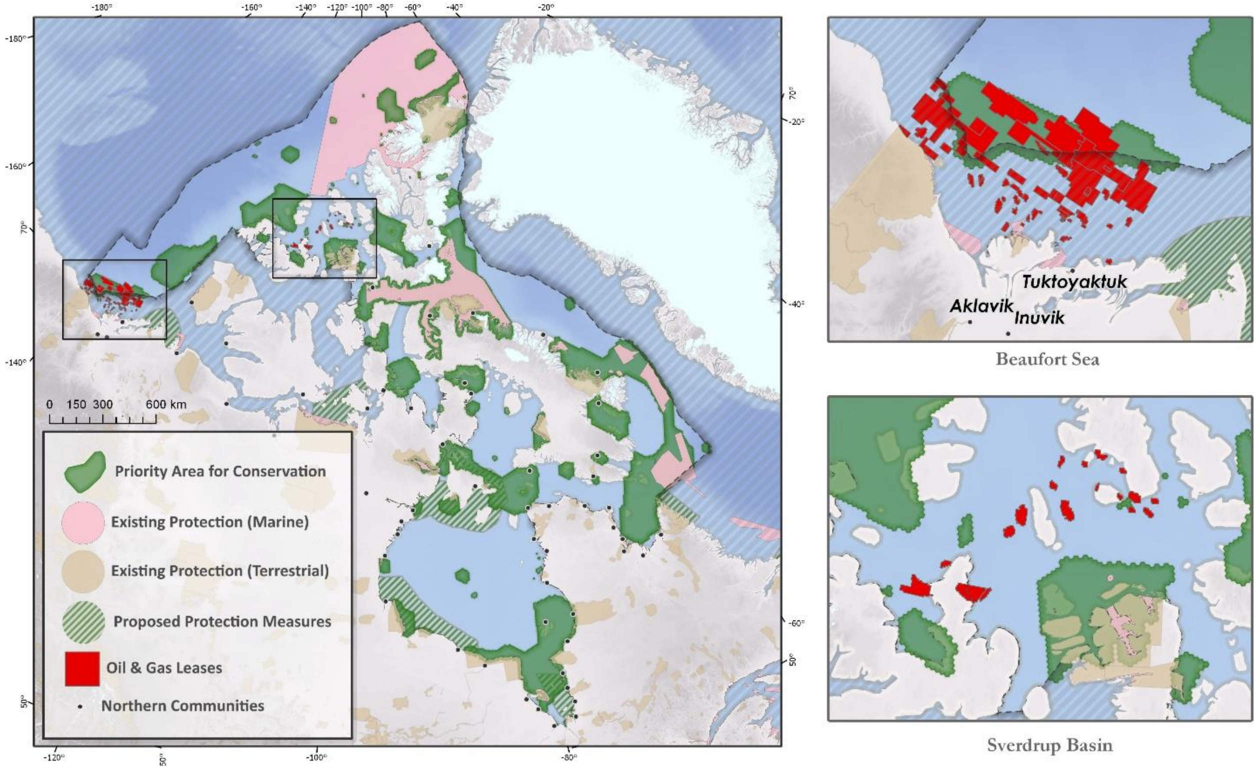

Figure 10.1. Overlap between oil and gas leases and PACs in minimum target scenario.

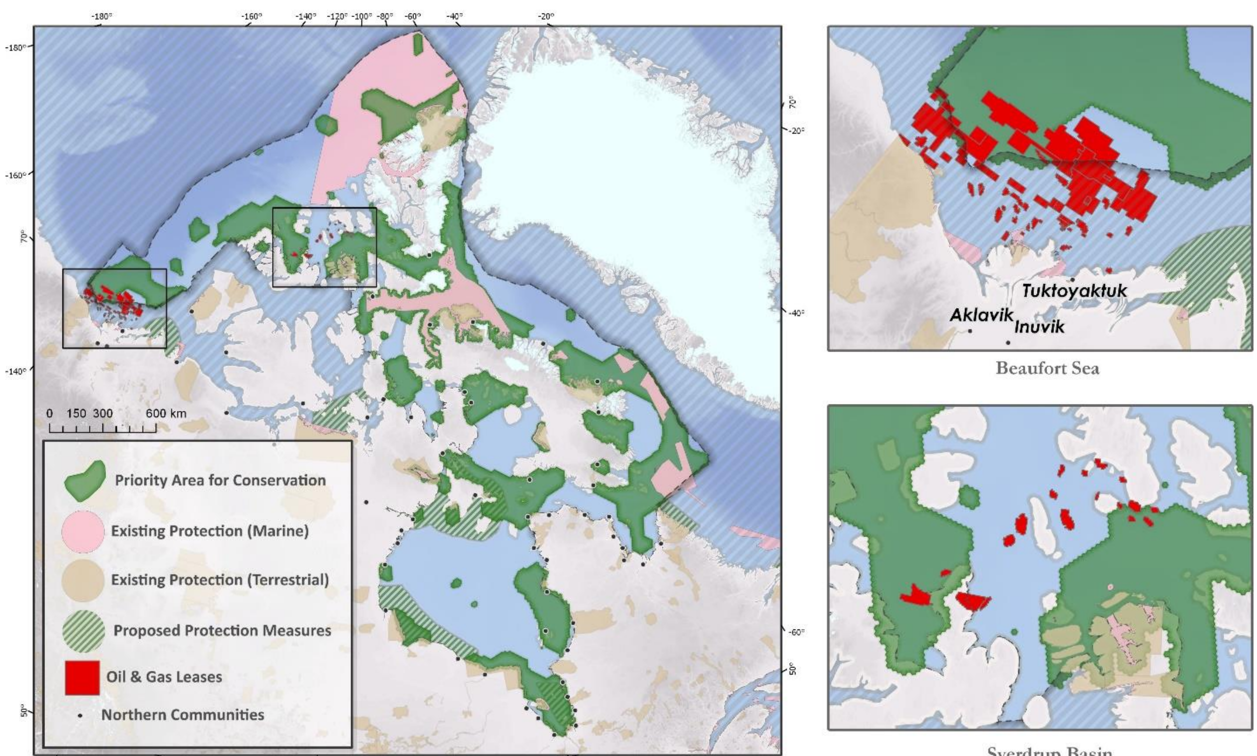

Figure 10.2. Overlap between oil and gas leases and PACs in median target scenario.

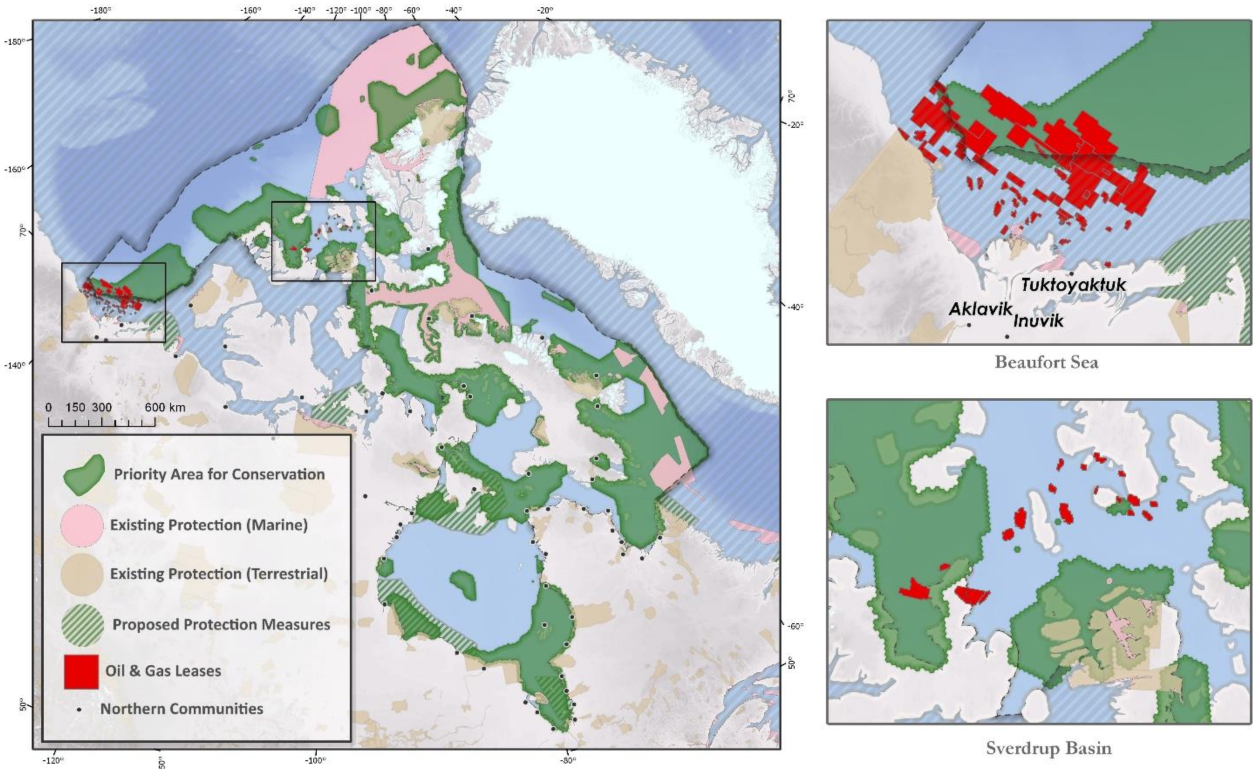

Figure 10.3 Overlap between oil and gas leases and PACs in high target scenario.

As summer sea ice retreats in the Arctic, new shipping routes are becoming possible. As the demand for resources continues to grow, new development opportunities arise in the Arctic, with new stresses that, if not properly managed, could put ecosystems and cultures at risk. Increased shipping brings a variety of benefits and impacts. Therefore, understanding and mitigating the risks while ensuring benefits to people in the north is critical. The challenge is to establish appropriate shipping regulations, so as to minimize the impacts but provide opportunity for people in the Arctic.

Overlap between Shipping and the PACs

The overlaps between ship tracks and the PACs (minimum, median and high scenarios) are shown in Figure 10.4, Figure 10.5, and Figure 10.6, respectively. The spatial data used to create these maps came from onboard Automated Identification System (AIS) point data obtained from Exact Earth for the year 2017 (www.exactearth.com).

The highest density of shipping activities occurs within the Tallurutiup Imanga National Marine Conservation Area and the Hudson Strait area due to mining operations (i.e. Mary River mine in Nunavut and Raglan Mine in Nunavik). Fishing vessel activity in Baffin Bay and Davis Strait is also considerable.

In 2017, marine vessels transited approximately 725,000 km within the MECCEA study region. The portion of this travel that took place within areas identified as PACs ranged between 56 to 71% for the minimum and high protection scenarios, respectively. Unsurprisingly, a similar trend and related trends can be observed when looking at the overlap between PACs and areas identified as shipping corridors, which range from 45 to 62%.

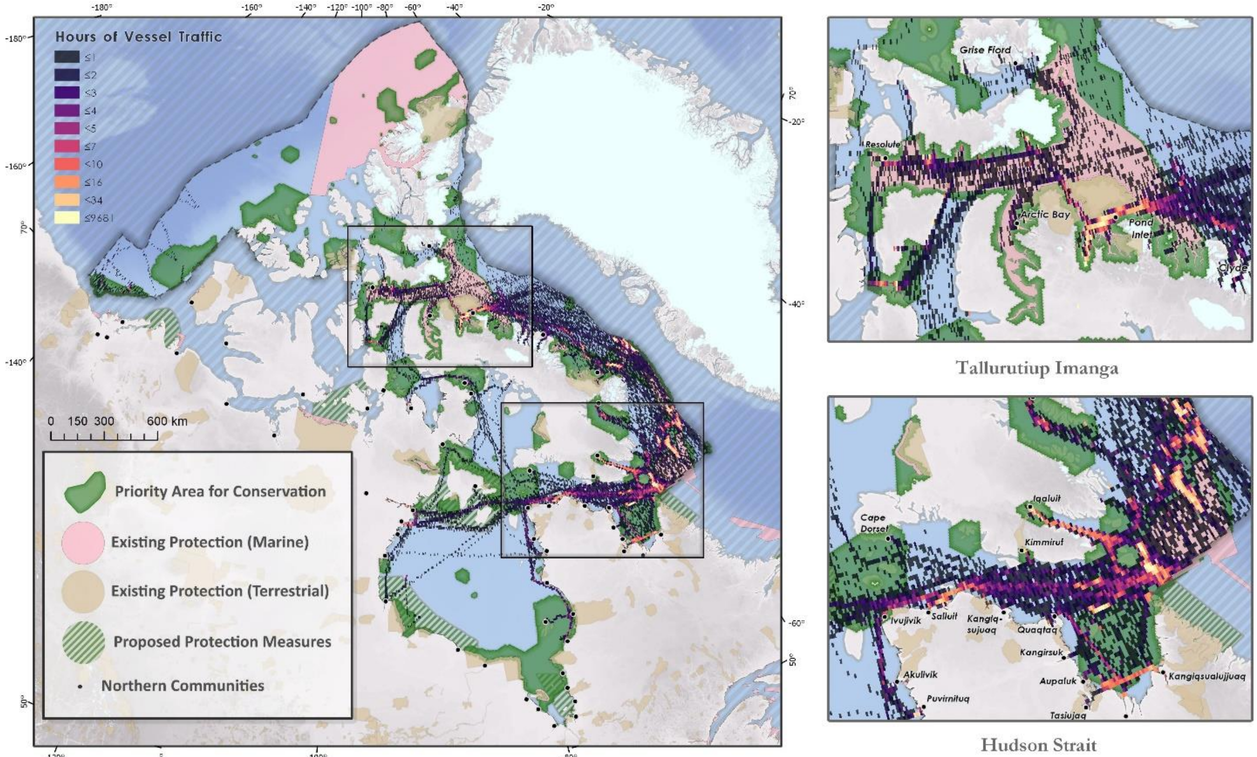

Figure 10.4. Overlap between ship tracks (2017) and PACs in minimum target scenario.

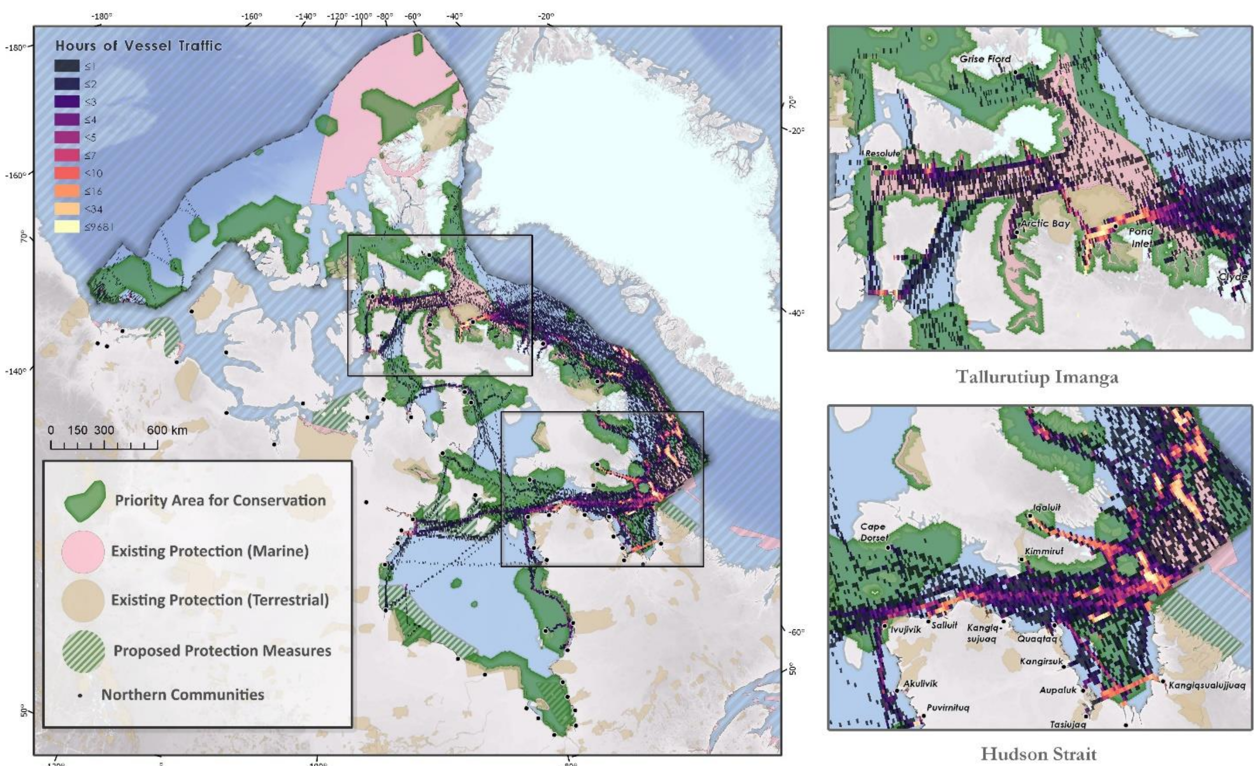

Figure 10.5. Overlap between ship tracks (2017) and PACs in median target scenario.

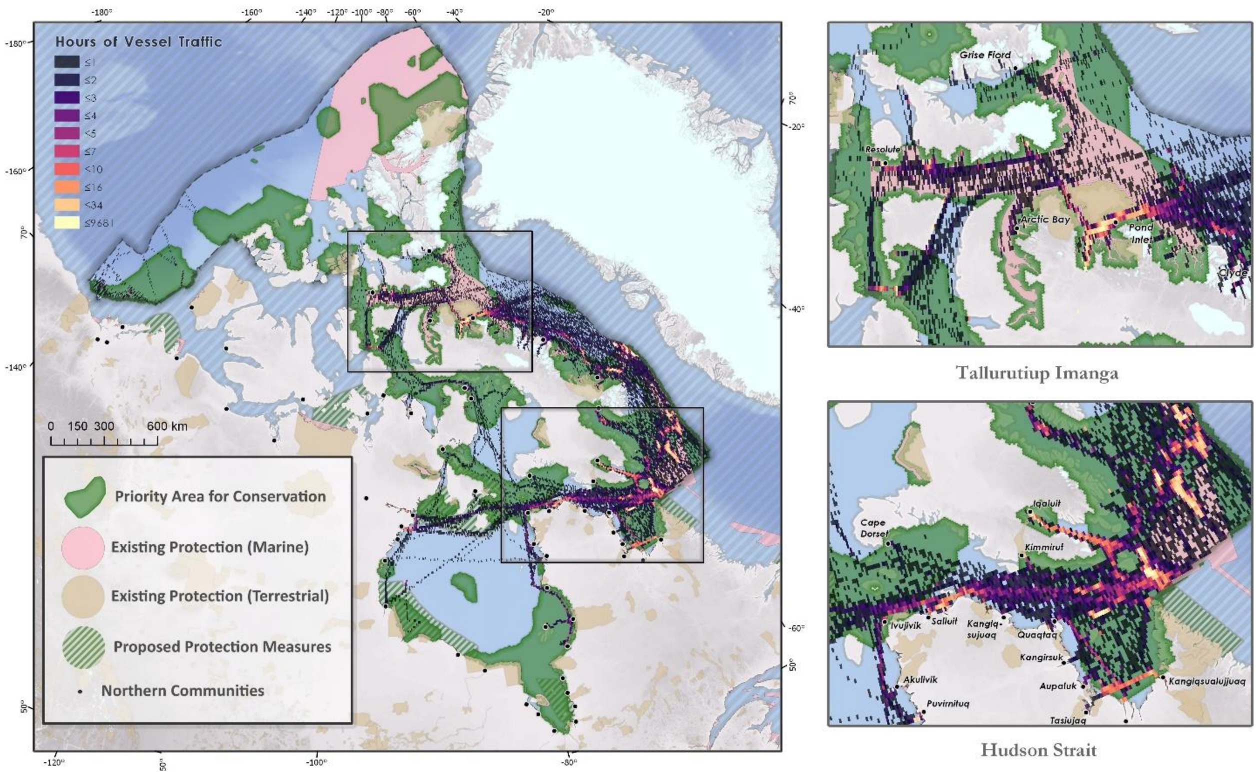

Figure 10.6. Overlap between ship tracks (2017) and PACs in high target scenario.

Impacts from Shipping

The impacts to marine ecosystems from shipping can be severe, and the risks are real to both marine habitats, and Indigenous and community food security in the Arctic. Risks are equally high if essential goods and development cannot reach people in the north.

Some of the biggest risks and impacts from marine shipping include:

Oil spills: Groundings, shipwrecks, accidents or fires can release oil into sensitive habitats where the nearest clean-up equipment and crews may be hundreds of kilometres away. In 1989, for example, the Exxon Valdez tanker struck a reef off the coast of Alaska, spilling more than 40 million litres of oil that contaminated over 1,500 kilometres of coastline and killed hundreds of thousands of animals (Piper, 1993). Spills are a particular concern in the Arctic, where crews have only a narrow window of time to contain spills and salvage the ship before winter darkness and freeze-up set in.

Pollutants: Ships generate a wide range of pollutants that can create both immediate and long-term environmental damage, including garbage, sewage, grey water, and oily waste (e.g. Walker et al., 2019). For marine birds, oily waste inhibits their natural ability to thermoregulate, leading to energy loss, hypothermia, and even death. Potential environmental impacts of grey water and sewage include shellfish contamination, algal blooms, lowered oxygen levels in the ocean and introduction of microplastics.

Airborne emissions: Airborne emissions from marine vessels include greenhouse gases and other pollutants such as nitrogen oxide and sulphur dioxide, impacting local air quality, human health, and the global climate (e.g. Hongisto, 2014). Heavy Fuel Oil (HFO) and diesel-burning ships also produce black carbon. In the Arctic, this particulate matter settles on snow and ice, where it absorbs sunlight and accelerates melting.

Ship strikes: Many shipping routes in the Arctic directly overlap with whale migration routes or areas where these mammals congregate to feed, mate, give birth, and nurse their young—as indicated by the locations of the MECCEA PACs. Ship strikes of marine mammals are a serious conservation problem worldwide (e.g. Redfren et al., 2013).

Underwater noise: Shipping noise drowns out the whistles, clicks, and moans that some whales use to communicate, navigate, find food, and avoid predators. Higher noise levels also increase their stress levels (PAME, 2019).

Invasive species: The ballast water that ships load and unload when they take on new cargo, as well as organisms attaching to the hulls of ships, known as hull fouling, can contain invasive species. While new international rules require ballast water to be treated, there are still concerns about the effectiveness and enforcement of that new regime (see e.g. Transport Canada, 2019).

Habitat destruction: Among other potential effects, icebreakers break up the habitat that seals and walruses need for pupping, foraging, moulting and nesting and that polar bears need to hunt and travel. However, the impacts of icebreaker effects have been reported as not significant.[1] Meanwhile, the construction of new port infrastructure can have serious impacts on marine life, and even the simple act of anchoring can destroy sensitive seafloor habitats.

Disruption of food security for local livelihoods is a major concern. Oil spills, disturbance from underwater noise, the introduction of invasive species, discharges like grey water and sewage can all have severe impacts on species and habitats that local communities depend upon for food and culture.

Mining

The Canadian Arctic has not experienced any offshore mining to date. However, the region is home to several major mines and mineral prospects. Three mines currently in operation are Agnico-Eagle Mines Limited's Meadowbank gold mine near Baker Lake, Baffinland's Mary River project (iron) on north Baffin Island, and the Raglan Mine in the Nunavik (nickel and copper). These Arctic mines require extensive sealift support to bring in supplies/equipment and to transport ore and other products to market.

The impacts of Arctic mining on marine and coastal ecosystems include deposition of submarine tailings, which has been observed to cause long-term accumulation of metals in sediments and biota (Tolvanen et al., 2018). Other more severe impacts have also been observed, such as changes in the distribution and colonization patterns of the biota (Tolvanen et al., 2018).

Commercial Fishing

Within the MECCEA marine bioregions, commercial fishing occurs both offshore and inshore.

Offshore Fishery

The offshore commercial fishery occurs only in the waters of Baffin Bay and Davis Strait and is a major contributor to the economy of Nunavut. The offshore fishery in these waters mainly targets two species: the flatfish Greenland halibut (*Reinhardtius hippoglossoides*, also known as turbot) and Northern shrimp (*Pandalus borealis*). Together, these species represent over $100 million in landed value each year. The fishery in these waters is divided into Northwest Atlantic Fisheries Organization (NAFO) zones 0A and 0B. Nunavut interests control all the Greenland halibut quota in NAFO 0A, while Greenland halibut in NAFO 0B and Northern shrimp quota in both zones are split between Nunavut and fisheries operations from other parts of Eastern Canada.

[1]See https://www.arctictoday.com/coast-guard-evaluates-environmental-effects-new-icebreakers/

Overlap between Offshore Fishery and PACs

As shown in Figure 10.7, Figure 10.8, and Figure 10.9, all scenarios of PACs overlap significantly with combined fishing intensity data for halibut and shrimp fisheries. Between 49 and 69% of the portions of NAFO areas OA and OB that lie within the MECCEA study area coincide with our PACs. Furthermore, if one looks at the footprint of fishing activity within these areas, 63–79% of the actively fished region overlaps with PACs (DFO, 2017). This significant overlap is not surprising given the rich waters of Baffin Bay and Davis Strait. The same environmental and oceanographic factors that drive fisheries productivity in these areas also drive the important concentrations of marine mammals and overall biodiversity found here. The target species of the commercial fishery have also been the focus of much of the research on marine species in this region (e.g. Fisheries and Oceans Canada, 2009; 2018).

Impacts from Offshore Fishery

Potential impacts of the halibut and shrimp fisheries are in some ways similar to those risks posed by marine shipping, as both industries involve the use of large ocean-going vessels. That said, there are particular risks associated with the offshore commercial fishery.

Habitat damage: mobile (e.g. bottom trawl) and fixed gear types (e.g. longline and gillnet)—are used for offshore fishing in the MECCEA region. Bottom trawling involves hauling a heavy net across the bottom of the ocean and stirring up flatfish that live on the bottom and shrimp that live near the bottom before capturing them in a net. This fishing activity can be harmful to sensitive bottom habitats, particularly corals, sponges, and sea pens. This harm can be effected through direct interaction with fishing gear but also through the increased turbidity and sedimentation caused by fishing gear contacting muddy or silty bottoms near corals sponges and sea pens (e.g. Grant et al., 2019).

By-catch: There is potential for the capture of non-target species, or by-catch, in both the trawl fishery and the bottom-set gillnet fishery for Greenland halibut. The trawl fishery has taken steps, including the installation of the Nordmore grate on the cod-end of trawls used in the shrimp fishery to exclude large non-target catch such as marine mammals (Fisheries and Oceans Canada, 2018). The fishery can, however, impact sensitive species like wolffish and Greenland shark through by-catch (Fisheries and Oceans Canada, 2018, 2019). The bottom-set gillnet fishery for Greenland halibut also can cause by-catch of marine mammals and sensitive species.

Inshore Fishery

Inshore commercial fishing is a growing sector in Nunavut and is essentially non-existent in the other jurisdictions within the MECCEA marine bioregions (i.e. Nunavik, Eeyou Istchee, and along the Ontario and Manitoba coast of Hudson Bay and James Bay).

An example of inshore fisheries is the community of Pangnirtung on Baffin Island. Local harvesters in Pangnirtung have worked towards the development of an inshore and near-shore Greenland halibut fishery for over 30 years. Their efforts led to the designation of a Total Allowable Harvest (TAH) of 500 tonnes to be harvested in Cumberland Sound. The fishery is primarily in winter, using longlines set through the ice. Since 2014, the fishery has consistently brought in over 300 tonnes each year, with a value of over $2.4 million to the community (Nunavut Fisheries Strategy, 2016).

There is great potential for further growth of local commercial fisheries in the rest of Nunavut. The Nunavut Fisheries Strategy (2016) identifies a number of these opportunities, including inshore Greenland halibut fisheries in Pond Inlet, Qikiqtarjuaq and Clyde River, clams in Qikiqtarjuaq, and three species of shrimp and whelks near Iqaluit, Grise Fiord, Arctic Bay, Resolute, and Qikiqtarjuaq. There have also been attempts at developing a crab fishery in Cape Dorset and experimental fisheries surveys carried out in Kimmirut and Sanikiluaq.

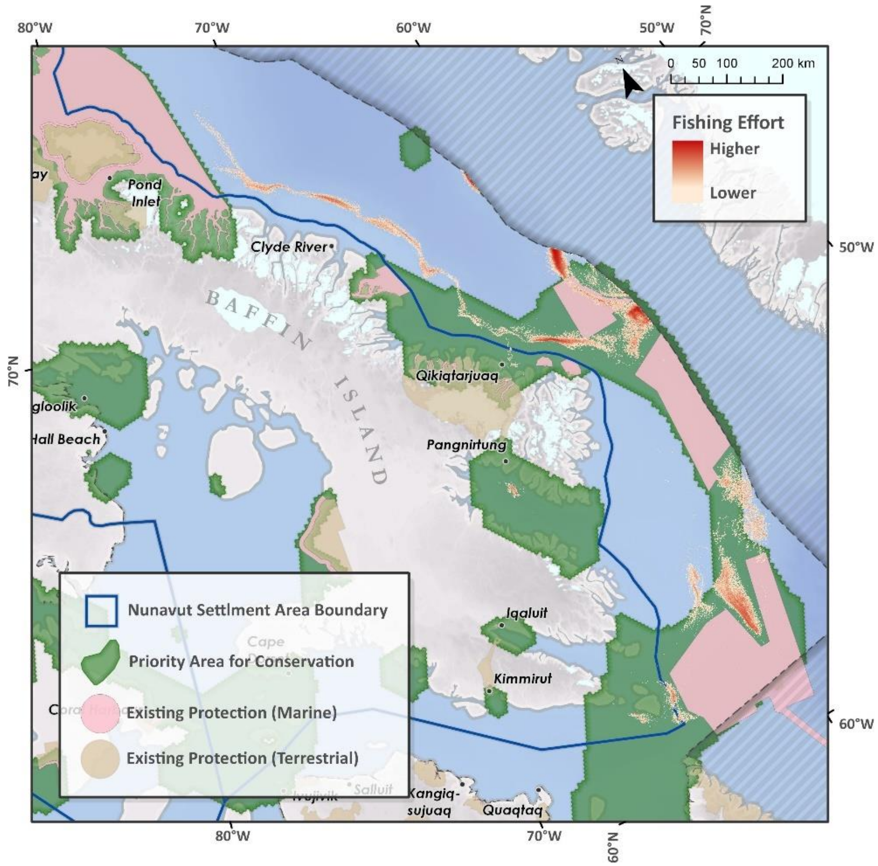

Figure 10.7. Overlap between fishing intensity for halibut and shrimp fisheries and PACs in minimum target scenario.

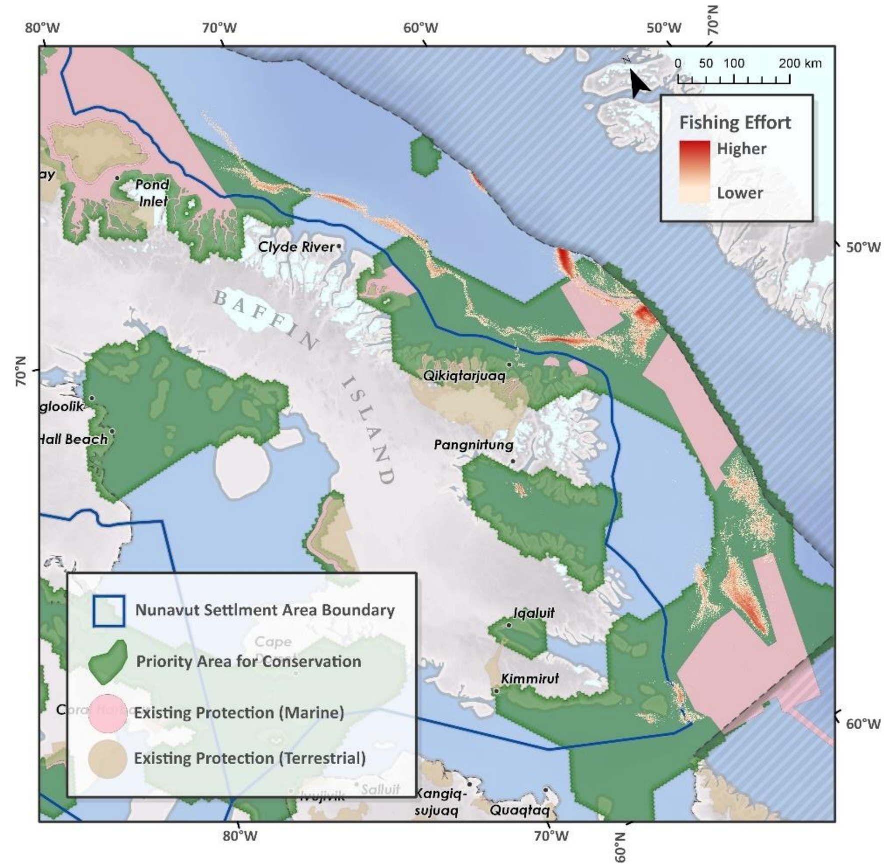

Figure 10.8. Overlap between fishing intensity for halibut and shrimp fisheries and PACs in median target scenario.

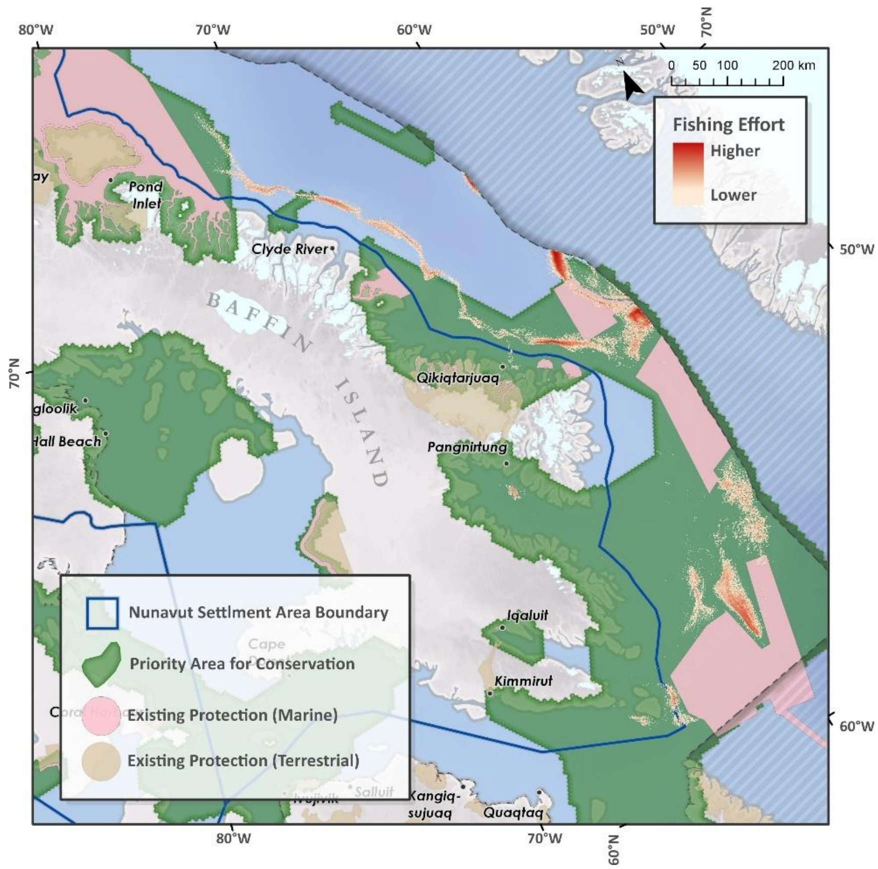

Figure 10.9. Overlap between fishing intensity for halibut and shrimp fisheries and PACs in high target scenario.

Arctic charr commercial fisheries are also taking place in Nunavut. The fisheries are co-managed by DFO, the local Hunters and Trappers Organizations (HTOs), and the Nunavut Wildlife Management Board. However, half of the commercial harvest occurs outside the MECCEA planning region, in the area of Cambridge Bay (Wheeland et al., 2018). The rest occurs in the vicinity of Pangnirtung and the Kivalliq region communities of Rankin Inlet, Chesterfield Inlet, and Whale Cove. Charr are captured primarily with gill nets as the fish move upstream (autumn migration into freshwater for over-wintering) and downstream (spring out-migration to marine waters for summer feeding) (Wheeland et al., 2018).

Impacts from Inshore Fishery

As inshore fisheries are still developing and could include a multitude of species and gear types, it is difficult at this time define the potential impacts. However, we can look at the current impacts of the through-ice longline fishery in Pangnirtung for Greenland halibut, as similar impacts would be found in other potential Greenland halibut fisheries in communities like Qikiqtarjuaq and Pond Inlet.

The longline fishery in Pangnirtung has faced issues with incidental capture of sensitive species, particularly Greenland shark and Arctic skate (Wheeland and Devine, 2018). Associated mortality can be lowered significantly through training of harvesters on proper handling techniques for by-catch species, which has been the case for Greenland shark in Pangnirtung in recent years.

Small-scale commercial Arctic charr fisheries have operated in different areas of Nunavut with differing impacts, for decades. A commercial fishery operated on the Sylvia Grinnell River from 1947 to 1951 and 1959 to 1966, prior to the presence of any regulations for such fisheries. Those harvests had significant negative impacts on the river's charr stocks, leading to the abandonment of the fishery due to decreasing catch per unit of effort. As of 2010, biological parameters on the river had not recovered to pre-exploitation levels (DFO, 2013).

OVERLAP AND POTENTIAL SYNERGIES BETWEEN THE PACS AND NUNAVUT INUIT USE AREAS

For thousands of years Inuit and coastal First Nations have depended heavily upon the productivity of the marine environment for subsistence. Most Arctic communities are located along the coastlines and are reliant upon the marine ecosystems. In Nunavut and Nunavik, virtually all the inshore and offshore areas within their respective Land Claim Settlement Areas are used as hunting and fishing areas. Cree First Nations in Southern Hudson Bay and James Bay also use coastal areas for various activities.

Nunavut Inuit use areas are based on areas identified by Nunavut community members in the Nunavut Coastal Resource Inventory as areas used by local people for hunting or camping, or as having cultural significance, such as burial sites, archaeological sites, or historical gathering areas. Unfortunately, no spatial data for locally used areas were publicly available for regions outside of Nunavut.

Overlap between Nunavut Inuit Use Areas and PACs

Figure 10.10, Figure 10.11, and Figure 10.12, illustrate the overlap between the PACs and Nunavut Inuit use areas. Between 49 and 70 % of Nunavut Inuit use areas coincide with the PACs. Given that Inuit use encompasses many activities, some which are not related to conservation, this degree of overlap can be expected. The reason why there are no overlaps within the offshore part of the PACs (beyond 12 nautical miles) is linked to the fact that Inuit live in coastal areas.

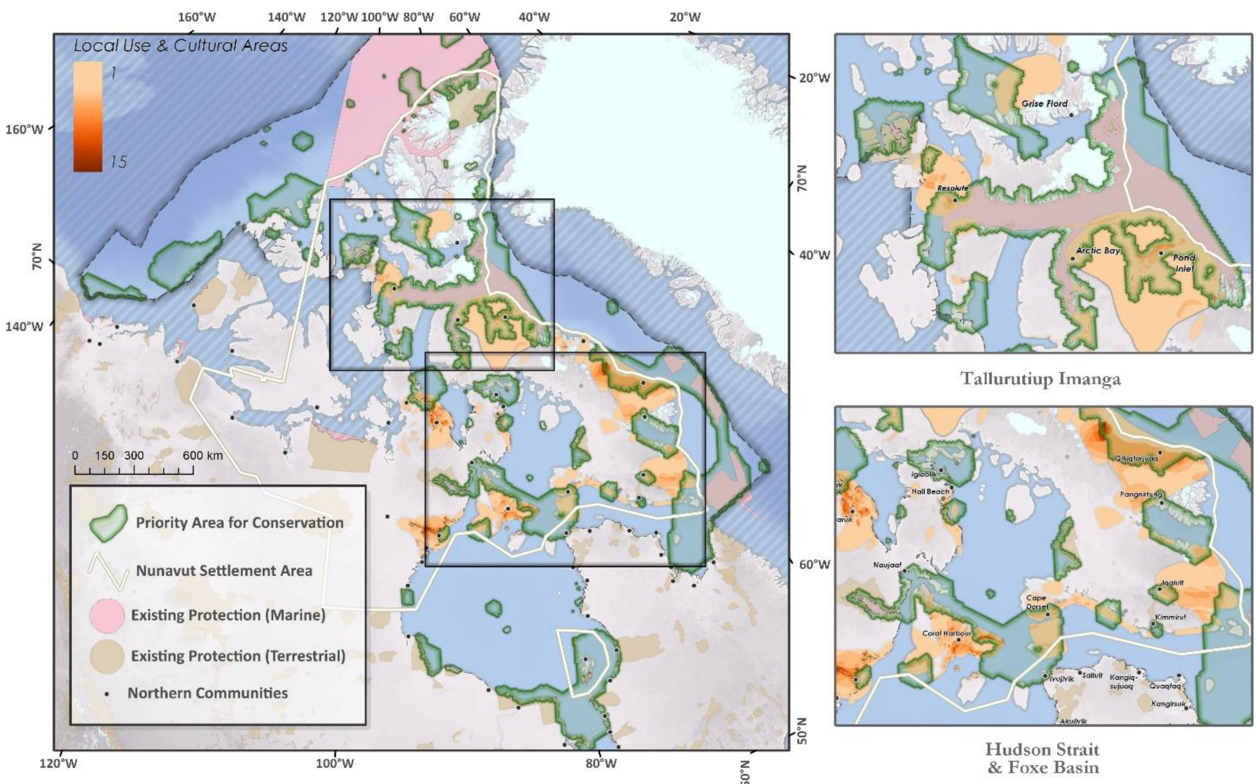

Figure 10.10. Overlap between Nunavut Inuit use areas and PACs in minimum target scenario.

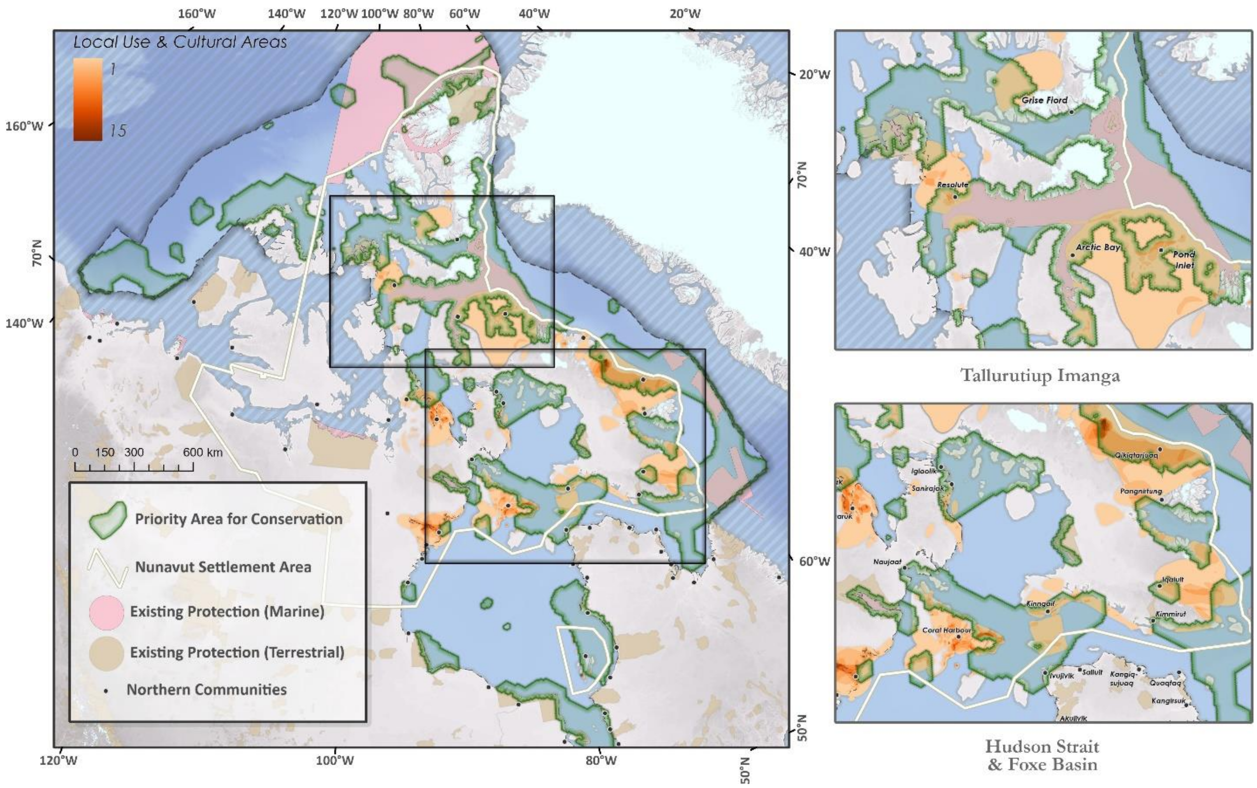

Figure 10.11. Overlap between Nunavut Inuit use areas and PACs in median target scenario.

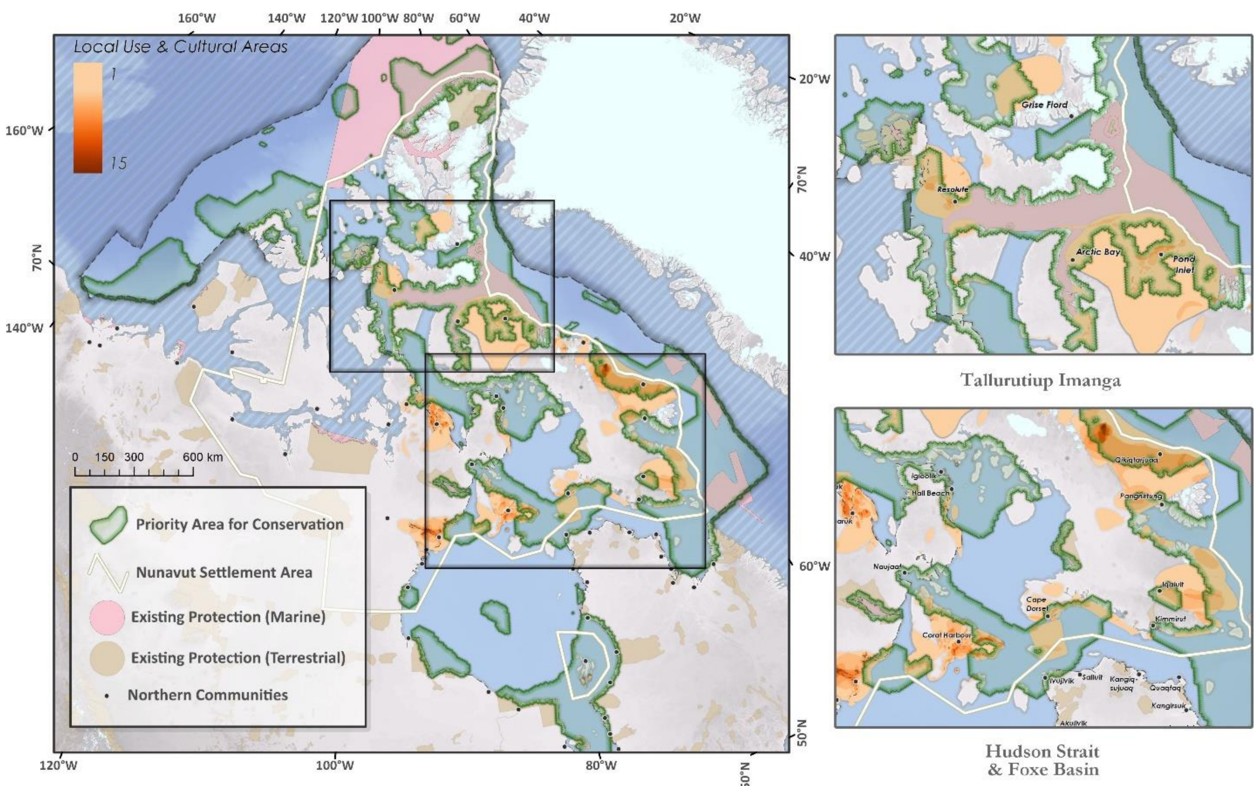

Figure 10.12. Overlap between Nunavut Inuit use areas and PACs in high target scenario.

Overlap and Potential Synergies between the PACs and the Draft Nunavut Land Use Plan (DNLUP)

Nunavut is currently working towards implementing a territory-wide land use plan, which will cover both the land and waters of the Nunavut Settlement Area. The Nunavut Planning Commission's 2016 draft iteration of this plan was used for the overlays with the MECCEA analysis. While the features designated within the 2016 DNLUP (DNLUP, 2016) are varied in terms of their intended objectives, a large portion is included to meet objectives oriented towards stewardship and conservation.

At the highest level, areas identified within DNLUP fall into 2 major categories: areas identified for protection, and areas identified for special management considerations. While the former category recognizes areas expressly for conservation purposes, it is important to note that in many instances, special management areas still have proposed regulations that are designed for protection of species or habitats (e.g. marine migratory bird habitat).

As illustrated in Figure 10.13, Figure 10.14, and Figure 10.15, the overlaps between the DNLUP Special Management Areas and the MECCEA PACs range between 80 and 94%, while the overlaps with the DNLUP Protected Areas range from 70 to 77% of the MECCEA study region, for minimum to high target scenarios, respectively. This high proportion of overlap is unsurprising given that DNLUP seeks to steward many of the same biological resources considered within the MECCEA process. Most areas identified by the DNLUP have an objective relating to a specific purpose. This is highlighted in Figure 10.16, Figure 10.17, and Figure 10.18, which illustrate the variety of areas identified by the land use plan categorized by the type of conservation-oriented feature (e.g. species, polynya).

In comparison to this, the MECCEA PACs highlight areas that contribute to conservation objectives related to a multitude of species, as well as other aspects of biodiversity such as ecosystem processes. Thus, areas where PACs overlay conservation-oriented measures within the DNLUP can highlight how these areas can contribute to the protection of values that the land use plan may not have originally considered. For instance, an area identified for protection of beluga habitat in DNLUP may be identified by MECCEA for beluga, walrus, and Arctic char.

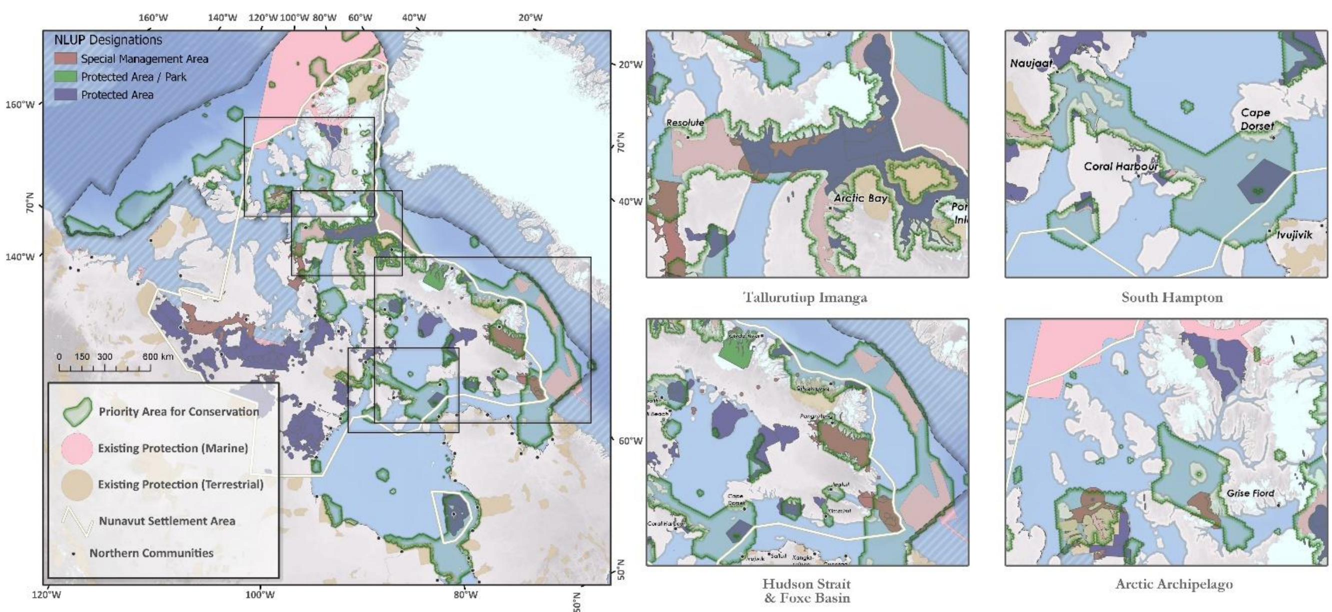

Figure 10.13. Overlap between DNLUP Special Management Areas and PACs in minimum target scenario.

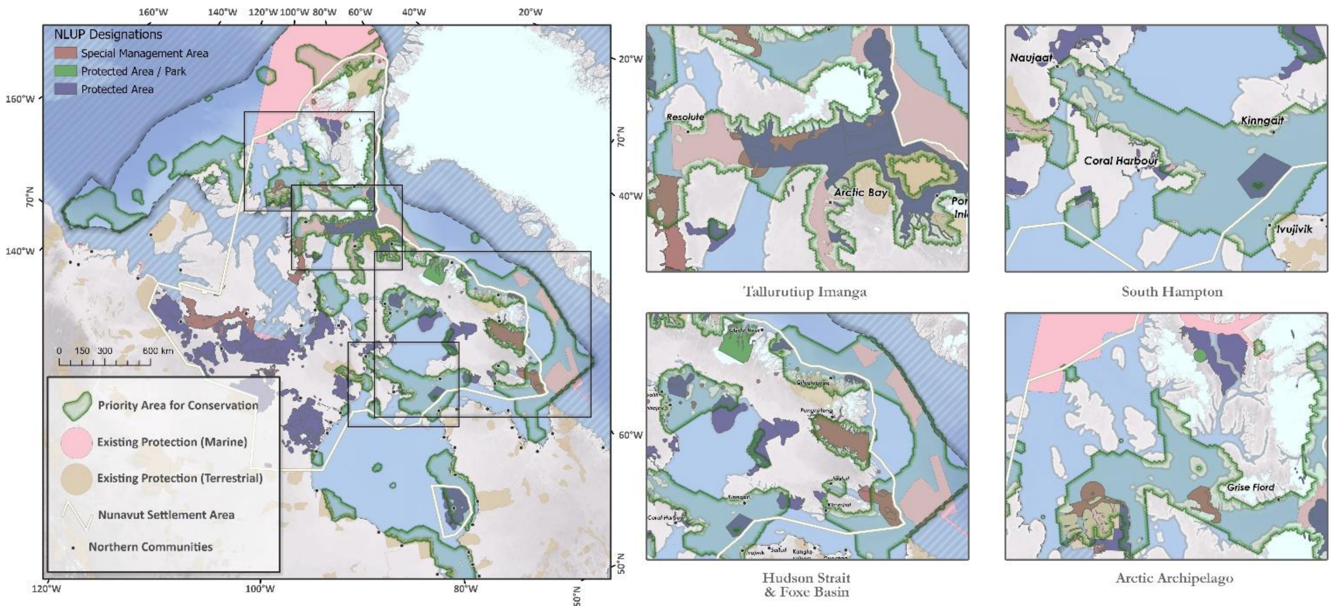

Figure 10.14. Overlap between DNLUP Special Management Areas and PACs in median target scenario.

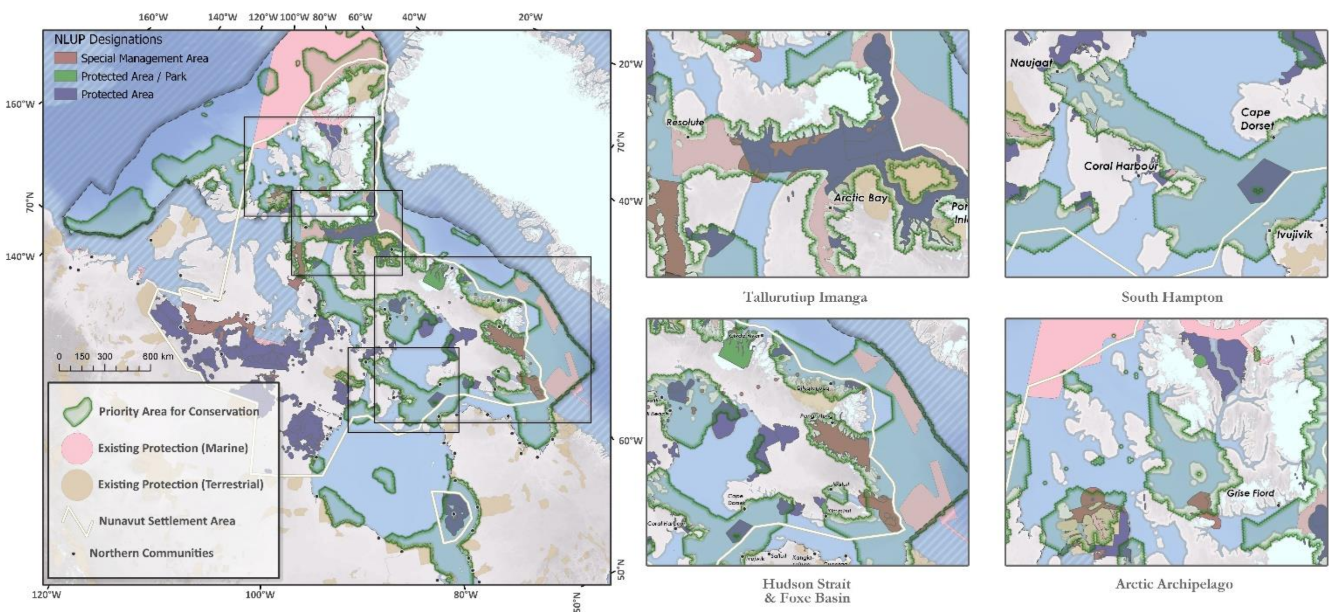

Figure 10.15. Overlap between DNLUP Special Management Areas and PACs in high target scenario.

Table 10.1 indicates how the different types of marine conservation-oriented features within the DNLUP area are captured by the MECCEA PACs. The large degree of overlap seen in this table indicates good coincidence between the regional priorities of the land use plan and the conservation priorities of MECCEA. Although the methodology and expressed purposes of the MECCEA and the DNLUP plans are each unique, a clear synergy exists in areas identified for conservation within the land use plan and within the MECCEA PACs. Information generated through the MECCEA study may, therefore, help to support and reinforce the need for protecting these areas by providing a comprehensive representation of various conservation and land use priorities. The MECCEA study also supports the need for further detailed local study, decision-making and management. Consideration of management forms the subject of the next chapter.

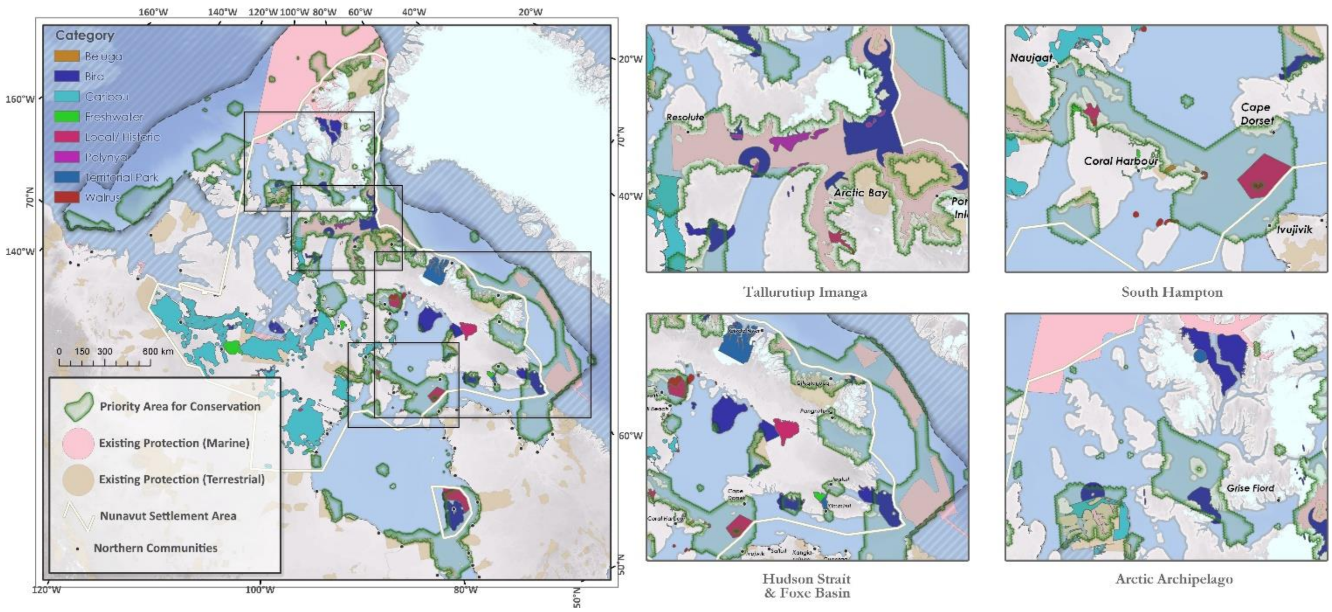

Figure 10.16. Overlap between conservation-oriented features within DNLUP and PACs in minimum target scenario.

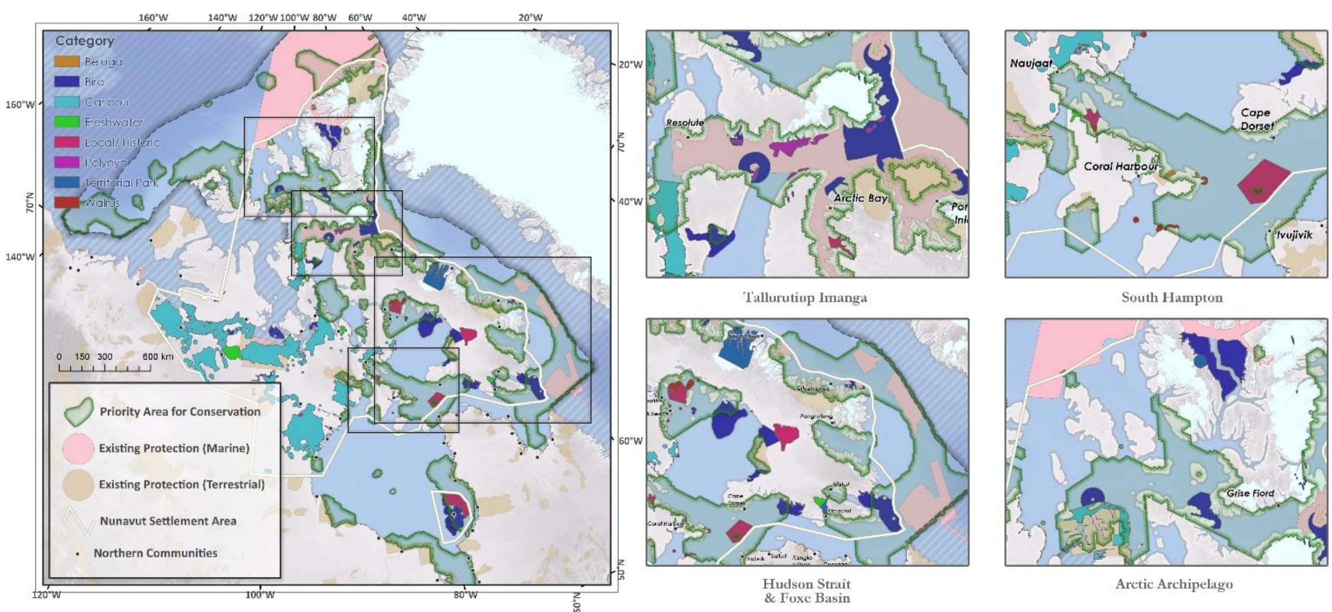

Figure 10.17. Overlap between conservation-oriented features within DNLUP and PACs in median target scenario.

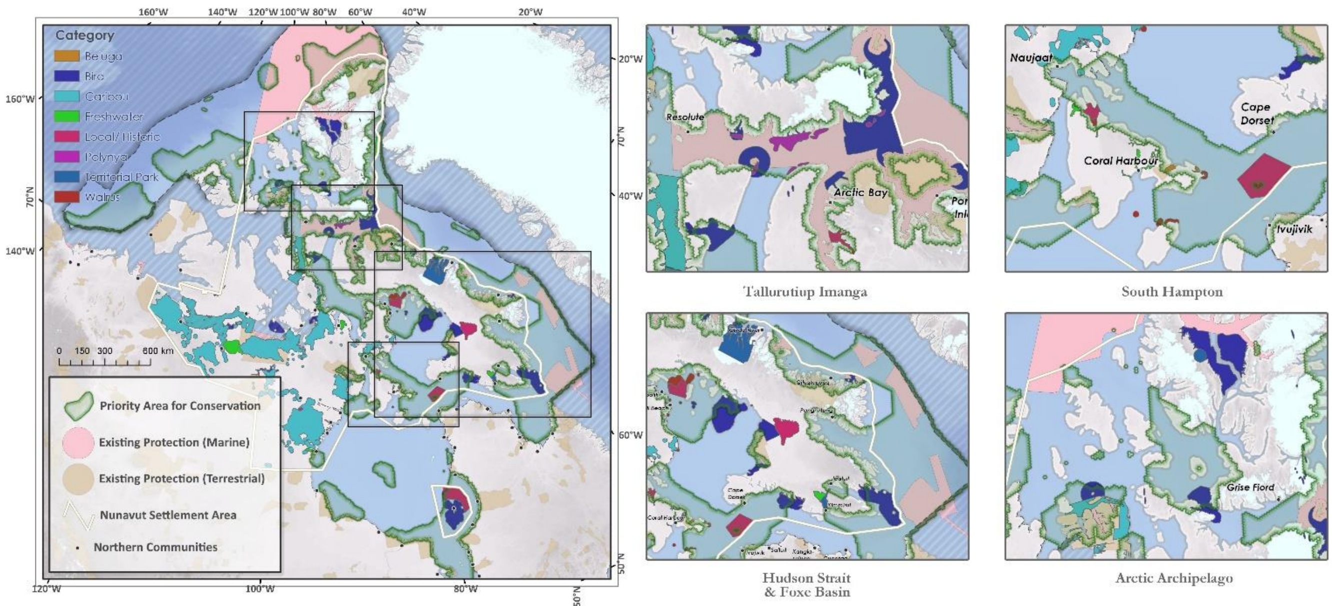

Figure 10.18. Overlap between conservation-oriented features within DNLUP and PACs in high target scenario.

Table 10.1. Showing how the different types of marine conservation-oriented features within the DNLUP area are captured by the MECCEA PACs. The high coincidence indicates good alignment between the regional priorities of the land use plan and the MECCEA PACs.

DNLUP Feature Category*	% of Features in Marxan Scenario PACs			Area of Features in Marxan Scenario PACS (km^2)		
	Minimum	Median	High	Minimum	Median	High
Beluga	99.0	99.0	99.0	346	346	346
Bird	70.8	67.8	78.9	68,553	65,672	76,387
Caribou	42.3	46.1	60.5	11,131	12,128	15,912
Freshwater	56.3	80.8	83.8	2,461	3,532	3,666
Local/ Historic	93.0	98.6	96.5	27,704	29,389	28,764
Polynya	98.8	100.0	97.6	3,153	3,191	3,113
Walrus	56.8	88.7	91.8	2,809	4,384	4,540

*Areas used for the overlap proportion are based on polygons in the DNLUP which have been clipped to the extent of the MECCEA study area for more accurate comparison.

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CHAPTER 11: RECOMMENDATIONS AND MANAGEMENT CONSIDERATIONS

INTRODUCTION

Our purpose here is to present WWF-Canada's key recommendations and briefly review what constitutes WWF-Canada's views of best management practices for the recommended MECCEA PACs and network, so as to ensure persistence of conservation features as a whole. This is a subject of considerable current interest, covered in several publications, e.g. Worboys et al. (2015). The PACs considered in this chapter are the minimum, median and high target scenarios with BLM of 10, selected at the conclusion of Chapter 8.

KEY RECOMMENDATIONS

WWF-Canada recommends that:

- the Government of Canada work with Indigenous communities and other key stakeholders to develop a Marine Protected Area Network in the Canadian Arctic as a major component of Marine Spatial Planning, to enable Integrated Oceans Management and Ecosystem Based Management.
- a "toolbox" of marine conservation and management measures be used for Marine Protected Area Network implementation, including:
    - Federal, provincial and territorial legislation;
    - Indigenous Protected and Conserved Areas (IPCAs); and
    - Other Effective Area-Based Conservation Measures (OEABCMs).
- a stepwise approach to marine conservation be adopted, beginning with a 30% minimum target by 2030, and increasing to 50% by 2050.
- the Ecologically and Biologically Significant Areas (EBSAs) outside of PACs should be managed with a high degree of risk aversion to prevent harm to biodiversity.

MANAGEMENT OF INDIVIDUAL PRIORITY AREAS FOR CONSERVATION

Each of the PACs identified by Marxan in the four bioregions is very different in its combination of features. For example, in the Eastern Arctic, Lancaster Sound is an important feeding area for several Arctic priority species. In the Arctic Basin, where we have few data and little information, the series of canyons (gullies) will likely become ecologically important features and change dramatically as seasonal ice cover recedes. In Hudson Bay, the significance of wetlands for bird migration and eelgrass beds in James Bay are important features. In the Arctic Archipelago ice-dependant species and polynyas are key features.

These differences among PACs reflect the heterogeneity of the marine environmental, and the strength of Marxan lies in its ability to spatially quantify it. However, this also means that each PAC—whether it becomes an MPA, NMCA, IPCA, other type of protected area (see Text Box 11.1), or is managed by OEABCM—requires an individually designed management plan. This management plan should consider environmental features, ecological processes, and seasonal biological use, as well as regulating authority, rightsholders, and stakeholder engagement. There is growing experience both worldwide (e.g. Kelleher, 1999; Day et al., 2015) and in Canada in developing management plans for individual marine protected areas (e.g. DFO, 1999).

Regulating Authority and Indigenous Peoples

Marine protected areas in Canada can be established through several different pieces of legislation (see Chapter 1) including: *Oceans Act* (1996), *Fisheries Act* (1985), *Canada National Marine Conservation Areas Act* (2002), *Canada Wildlife Act* (1985), *Migratory Birds*

Convention Act (1994), and a series of other provincial and territorial departments and agencies, as well as Indigenous organizations.

Descriptions of some legislation and responsibilities, including Indigenous peoples and international obligations, are given in Text Boxes 11.1. and 11.2. Currently, this legislation addresses a range of Indigenous involvement in federal marine protected areas, from participation in advisory boards to co-management arrangements.

Text Box 11.1. Federal marine conservation jurisdictions and Indigenous peoples.

Fisheries and Oceans Canada: *Oceans Act* Marine Protected Areas (MPAs)

The Oceans Act (OA) provides an enabling environment:

- Section 32(c) allows for establishment or recognition of advisory or management bodies jointly with "affected Aboriginal organizations".
- Section 2.1 specifies that nothing in the Act shall be construed as to abrogate or derogate from any existing aboriginal or treaty rights.

- Some OA MPA co-management bodies have been established under modern land claim agreements to provide advice and recommendations to the Minister, with ultimate decision-making authority resting with the Minister.
- For OA MPAs outside of modern land-claims areas, engagement of Indigenous stakeholders is typically through multi-stakeholder advisory committees and/or bilateral engagement efforts.
- OA MPAs respect Indigenous rights to fish for food or engage in social and ceremonial purposes where conservation is not a concern.

Parks Canada Agency (PCA): National Marine Conservation Areas (NMCAs) and Marine Portions of National Parks

- Cooperative management is a common feature in national parks, national marine conservation areas, and other marine areas administered by PCA.
- Both the *Canada National Marine Conservation Areas Act* and *Canada National Parks Act* involve the participation of Indigenous peoples in the planning, management, and operations of marine areas administered by PCA.
- Modern treaties and land claim agreements include provisions for consultation and cooperation in marine areas administered by PCA and in some cases Impact and Benefit Agreements as a prerequisite for establishment.

The Government of Canada and the Qikiqtani Inuit Association recently signed an Inuit Impact and Benefit Agreement (IIBA) required for the establishment of Tallurutiup Imanga NMCA, including the newly designated Tuvaijuittuq MPA.

- "Reserves" are created in circumstances where the area is subject to an Aboriginal rights claim accepted by the Government of Canada.

Environment and Climate Change Canada (ECCC): National Wildlife Areas (NWAs) and Migratory Bird Sanctuaries (MBSs)

- Traditional Indigenous practices and activities (e.g. access and harvest) are allowed in all portions of NWAs and MBSs.
- Co-management committees have been established where NWAs and MBSs fall under modern land claims (e.g. 8 MBSs and 5 NWAs in Nunavut; 1 NWA in Yukon) to play an advisory role in the management of the area by making recommendations to the Minister on all aspect of protected areas planning and management. Recommendations made are consensus-based or voted by majority. Ultimate decision-making and authority remain with the Minister.
  - The *Canadian Wildlife Act* is a more flexible instrument than the *Migratory Birds Convention Act* and better suited for co-management.
  - Scott Islands will be the first fully marine NWA and will be collaboratively managed with the Quatsino and Tlatlasikwala First Nation and ECCC.

Text Box 11.2. Indigenous Peoples and marine conservation.

Historic treaties have only addressed a portion of Aboriginal rights to land across Canada. Land and resource-related negotiations are still underway in parts of the country where treaties were never signed.

The modern treaty era began in 1973 after a Supreme Court of Canada decision that recognized Aboriginal rights for the first time. This decision led to the development of the Comprehensive Land Claims Policy and the first modern treaty, the James Bay and Northern Québec Agreement signed in 1975 and the last one signed in 2016. The Nunavut Agreement was signed in 1993.

Each modern land claim has specific provisions for establishing protected and conservation areas. Below are general and specific requirements within Articles 8 and 9 of the Nunavut Agreement.

GENERAL 9.2.1

In addition to the establishment of National Parks (Article 8), other areas that are of particular significance for ecological, cultural, archaeological, research, and similar reasons require special protection. Inuit shall enjoy special rights and benefits with respect to these areas.

CONSERVATION AND MANAGEMENT 9.3.1

Government, in consultation with Inuit, shall conduct a study to determine the need for new legislation or amendments to existing legislation to designate and manage Conservation Areas in the terrestrial and marine environment in the Nunavut Settlement Area. This study shall be completed and published by Government within two years of the date of ratification of the Agreement.

The establishment, disestablishment or changing of the boundaries of Conservation Areas related to management and protection of wildlife and wildlife habitat shall be subject to the approval of the Nunavut Wildlife Management Board pursuant to Sub-section 5.2.34(a). Conservation Areas shall be co-managed by Government and the DIO as provided in Section 9.3.7.

Inuit Impact and Benefit Agreements (IIBAs)

No National Parks nor Conservation Area shall be established in the Nunavut Settlement Area until the obligations set out in Articles 8 and 9 are met. Where the Government of Canada, the Territorial Government and the Designated Inuit Organizations (DIO) are agreeable, the Territorial Government may be made a party to the negotiation and conclusion of an IIBA pertaining to a National Park and Conservation Area.

Prior to the establishment of a Park or a Conservation Area in the Nunavut Settlement Area, the Government responsible for the establishment of the Park/Conservation Area, in concert with other affected federal government agencies, and a DIO shall negotiate, in good faith, for the purpose of concluding an IIBA. An IIBA negotiated under this Article shall include any matter connected with the proposed park/conservation area that would have a detrimental impact on Inuit, or that could reasonably confer a benefit on Inuit either on a Nunavut-wide, regional or local basis.

Current Indigenous Involvement in Federal MPAs

Currently there is a range of Indigenous involvement in federal marine protected areas, from participation in advisory boards to co-management (Text Box 11.1).

From co-management to joint decision making:

- Despite this co-management arrangement for protected areas, many domestic reports /recommendations and processes call for increased Indigenous governance. This includes considerations of the concept of Indigenous Protected and Conserved Areas (IPCAs). For example, the Edéhzhíe protected area established by the Dehcho First Nation under their traditional law is the first formally recognized IPCA in Canada. The Dehcho First Nation propose that it also be designated a NWA with a joint decision-making mechanism.
- The Government of Canada is committed to renewing its relationship with Indigenous peoples, making the recognition and implementation of rights the basis for all relations between Indigenous peoples and the federal government.

(*Continued next page*).

Text Box 11.2 (cont.). Indigenous Peoples and marine conservation.

- "Taking Action Today: Establishing Protected Areas for Canada's Future"—House of Commons Standing Committee on Environment and Sustainable Development (ENVI) 2017 Report:
    - Recommends that Canada pursue common conservation objectives and reconciliation through a nation-to-nation relationship with Indigenous peoples, including:
        - pursuing the expansion of federal protected areas to protect areas of highest ecological value within traditional territories of Indigenous peoples;
        - implementing and respecting co-management arrangements;
        - establishing a federal point-of-contact with decision-making authority to facilitate negotiations for federal protected areas in Indigenous territories;
        - working with Indigenous peoples to designate and manage Indigenous Protected and Conserved Areas (IPCAs) within traditional territories and incorporate these areas into Canada's inventory of protected areas by amending applicable legislation.
- A New Shared Arctic Leadership Model Report (2017)
    - Mary Simon was Minister Bennett's Special Representative on Arctic Leadership tasked with providing advice on two topics:
        - New ambitious conservation goals for the Arctic in the context of sustainable development
        - The social and economic priorities of Arctic leaders and Indigenous peoples living in remote Arctic communities

  The Report recommended:
    - a "conservation paradigm shift in the Arctic" through a "conservation economy" in which conservation is tied to building and maintaining strong and healthy communities;
    - recognizing existing land and marine conservation planning designations;
    - a "whole of government approach" to impact and benefit agreements that meet or exceed best global standards;
    - long-term stable funding to support locally-driven terrestrial guardians and Arctic coastal and marine stewardship programs;
    - Indigenous Protected Areas (IPAs) as one tool to achieve a conservation economy; and
    - IPAs "decolonize conservation" and contribute to healing and reconciliation by: (i) supporting communities and individuals in regaining land-based life skill; (ii) reconnecting youth with their cultural traditions and language; (iii) collecting and documenting Indigenous knowledge; and (iv) guaranteeing there will always be places that are theirs.

International Context

- Increasing international recognition of the contribution of Indigenous-led conservation to biodiversity.
- Increasing recognition and support of Indigenous leadership and self-determination with respect to protected and conserved areas.
- Indigenous Protected Areas (IPAs) have existed in Australia since the late 1990s (mostly terrestrial).
- Release of the IUCN and CBD Parties'–Recognition of 'Indigenous and Community Conserved Areas' (ICCAs) in the early 2000s.
- IUCN guidance on protected areas management categories acknowledges Indigenous rights, responsibilities, and priorities.
- The IUCN recognizes four broad types of protected areas governance, including governance by Indigenous peoples and local communities.

Arctic marine conservation should be informed by the leadership and priorities of Indigenous peoples. This includes identifying research agendas, selecting sites, determining appropriate management regimes, monitoring, and enforcement. Indigenous-lead protection mechanisms should be an important part of the protection “toolbox” in the Arctic and can also benefit local communities through the creation of a conservation economy, through stewardship programs, training opportunities, supporting a sustainable hunting economy, and other mechanisms.

Involvement of Indigenous peoples is also important given the recent findings of Schuster et al. (2019). Their study showed that the total diversity of vertebrate taxa was higher—on lands either managed or co-managed by Indigenous groups—than on lands either randomly selected areas or managed as formally protected areas. Although this relationship does not appear to have been tested in the marine environment, the same stewardship responsibilities and results may well apply.

MANAGEMENT PLANS, ZONING, PERMITTED ACTIVITIES

Each existing marine protected area in Canada is associated with particular conservation objectives and with regulations and management plans to achieve these objectives by managing activities that can harm living marine organisms or their habitat. Monitoring protocols and strategies are also developed for each protected area to evaluate effectiveness in achieving conservation objectives.

The term “effectively and equitably managed” (Aichi Target 11, CBD, 2018) implies several things, but indicates that, at a minimum, a management plan is required for each protected area. The term “other effective area-based conservation measures” may also be interpreted in several ways (see CBD, 2018). Taken together, we can say that Canada has established, or is developing management plans for each of its protected areas (see Appendix 1) that are explicit in what each of them is intended to accomplish.

Marine protected areas do not typically afford complete protection against all human activities throughout the entire area (see Text Box 11.3). Rather, each protected area is zoned so as to permit or restrict a given set of activities within specified and spatially designated zones (see Day and Roff, 2000; Agardy, 2015).

The MECCEA study does not propose any specific zoning or protection categories for the PACs identified in this report, as this would be a function and responsibility of the appropriate regulating authority (see above). However, any protected areas designated by statutory authority in the Canadian Arctic, should afford a high level of protection to its habitats throughout its area.

Permitted activities would necessarily include hunting and fishing by Indigenous peoples and innocent passage of ships (likely subject to speed limits at critical times of the year as in the Gulf of St Lawrence). As for all other protected areas in Canadian waters, activities would be permitted or restricted on a site-specific basis, as appropriate to the presence of conservation features.

MANAGEMENT OF POTENTIAL IMPACTS

The predominant impacts in the four marine bioregions have been reviewed in Chapter 10. Any assessment of impacts assumes that we have adequate indices of prior environmental status or health (Rice, 2003). A full consideration of this subject lies beyond the scope of the present study. Impacts on the marine environment as a whole have been reviewed *inter alia* by Halpern et al. (2008) and Ban et al. (2010).

Here, we simply stress three points considered of major importance.

The first principle to be stressed is about the linkage between protection "tools" and conservation objectives; this should be evident from the foregoing, and from examples in Table 11.1. For example, some distinctive habitats of known and limited distribution (e.g. deep seas corals) can be effectively protected within the confines of individual PACs.

Table 11.1. Examples of linkage between conservation objectives and management protection tools.

Conservation Objective	Management within PACs? Y/N	Management "Tools"
Marine Mammals Seasonal Migration Routes	N	Ship avoidance, speed regulations
Key habitats for all species	Y	Complete protection in PACs
Areas of High Productivity	Y	Monitor and Regulate local coastal pollution. Regulate ship discharges
Foundation benthic species	Y	Regulate bottom trawling areas
Ensure oceanographic connectivity among PACs	N	Identify and protect Source and Sink recruitment areas
Protect Ice Edge, coastal leads	N	Remote sensing and seasonal protection

However, additional tools as protection measures are also required beyond PACs, for example within known marine mammal migration routes at least during the major migration events. Key habitats, such as the ice edge, ice bridge, shore leads, and polynyas, also require conservation measures going beyond what PACs can achieve. For these areas, protection tools need to be applied not only on a seasonal basis but also on a real-time spatially variable basis, as determined by remote sensing. These kinds of "mobile pelagic protected areas", to protect both migratory species AND motile habitats, have been advocated in the past (e.g. Gubbay, 2006). They are entirely feasible but have not yet been applied in Canada.

A second principle is the concept of connectivity among a network of PACs. The significance of a network, as a mutual support system among as coherent set of PACs, has been described in Chapter 9. The significance of replication of PACs and connectivity among them constitutes a major form of "insurance policy" against environmental impacts of all types and cannot be over-estimated.

A third principle is the significance of monitoring. The goal of protecting all components of biodiversity in a bioregion is an ambitious one, but not all components of biodiversity can be monitored. An effective monitoring program entails both field census and remote sensing, and it should be designed to detect changes in key conservation features and effectiveness of the network in achieving the conservation objectives. It is therefore an important contribution to adaptive management (Hiscock, 2014). However, attention in most monitoring programs has been limited to specific locations and for limited documented impacts (e.g. DFO,2010). A broader consideration of monitoring, to evaluate bioregional impacts on an entire Arctic network, needs serious and immediate attention.

MANAGEMENT IN RELATION TO EBSAS, THE NETWORK AND ARCNET

Relation to EBSAs

The unique nature of the Arctic points to the vital importance not only of the siting of marine protected areas, but also for the broader scale management of EBSAs in concert with such protected areas. Widespread species such as seals and migratory species cannot be effectively protected solely within protected areas. Such species need additional levels of protection and policies, such as season- and location-specific rules on vessel speed reduction.

The potential role of management at the scale of EBSAs in protecting migration corridors was considered in Chapter 9. However, their significance goes well beyond this, as indicated in DFO (2004). Due to their biological or ecological significance, EBSAs are to be managed with a greater degree of risk aversion, but this does not confer any special legal status or management protocols.

As shown in Figure 11.1, Figure 11.2, and Figure 11.3, the PACs lie significantly within Arctic EBSAs covering some 60% of their areas in all three scenarios. This is a strong indication that the PACs are aligned with DFO's criteria for identifying EBSAs, but being smaller this also indicates that they are core areas for marine protection.

Unfortunately, there is currently no policy or guidance on how to use EBSAs in management outside the development of marine protected area networks (DFO, 2009). Due to the fact that many EBSAs are very large and that the geospatial data layers underneath them are not readily available, they have not been used for informing planning processes such as the Nunavut Land Use Plan or for individual environmental assessments.

A key difference between EBSAs in the Arctic bioregions and those in temperate waters is the variability in their ecological features in space and time. Arctic EBSAs all involve features that are difficult or impossible to manage solely according to the static properties that describe marine protected areas. Rather, because of their variability, they require real-time knowledge and management. Fortunately, because much of this variability is associated with ice conditions, and these can be monitored in real time, adaptive management and real-time application of precaution is practicable.

Text Box 11.3. Protection levels for Canadian marine protected areas and proportions fully protected.

Despite the tally of Canada's marine protected areas (Appendix 1.), two major considerations may compromise the long-term value of these areas.

First, the long list of "regulated areas" describes regions that are closed by regulation—not by legislation. Such areas, though offering valuable protection for fisheries resources and for benthic invertebrate communities such as sponges and cold-water coral assemblages, can be re-opened by ministerial authority.

Second, in Marine Protected Areas proper (MPAs under DFO) and National Marine Conservation Areas (NMCAs under Parks Canada), though both types of protected area are established under federal legislation, they may only fully protect a small percentage of the entire area in terms of "no-take" zones.

The actual proportion of a marine protected area that is fully protected varies significantly among sites. For example, in The Gully protected area off the east coast of Canada, its total area encompasses 2,364 km^2—the largest underwater canyon in the western North Atlantic. However, of this total area, only the central and deeper core region of 475 km^2 is fully protected—some 20%. In the Gwaii Haanas NMCA, only 3% of the marine area was zoned in strict protection.

The criteria for what should be counted as a "fully-protected" areas are subject to various interpretations and challenges (see e.g. Aten and Fuller, 2019), making it difficult to apply the same mathematics across all locations, varying jurisdictions, permitted and prohibited activities, and zoning patterns. A review of this issue by the Canada Parks and Wilderness Society (CPAWS, 2015) covering all federal and provincial sites that Canada counts as protected areas reveals that: "the level of protection for these special places that are intended to protect our most precious marine species and habitats are weak, and too many harmful industrial practices are allowed to continue even after an MPA is legally designated. This is in stark contrast to the protection we afford our terrestrial protected areas."

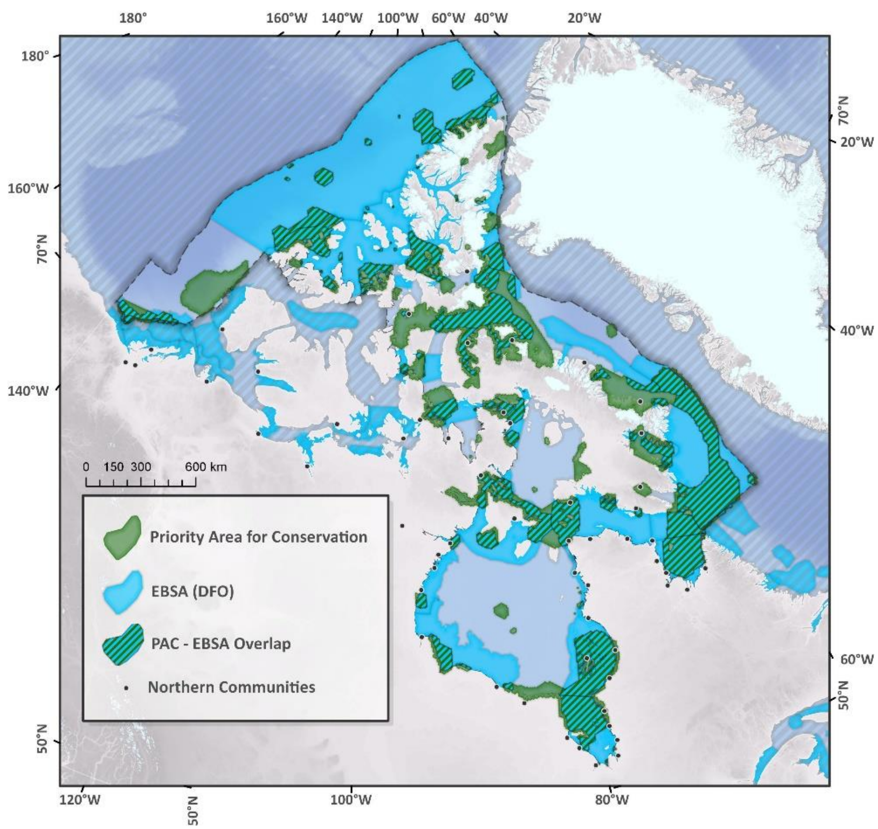

Figure 11.1. Marxan minimum protection scenario and EBSAs, showing spatial overlaps.

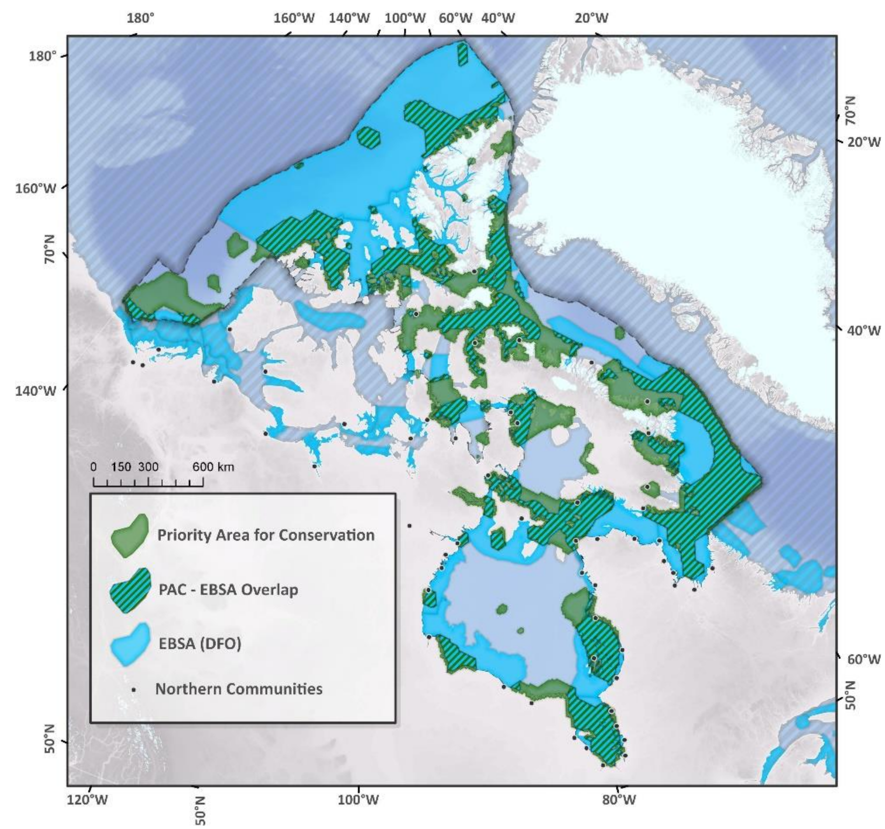

Figure 11.2. Marxan median protection scenario and EBSAs, showing spatial overlaps.

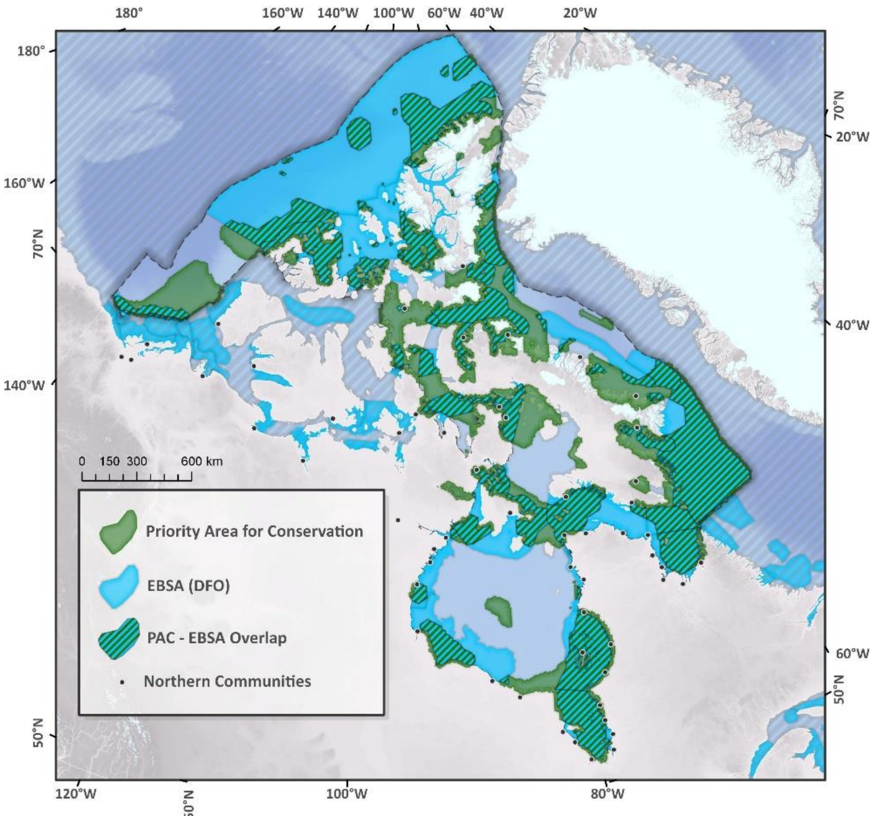

Figure 11.3. Marxan high scenario and EBSAs, showing spatial overlaps.

Relation to the Network and ArcNet

In the Canadian Arctic marine bioregions, there are several agencies promoting and developing protected areas (see above). However, there has been very little consideration of how existing protected areas (locked in for our Marxan analyses) may support broader conservation objectives within a bioregion. The MECCEA study is the first, within the Canadian Arctic marine bioregions, to attempt an evaluation of a set of protected areas (the PACs), in terms of their coherence, their conservation features, and their network properties.

In the Scotian Shelf region, there has there been a continued history of integrated planning for marine conservation, which includes defining a coherent set of PACs and their network properties. Here, studies were started by a partnership of the Conservation Law foundation (CLF) and WWF-Canada, which included the Gulf of Maine (CLF-WWF, 2006). This study area was subsequently re-examined by DFO (Horseman et al., 2011), and its network connectivity was reported in Roff and Zacharias (2011). This bioregion has now been studied exhaustively a third time by DFO (Marty King, personal communication), but results have not yet been released. Such integrated studies are needed in all the marine bioregions of Canada.

Both EBSAs and PACs should be used as a knowledge basis for developing Marine Spatial Plans and for implementing Integrated Oceans Management/Ecosystem Based Approach for management with the aim of avoiding or mitigating detrimental environmental effects on those significant areas. Because areas adjacent to PACs contribute significantly to the ecological value and biodiversity of PACs, they should also be managed in a manner that maintains their function and integrity.

Now that patterns of connectivity among the PACs have been defined by the MECCEA study (and should be refined in due course), a series of new issues enter the process of marine conservation planning. Specifically, all aspects of mutual ecological support among designated protected areas must be examined as indicated in Chapter 9. For example, areas that can be defined as important larval sources or sinks for recruitment, or areas important to other aspects of network resilience (see below), will require special consideration when planning a true network of PACs.

Two important questions now arise. First, who manages a network as a whole, both nationally and internationally? Second, how are networks integrated with other contiguous domestic and international conservation efforts?

Nationally: the Government of Canada is responsible for the development of marine protected area networks as stated under section 35.2 of the *Oceans Act*: "For the purposes of integrated management plans referred to in Sections 31 and 32, the Minister shall lead and coordinate the development and implementation of a national network of marine protected areas on behalf of the Government of Canada."

However, developing and then managing such networks has to be done in close collaboration with all federal agencies, provinces and territories, rightsholders and key stakeholders for it to be successful, and it ought to be placed within the context of marine planning at large.

Internationally: In addition to national networks, in the context of marine conservation in the whole Arctic, there is a need to identify networks of PACs that include areas outside the EEZs. ArcNet has taken leadership to identify pan-Arctic scale PACs both within and outside EEZs, but who will ultimately be responsible to establish and manage the network and PACs outside national boundaries? This will require management of the entire network, and national management plans that integrate with international initiatives in the marine Arctic as a whole. The Arctic Council should have an important role to play, but ultimately, a legally binding agreement among Arctic States will most likely be needed.

These aspects of marine conservation, network management, and international integration among networks (networks of networks) have only recently received attention (see e.g. IUCN, 2008; Brock et al., 2012).

MANAGEMENT FOR THE FUTURE—A RAPIDLY CHANGING ARCTIC

The MECCEA study has focussed primarily on static PACs. However, it is important to put these individual protected areas into the overall context of a rapidly changing and variable Arctic environment.

It is relatively easy to list the types of future changes to be expected in the marine Arctic environment. The main changes relate to trends in reducing ice cover and increasing temperature. Related and expected consequent changes are summarized in Text Box 11.4. More difficult to predict are the magnitude and timing of such changes, their overall environmental and ecological impacts, their spatial extent, and the consequences on trophic interactions.

Adapting to Climate Change

A general consideration for environmental management is encapsulated in the Precautionary Principle and Approach. However, in the marine Arctic, even a "reactionary approach" may be too late because of the speed of change. Rather we need an Anticipatory Approach. In a region where conditions are changing more rapidly than anywhere else in the world (Gascard et al., 2019), we should attempt to anticipate environmental changes and consequent ecological responses, as the basis for on-going conservation efforts. This entails appropriate visioning about future ecological trajectories and management strategies.

Text Box 11.4. Changes expected in the marine Arctic in coming decades.

1. Decrease in extent of ice cover and thickness. Volume of ice cover has decreased by 75% over the last 40 years (Gascard et al., 2019).
2. The Canadian Arctic will hold the Last Ice Area (LIA), where multi-year sea ice is expected to persist until 2050 (Huard and Tremblay, 2013).
3. Decreased ice cover and increasing sea surface temperature will result in a northward shift of climate zones and associated flora and fauna (Poloczanska et al., 2016).
4. The unique sympagic community of algae, not found outside ice covered polar regions, will be reduced in spatial extent Christiansen (2017).
5. Annual productivity of phytoplankton production will increase in parallel (Arrigo et al., 2008; Ardyna et al., 2014).

   These projections should be parsed into regions that are, at present:

   - open year-round where production may not change greatly;
   - seasonally covered with first year ice that will begin to remain open, where phytoplankton production may increase.
   - permanently covered by multi-year ice that will begin to only have seasonal first year ice and will see an increase in production of the sympagic community and the phytoplankton community.
6. Production of both inter-tidal and sub-tidal macrophytic algae may undergo significant increases (Krause-Jensen and Duarte, 2014) as climate change progressively removes ice cover and allows increase light penetration to sub-tidal benthos.
7. Changes in the relative development of pelagic and benthic communities and associated trophodynamic energy pathways and food webs are likely, as consequences of the above changes Christiansen (2017).
8. Changes in patterns of connectivity, both for migratory species and for larval dispersal can be expected (e.g. Alvarez-Romero et al., 2017).
9. Further distribution changes will inevitably occur as some species increase their northern limits (e.g. Hallowed et al., 2013). Invasions from the Pacific and Atlantic Oceans via the Beaufort Sea and the Arctic Basin will increase due to both active migrations and larval recruitment. Larval forms of temperate species already appear in Arctic locations (Ershova et al., 2019) indicating rapid changes in species assemblages in response to changing habitat conditions.
10. The environmental and ecological consequences of these invasions have not been assessed nor have they been considered in conservation planning for the Arctic marine environment.

This requirement means the consideration of at least four things: evaluation of the present status and role of existing MECCEA PACs; evaluation of which species and PACs are vulnerable to change and which are resilient and why; evaluation of present food webs and expected changes; and planning and Adaptive Management for the changes envisioned.

Role of Existing MECCEA PACs

Whatever the future may hold, existing PACs will always have environmental and ecological functions irrespective of climate change scenarios. These basic functions of protected areas have been considered, e.g. by Roberts et al. (2017), and are summarized with their management role in Text Box 11.5.

There is no guarantee that the ability of MECCEA's network of PACs to meet its original conservation objectives will be uncompromised by climate change. Indeed, the PACs may not retain their original conservation objectives if their priority species, key habitats and ecological processes have shifted to other areas. The only way to offer some adaptation to climate change is through a "climate smart" network management plan that requires: (i) the monitoring of climate conditions that may impact the existing PACs' ability to meet conservation objectives; (ii) the reassessment of the suitability (and location) of protected areas as climate change unfolds; and (iii) management in the context of the whole Arctic.

This involves reassessment of vulnerability and resilience and should examine the option of recalibration or relocation of PACs. Any changed role of protected areas will require new assessment of management plans.

Text Box 11.5. Basic functions of protected areas in the mitigation of climate change effects and carbon sequestration (adapted from Roberts et al., 2017).

1. Reduction of impacts, such as fishing and mining, in marine reserves prevents biodiversity loss, promotes ecosystem recovery, maintains ecosystem services, and confers resilience.
2. Large species populations found in protected areas are more resistant to extinction than smaller ones, by providing a better buffer against declining numbers. Their greater reproductive output helps make populations more resilient.
3. By maintaining genetic diversity, the chances of species adapting to changing sea temperatures and other environmental changes is increased.
4. Protected areas can act as refuge steppingstones for migratory species and provide safe “landing zones” for climate migrants.
5. Identifying areas of the ocean where conditions are most stable may provide climate refugia.
6. Protection of the seabed from disturbance will prevent the release of carbon held in sediments.
7. Protected areas can form an important network of observatories and ecological and climate monitoring stations.
8. Until recently, neither decision-makers nor protected area managers have directly considered climate change and ocean acidification in the design, management or monitoring of protected areas or networks, but this is beginning to change.

Assessment of Vulnerability and Resilience of PACs

It may be tempting to consider vulnerability and resilience as ecological antonyms, but they are not quite. Regarding conservation planning, Pressey et al. (1996) defined vulnerability as, “the likelihood or imminence of biodiversity loss to current or impending threatening processes” (see also Wilson et al., 2005). Compare this to Holling (1973)’s original definition of resilience as, “The magnitude of the disturbance that a system can absorb without fundamentally changing.”

Because the Arctic marine environment <u>is</u> fundamentally changing, to become progressively more like the characteristics of present north temperate systems, this means that analysis of vulnerability and resilience becomes a fundamental requirement for management purposes. A basic framework for such analysis, with some examples, is given in Table 11.2., and the subject has been more fully explored by Brock et al. (2012).

<u>Vulnerability</u>

We have not undertaken any comprehensive vulnerability assessment of the PACs overall; this would take us well beyond the original goals and objectives of MECCEA. A report on vulnerability of Arctic EBSAs has been prepared by Speer and Laughlin (2011). However, this sort of evaluation would be done by the Government of Canada before the formal designation of an area as protected. Nevertheless, we present the start of an evaluation in order to stimulate further consideration of a critical subject in the Arctic. We also note that we already have a partial assessment of vulnerability of our individual priority species, as part of the target setting process (see Chapter 7), but this assessment can be taken further.

Table 11.2. A suggested framework for some vulnerable and resilient CFs from MECCEA. This type of analysis would form one aspect of adaptive marine conservation management.

Vulnerable		Resilient	
Species	**Habitats/Ecosystems/Processes**	**Species**	**Habitats/Ecosystems/Processes**
Individual priority species (see Chapter 6)	E.g. slow growing “foundation” species assemblages: deep sea corals, sea pens, and sponges. PACs with assemblages of vulnerable priority species (see Chapter 11) Narrow passages for marine mammal migrations Food webs	Not assessed by MECCEA	Physically-driven distinctive areas such as upwellings, polynyas, and tidal gyral systems. Food webs

Note that emphasis in “Vulnerable” is to human impacts while in “Resilient” emphasis is to climate change effects.
Note also that food webs may be either vulnerable or resilient.

The average vulnerability of each MECCEA PAC was calculated based on the average vulnerability scores of the conservation features contained in it. Figure 11.4, Figure 11.5, and Figure 11.6 show the results for each of the 3 scenarios. Monitoring of priority features would lead to updated vulnerability scores, which would be vital for management plans. Further analysis of vulnerability of both individual species and the PACs where guilds of such species presently aggregate seasonally is clearly needed.

Also vulnerable to several impacts are the narrow passages of our betweenness centrality analysis (see Chapter 9) and the seasonally variable ice edge zone. These important areas for marine mammal migrations and feeding deserve special management attention in the future.

Resilience

Many individual species or communities of broad geographic distribution in the Arctic will be resilient to climate changes. We have made no assessment of these, but an inventory of refugia is feasible (see e.g. Ban et al., 2016).

Many marine habitats or ecosystems that are naturally resilient (Agardy et al., 2010), especially regions of high natural production, can be readily defined in the Arctic as indicated in the RACER study (Christie and Sommerkorn, 2012). These generally physically-driven regions, predominantly “ergoclines” (Legendre et al., 1986) and distinctive areas (Roff and Evans, 2002), include gyres, upwellings, polynyas, and coastal leads, producing the associated rich seasonal feeding grounds (e.g. Yurkowski et al., 2019). Their locations can be remotely monitored, and their probable future behavior modelled from physical oceanographic data. Management regimes for the future can therefore be devised.

“Recalibration” of PACs and Connectivity

Individual PACs can still be expected to be a part of any future conservation plan for the marine Arctic environment. Their continued functions in a fixed location were indicated above. In areas of natural resilience their location may be fixed. However, in the face of a rapidly changing Arctic environment, the function or even location of PACs may need to change (e.g. Tingley et al., 2014) if they are no longer efficiently located (e.g. Tittensor et al., 2019), or if they are found to be in the “wrong” place.

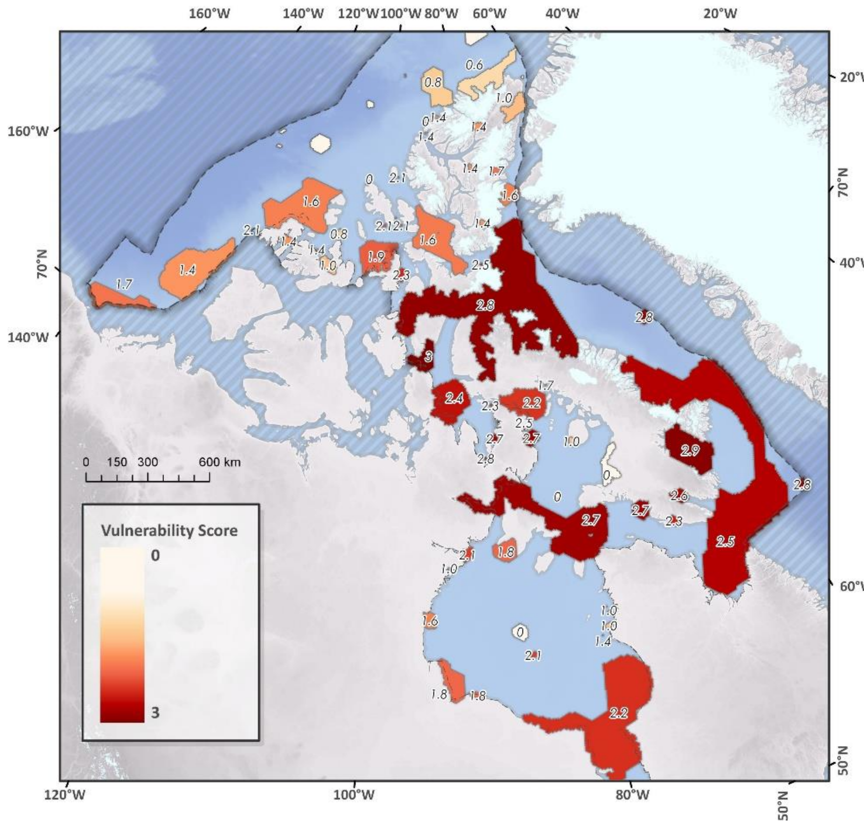

Figure 11.4. Minimum target scenario showing summed vulnerability of conservation features in PACs.

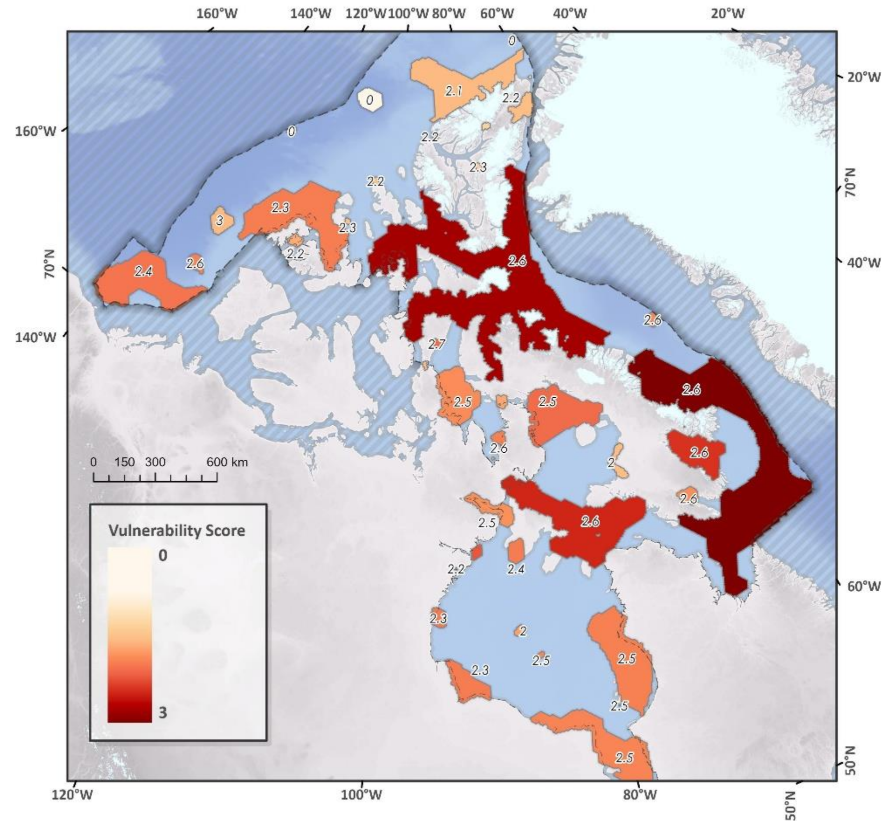

Figure 11.5. Median target scenario showing summed vulnerability of conservation features in PACs.

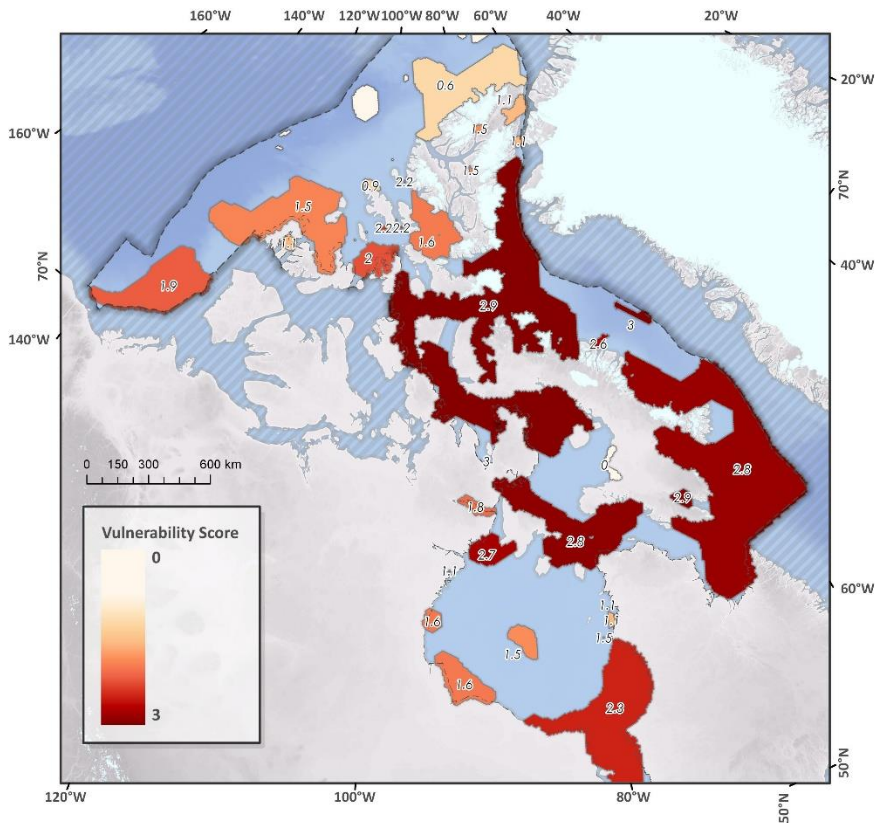

Figure 11.6. High target scenario showing summed vulnerability of conservation features in PACs.

In this respect, the concept of seascapes becomes vital, since we can potentially adjust or relocate representative areas based on changing geophysical and oceanographic data. This is ecosystem/habitat recalibration (see Text Box 11.6). Such a management review of seascape variables and parameters would allow the boundaries of PACs to be reset as ecosystem conditions move northward, or even allow PACs to be relocated to areas now conforming to their original habitat characteristics. In effect, such adaptive management addresses the "Shifting Baseline Syndrome" (Pauley, 1995) by shifting the baseline itself.

Another important way to look at the effects of a warming climate on MECCEA's results is through the connectivity analysis. Running the larval tracking simulation using physical ocean model outputs (see Chapter 9) that are driven by various emissions scenarios (e.g. 'business as usual', reduced emissions etc.) would provide a spectrum of connectivity patterns that could be expected in the future (e.g. Alvarez-Romero et al., 2018).

We cannot simply ignore these problems because they are too complex. Conservation in the marine Arctic must involve not only assessment of present features and status but also imaginative adaptive marine conservation management as, for example, in Magris et al. (2014).

ADAPTIVE MARINE CONSERVATION MANAGEMENT

It has been argued that protected areas are a necessary but not a sufficient solution (e.g. Allison et al., 1998). The sufficient solution involves inter alia: fisheries management, protection of migratory species, and control of pollution. In the Arctic, we need to go further still, because the Arctic is changing so rapidly.

Text Box 11.6. Representative area seascapes and their potential recalibration.

As climate change causes redistribution of habitat characteristics, at least some of the variables/parameters contributing to both pelagic and benthic seascapes could be redefined (Table 11.6.1):

1. To describe the new seascape characteristics of existing PACs; or
2. To identify new regions with the same characteristics as the original PACs, thus providing potential relocation sites.

Table 11.6.1. Potential approaches for recalibrating seascapes.

Pelagic Seascapes	
Present variable or parameter	**How used**
Sea ice	Variable, remote sensing
T-S water masses (from CTD)	Annual models of redistributions?
Seasonal stratification (as $\Delta\sigma_t / \Delta d$) x 100	Not available for recalculation?
Additional variables available	
Surface temperature	Remote sensing
Surface chlor *a*	Remote sensing
Polynyas and shore leads	Remote sensing
Benthic Seascapes	
Present variable or parameter	**How used**
T-S water masses (from CTD)	Annual models of redistributions?
Geomorphic features	Fixed locations
Near bottom current speed	From oceanographic models
Additional variables available	
To be determined	

Establishing protected areas may be the best *current* response, but it can be argued that protected areas—static entities—are an incomplete solution to a rapidly changing environment (e.g. Tittensor et al., 2019). In fact, given that our planning in MECCEA is based on recent historical (possibly temporally biased) data, it could be argued that we are planning for the past.

We need to question what changes have already happened in the Arctic, because much of our data is historical and collected prior to or during a major period of climate change impacts. Much physical oceanographic data is older; fisheries and benthos data were both accumulated over many years.

Not all changes in the marine Arctic are likely to be adverse. Some may have positive aspects. For example, the Canadian marine Arctic is the home of the LIA (Last Ice Area), centred on the Arctic Archipelago and Arctic Basin. It isprojected to be the last place in the Northern Hemisphere that will retain a year-round ice cover until about 2050 (Huard and Tremblay, 2013). It may become home to many new biological activities. A betweenness centrality analysis (see Chapter 9), including narrow passages, indicates that other migration routes including the LIA area, are likely to open up or become more highly used.

In the Arctic Basin there is a set of over 20 canyons (Figure 11.7) whose average size is equal to "The Gully" marine protected area off Nova Scotia. If these features all behave ecologically like

The Gully, when the permanent ice of the Arctic Basin is lost, then the entire region is likely to see major seasonal feeding areas for marine mammals. This could be considered a new ecological phenomenon—"ecological emancipation".

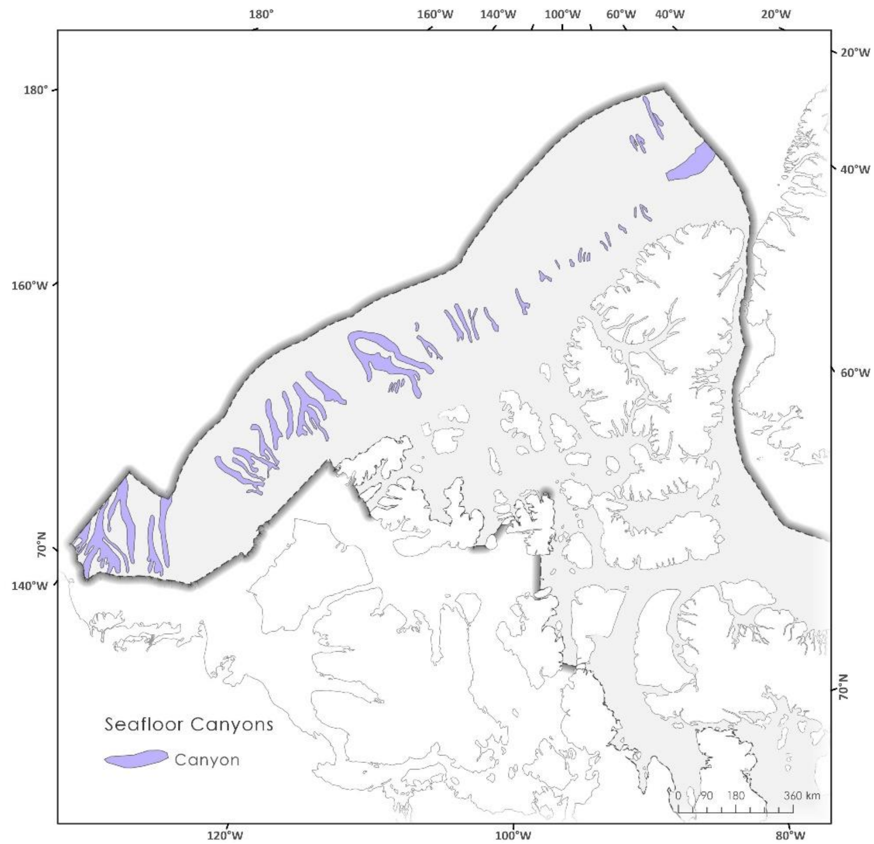

Figure 11.7. Canyons in the Arctic Basin bioregion.

There are insufficient data to follow the historical timing of many biological changes. A full consideration of historical changes, expected future changes, and appropriate management responses lies beyond the scope of this report, but is badly needed. The clear requirement for the future is the need for increased field and remote sensing monitoring, and innovative planning, as a firm basis for adaptive marine conservation management in the Canadian Arctic. As Harris et al. (2017) have said, “Arctic marine conservation is not prepared for the coming melt.”

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CHAPTER 12: ACCOMPLISHMENTS, LIMITATIONS AND CHALLENGES, KEY MESSAGES, AND NEXT STEPS

INTRODUCTION

This final section of the report looks back—on the MECCEA study's novel accomplishments—and it also looks forward to how its findings could be applied for effective marine conservation. Some items are repeated among sections of this chapter, for emphasis and context.

MECCEA ACCOMPLISHMENTS

1. The MECCEA study covers a vast area of the Canadian Marine Arctic—four entire bioregions. Other Canadian marine conservation studies have only reported on a single bioregion.
2. The MECCEA study represents the first comprehensive and quantitative spatial planning study for conservation in the Canadian marine Arctic, encompassing four of its five bioregions.
3. A unique approach to target setting was developed using a combination of defined algorithms and a customized expert vulnerability assessment for specific conservation features.
4. Marxan analysis ensured that, wherever possible, conservation features were split by the boundaries of each bioregion, resulting in network designs that can function at the scale of a single bioregion as well as across the entire study area and helping to account for data scarce areas. Recommendations for PACs within any individual bioregion should be the same as those within all four bioregions combined.
5. Regarding replicability (and redundancy), having conservation features replicated across bioregions helped to attain an even distribution of PACs across the MECCEA planning region, despite the lack of data in areas of the Arctic Basin and Arctic Archipelago.
6. The MECCEA results provide a basis for evaluating overlaps between areas of ecological significance with commercial activites, such as shipping and offshore fisheries, as was initially assessed in this report.
7. MECCEA has undertaken the first evaluation of some of the main aspects of connectivity among a set of Arctic PACs, including seasonal use areas by priority species, land-water interactions, migration corridors, and oceanographic flow patterns.
8. The connectivity study identified PACs that are oceanographically well-connected and those that are relatively isolated, but which may nevertheless connect over longer periods or connect to protected areas beyond the MECCEA study area.
9. A novel application of a betweenness centrality study of narrow passages has located critical pathways for marine mammal movements.

MECCEA LIMITATIONS AND CHALLENGES

1. Data in the Canadian marine Arctic is sparse and uneven among bioregions. This requires the use of data surrogates, as used in our seascapes. Although such relationships, for example between geophysical variables and biological communities, are known to be robust in other regions, they have not been calibrated here.
2. The study was based on available data, collected over several years (in some cases decades) and presented as if synoptic. This may have introduced temporal biases which have not been analyzed or interpreted. This is unavoidable in a data-sparse environments but is of particular concern in a rapidly changing Arctic environment. However, in each case, we have reported the time frame over which data were collected or observed.

3. Two further major problems encountered in this study are: sparsity of biological data in general, and uneven data distribution with a bias of far less data for the Arctic Basin and Arctic Archipelago.
4. A Delphic process based on expert opinion was used for evaluation of some conservation features (e.g. marine mammals, birds, fish, and eelgrass). This can be subjective. To avoid this, we produced scenarios for minimum, median, and high conservation targets ranges.
5. By design, socio-economic information was not used to develop the scenarios for PACs. The WWF-Canada strategy was to identify the ecological features of PACs and their network only.

ADDITIONAL CONSIDERATIONS

1. The MECCEA study can help identify where Canada should focus efforts in meeting the next international marine protection targets of 25% by 2025 and 30% by 2030. Decisions on the establishment of a final network of protected areas depends on a balanced evaluation of several factors including conservation targets, number and size of areas, boundary lengths, replicability, and irreplaceability.
2. The MECCEA PACs should be used to inform future marine planning efforts. The approach and methods used in the MECCEA study could be readily applied in the remaining Arctic bioregion—the Western Arctic—so that a comprehensive conservation plan can be developed for all Canadian Arctic seas.
3. The results of the MECCEA study should be integrated with other contiguous Canadian marine bioregions and with ArcNet, with respect to both PACs and connectivity studies.
4. With loss of ice cover in a few decades, a set of previously unrecognized canyons in the Arctic Basin are likely to become "emancipated ecosystems" of prime biological importance.
5. Given that the Arctic is warming almost three times faster than the global average and that largely ice-free summers are expected in the Arctic Ocean by mid-century, WWF-Canada urges that precaution be taken by adopting a stepwise approach to marine conservation, beginning by protecting 30% by 2030, and increasing to 50% by 2050. This is consistent with our minimum to high target set of scenarios. This is also consistent with the most recent commitments to marine protection by the Government of Canada (see Chapter 1).

NEXT STEPS

Next Steps for Marine Conservation in the Canadian Arctic.

A consideration of next steps should distinguish between proximate needs and those required in the context of climate change.

Proximate steps should include the following:

Complete the conservation planning process for the Canadian marine Arctic, by extending it to include the Western Arctic.

Implement a comprehensive plan for Arctic marine conservation, which recognizes a coherent set of PACs, and that constitutes a true network of marine protected areas.

Integrate the network of Canadian Arctic PACs with neighboring Canadian marine bioregions.

Integrate the Network of Canadian Arctic PACs with protected areas in neighboring national marine and coastal waters, and the circumpolar Arctic.

Next Steps - Acclimation

In general, human societies respond to changes after they have occurred. In the marine Arctic, we can be reasonably certain of what the future holds and what it could look like. This presents a prime opportunity to anticipate and plan in advance.

The challenge then is to recognize and accept the changes already occurring in the marine Arctic, to extrapolate to future expected changes, and to plan to adapt to them. This is adaptive marine conservation or acclimation, an old and well-understood physiological phenomenon. We now need to apply this older concept to a new purpose, from individual organisms to whole ecosystems, in terms of their vulnerability and resilience.

This means that our conservation plans need to be periodically revised, and the sites of static PACs may even need to be relocated. Given good monitoring data, both on the ground and by remote sensing, as a basis for reassessment of distinctive areas and priority species and recalibration of seascapes, this should be a realistic proposition. The time has now come to accept this reality and to rise to the challenge of how best to adapt to a rapidly changing Arctic environment, and how best to protect its biodiversity for the future.

GLOSSARY OF TERMS AND ACRONYMS

Not all scientific terms are included here. Words in common use and those not requiring further definition for purposes of this study, are not included.

Other terms used and defined in Text Boxes (e.g. Table 4.2 geomorphic definitions) are not included here.

Anadromous Applied to fish, ascending from the sea to breed in rivers and lakes.

Assemblage (of species) A group of species commonly found together. More neutral than the term “community” which assumes biological interactions among the members of an assemblage.

Bathymetry The measurement of depth of water.

Benthic realm Pertaining to the bottom of the sea, and the animals and plants living there.

Benthos The plants and animals of the Benthic Realm.

Biodiversity The sum total of the variety in all living organisms from the genetic to the ecosystem level, and the structures and processes which support them.

Biodiversity structure Any component of biodiversity that can be measured or enumerated but has no dimension of time. These are static quantities such as numbers or distributions of organisms, the size of geological features or the spatial variation in concentration of chlorophyll.

Biodiversity processes Any component of biodiversity that varies over time, such as the rate of primary production, or change in population density of organisms over time. For example, the rate of loss of ice over time.

Biogenic habitat Is habitat created by living organisms, which provides essential ecosystem functions and services, such as physical structure, nutrient cycling, shelter for other organisms and increases in production.

Bioregion Is an ecologically and geographically defined area, which can be separated from contiguous areas by its features.

Bioregionalization scheme The process of defining bioregions by describing their biological, geophysical, and geographic features.

Chlorophyll (chlor) a The major photosynthetic pigment in plants.

Coarse- and fine-filter approaches to conservation A coarse filter generally applies to larger scale representative features; a fine filter generally applies to individual species or particular distinctive areas.

Coastal inlets Any invagination of the ocean into the land; comprising both bays and estuaries.

Coherent set of mpas A set of Priority Areas for Conservation which collectively represent all regionally identified biodiversity components.

Community (see also Assemblage) A group of biologically interacting species commonly found together.

Connectivity The state or extent of being connected or interconnected, as applied to a set of protected areas. See **Network**.

Conservation feature Any component of biodiversity for which we can derive data, and which warrants inclusion *(in sui juris)* in a conservation plan at any level of the spatial or ecological hierarchy.

Conservation target A goal or objective for the level of protection of a conservation feature.

Corals, sea pens, sponges At higher latitudes these are deep-sea invertebrates often forming extensive reefs. Considered as Foundation or 'Engineering' species or communities of species, they provide habitats for a diversity of other species.

CTD Conductivity (a measure of salinity), temperature and depth measurements taken as physical descriptors of a water column.

Dispersal The process of passive movement within water as determined by local currents.

Distinctive areas The "extraordinary" habitats of a region. They are discontinuous and do not occupy all areas within a region. Such areas are often distinguished by Geophysical Anomalies and the presence of priority species or aggregations of a species, which exploit them for resources or refuge from predators. Key habitats belong in this category.

Ecologically and Biologically Significant Areas (EBSA) Through scientific criteria, EBSAs have been identified as areas of particular importance for the healthy functioning of the oceans. The criteria for EBSAs include: uniqueness or rarity; special importance for life history; importance for threatened, endangered species or habitats; high biological productivity or diversity.

Ecoregion Ecological region - is an ecologically and geographically defined area that is smaller than a bioregion.

Exclusive Economic Zone (EEZ) These are areas of the sea, generally extending 200 nautical miles from a country's coastline, to which the coastal countries retain special rights to exploration and use of marine resources.

Fine- and coarse-filter See under coarse-filter above.

Focal species Those individual species to which our attention or research interest is preferentially directed (also referred to as priority species). Typically, these include the "charismatic megafauna" such as marine mammals, and the larger species of fish of commercial value, or other top predator species.

Geomorphology Is the scientific study of the origin and evolution of topographic and bathymetric *features* created by physical, chemical, or biological processes operating at or near the Earth's surface.

Geomorphic feature The shapes of earth's physical features; in the oceans such as basins, banks, canyons.

Geophysical anomaly Any of the earth's geophysical features that stand out as distinctive in a region.

Hierarchical approach to marine conservation The process of recognizing the spatial arrangement of conservation features of a region within a multi-dimensional geophysical and biological framework.

Hotspots Unfortunately used in a variety of meanings, but most frequently used to denote regions of high species richness of one or more taxonomic groups.

Ice algae The unicellular plants of the Sympagic Community at the bottom of the ice.

Ice edge community An ecologically complex area that can consist of at least four separate features, including polynyas, open shore leads, the edge of seasonal ice retreat, and edges of floating ice including icebergs.

Indigenous Knowledge (IK) Local and indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings (more commonly referred to as Inuit Qaujimajatuqangit by Inuit).

Key habitat An area where one or more specific, and important life history stages for a species takes place, other than migration corridors.

Marine bioregion A bioregion (see above) in the marine environment.

Marine Protected Area The IUCN definition is: "a clearly defined geographical space recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values."

Marxan is a decision support tool that can guide scientists and managers alike throughout different stages of the systematic conservation process. This planning software has been widely utilized in the identification of biodiversity gaps, the selection of cost-effective areas for conservation investment, multiple-use zoning, and trade-offs analysis

Microphytic/macrophytic algae These are simple non-vascular plants. They may be microscopic or very large such as kelps.

Migration The process of active movement from one location to another, generally for feeding and/ or reproduction.

Migration corridor A favoured route for migrating animals.

Narrow passages Regions of the oceans between landforms or islands where water flow is constricted.

Network of Marine Protected Areas A coherent and oceanographically connected set of marine protected areas that operates synergistically, in order to fulfill ecological aims more effectively than individual sites.

Other Effective Area-Based Conservation Measures (OEABCMs) A geographically defined area other than a Protected Area, which is governed and managed to achieve sustained biodiversity conservation.

Parameter Any metric, not measured directly by instrument, that quantitatively describes the environment from some combination of variables.

Pelagic realm The entire water column from surface to bottom of the ocean.

Planning unit The standardized minimum size of a region whose conservation features can be represented in Marxan.

Polynya An area of open water surrounded by sea ice; an area of unfrozen sea within the ice pack.

Productivity/production The capacity to produce in a region / the rate of primary carbon fixation in a region.

Priority species Any plant or animal species which is of management concern because of its conservation status, and/ or because it **forms a key element of a food web.**

Priority Area for Conservation (PAC) WWF-Canada has adopted the following definition and application:

> A Priority Area for Conservation (PAC) is an area of the marine environment that has proven biodiversity value and should be prioritized for future conservation efforts.
>
> PACs should be protected and managed using a combination of:
>
> - Federal, provincial, and territorial legislation;
> - Indigenous protected /conservation areas; and
> - Other Effective Area-based Conservation Measures (OEABCMs).

Pycnocline A vertical change in density within a water column caused either by an increase in salinity or a decrease in temperature with depth, or a combination of both. This leads to water column **Stratification**.

Redundancy Implies that a coherent set of marine protected areas has replicates of as many conservation features as possible. This acts both as "insurance" against environmental impacts, and as potential "steppingstones" for propagules in network connectivity.

Representative areas These are the "ordinary" continuous and contiguous habitats of a region. Describing the marine environment in terms of its geophysical representative features is of major importance in the arctic. This is because of sparse coverage in biological variables.

Resilience The magnitude of a disturbance that a system can absorb without fundamentally changing.

Rugosity Is a measure of small-scale variations of amplitude in the height of a surface. This spatial heterogeneity is generally linked to higher species diversity.

Salmonids The fish species of the salmon family.

Seascapes Formed from combinations of geophysical features that may not warrant individual consideration as conservation features. For example, combinations of temperature and salinity as water masses, act as descriptors of environmental conditions and habitat types at a hierarchical level between ecosystem and habitat. Combinations of geophysical features become of greater significance and planning importance than they would if considered in isolation.

Species richness Is a measure of the number of species in a region. Not to be confused with Species diversity.

Species diversity Is a measure of the abundance of individuals of each species among a set of species within a region.

Stock Generally applied to a separate population or management unit of an exploited species.

Stratification The tendency of a water column to separate into upper less dense and lower more dense layers, as a result of changes in temperature and salinity.

Surrogate A substitute that represents another feature. In conservation - generally a geophysical feature acting as "stand-in" for a type of biological assemblage.

Sympagic community The assemblage if ice-algae, and associated protozoa and small metazoan, living in the bottom layers of marine ice.

Systematic conservation planning Systematic conservation planning deals with selecting the locations, design, and management of Priority Areas for Conservation (PACs) that collectively represent the biodiversity of a region.

Variable Any quantity that can be measured directly in the environment by a calibrated instrument (e.g. temperature).

Vulnerability The likelihood or imminence of biodiversity loss due to current or impending threatening processes.

Water mass A body of marine water that can be defined by the combination of its salinity and temperature.

APPENDIX 1: LISTING OF ALL MARINE PROTECTED AREAS IN ALL FIVE MARINE BIOREGIONS OF THE CANADIAN ARCTIC.

MCT = Marine Conservation Targets

Bioregion	Conservation Area Name	Type of Site	Managing Authority	Size contributing to MCTs (km^2)	Conservation Objectives	Activities
Arctic Archipelago (14.1% protected)	Seymour Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	51	Protects the most important and largest known colony in Canada of the endangered Ivory Gull.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Tuvaijuittuq Marine Protected Area	Marine Protected Area (interim protection)	Fisheries and Oceans Canada	319,411 (33,988 within this marine bioregion)	The area possesses the oldest multi-year pack ice in the Arctic and is projected to be the place where sea ice persists the longest into the future. Given this area's existing importance for polar bears, cod, seals, etc., it will likely serve as a climate refugia for ice-associated communities as ice continues to recede.	Traditional activities and harvesting by Inuit communities will continue. No new human activities will be allowed to occur in the area for up to 5 years except for conservation research and emergency activities.
	Qausuittuq National Park	Marine extension of National Park	Parks Canada	1,179	Marine species in the region include polar bear, ringed and bearded seal, walrus, bowhead and beluga whale, and narwhal.	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted.
	Quttinirpaaq National Park	Marine extension of National Park	Parks Canada	2,342	Marine habitat has numerous deep fjords, with huge ice shelves extending from the north coast and its fjords, covering hundreds	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited.

					of square kilometers of the ocean. Moving pack ice covers much of the remainder of the park's marine waters. Species seen in the marine area include ringed seal, bearded seal, narwhal, and polar bear.	
Arctic Basin (38% Protected)	Tuvaijuittuq Marine Protected Area	Marine Protected Area (interim protection)	Fisheries and Oceans Canada	319,411 (285,423 within this marine bioregion)	The area possesses the oldest multi-year pack ice in the Arctic and is projected to be the place where sea ice persists the longest into the future. Given this area's existing importance for polar bears, cod, seals, etc., it will likely serve as a climate refugia for ice-associated communities as ice continues to recede.	Traditional activities and harvesting by Inuit communities will continue. No new human activities will be allowed to occur in the area for up to 5 years except for conservation research and emergency activities.
Eastern Arctic (22.5% Protected)	Prince Leopold Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	240	Protects one of the most important multi-species seabird colonies in the Arctic, which represents nesting habitat for thick-billed murres, northern fulmars, black-legged kittiwakes, and black guillemots. A variety of marine mammals also use these waters, including beluga and bowhead whales, narwhals, ringed and bearded seals, and polar bears.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Qaqulluit National Wildlife Area (NWA)	Migratory Bird Sanctuary	Environment and Climate Change Canada	396	Protects Canada's largest breeding colonies of Northern fulmars. Other nesting seabirds include black guillemots and various gull species. Walrus	Access to the NWA is restricted except for beneficiaries of the Nunavut Land Claims Agreement, for whom traditional harvest is permitted. For others, access to the NWA is by permit only, and most

					and ringed seal regularly use the waters of the wildlife area.	activities, including hunting, fishing, swimming, boating, dumping, commercial, or industrial activities, are not permitted.
	Akpait National Wildlife Area	National Wildlife Area	Environment and Climate Change Canada	743	Protects one of Canada's largest thick-billed murre colonies—about 10% of the Canadian population. Other nesting species include northern fulmars, black-legged kittiwakes, glaucous gulls, and black guillemots.	Access to the NWA is restricted except for beneficiaries of the Nunavut Land Claims Agreement, for whom traditional harvest is permitted. For others, access to the NWA is by permit only, and most activities, including hunting, fishing, swimming, boating, dumping, commercial, or industrial activities, are not permitted.
	Nirjutiqavvik National Wildlife Area	National Wildlife Area	Environment and Climate Change Canada	1,442	Protects a nesting colony representing 11% of the Canadian breeding population of thick-billed murres and 16% of the Canadian breeding population of black-legged kittiwakes, among others. A recurrent polynya occurs in the vicinity. The waters also provide important feeding grounds for polar bear, beluga, narwhal; and ringed, bearded, and harp seal.	Access to the NWA is restricted except for beneficiaries of the Nunavut Land Claims Agreement, for whom traditional harvest is permitted. For others, access to the NWA is by permit only, and most activities, including hunting, fishing, swimming, boating, dumping, commercial, or industrial activities, are not permitted.
	Bylot Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	1,765	Protects significant nesting colonies of thick billed-murres, black-legged kittiwakes and greater snow geese. The area is also a migration route and summering area for marine mammals including five species of seals and four species of whales. Polar bears also use the area in summer.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.

	Ninginganiq National Wildlife Area	National Wildlife Area	Environment and Climate Change Canada	2,834	Protects important marine habitat for bowhead whales and supports healthy populations of polar bears, ringed seals, king eiders, long-tailed ducks, dovekies, Northern fulmars, and narwhal.	Access to the NWA is restricted except for beneficiaries of the Nunavut Land Claims Agreement, for whom use of the area for economic, social, and cultural needs is permitted. For others, access to the NWA is by permit only, and most activities, including hunting, fishing, swimming, boating, dumping, commercial, or industrial activities, are not permitted.
	Davis Strait Conservation Area	Marine Refuge	Fisheries and Oceans Canada	17,298	To conserve sensitive benthic areas containing small and large gorgonian corals, sea pens, and sponges. This area is also home to commercially important benthic species such as Greenland halibut and northern shrimp.	Prohibits all bottom-contact fishing activities. Does not have the authority to manage other activities so mining or oil and gas activities could potentially be allowed in the future.
	Disko Fan Conservation Area	Marine Refuge	Fisheries and Oceans Canada	7,485	To minimize impacts on winter food source and overwintering habitat for narwhal and significant concentrations of large gorgonian corals, including large tracts of globally unique, high-density bamboo corals.	Prohibits all bottom-contact fishing activities. Does not have the authority to manage other activities so mining or oil and gas activities could potentially be allowed in the future.
	Auyuittuq National Park	Marine extension of National Park	Parks Canada	1,157	Marine component of park consists of deep fjords, which are habitat for numerous species of marine mammals including polar bear, narwhal, and beluga in addition to numerous species of fish and birds.	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited.
	Tallurutiup Imanga National Marine	National Marine Conservation Area	Parks Canada	109,000	Will protect a portion of the Lancaster Sound marine region, one of the richest marine mammal areas in the world. Polynyas are	Traditional activities and harvesting by Inuit communities will continue. Mining and oil and gas operations, including seismic testing, will be

	Conservation Area				productive feeding areas for narwhals, belugas, bowhead whales, ringed and bearded seals, walruses, harp seals, polar bears and a third of Eastern Canada's colonial seabirds. This site will support the sustainability of coastal Inuit communities and protect their marine heritage.	prohibited. Unknown if commercial fishing will be permitted.
	Sirmilik National Park	Marine extension of National Park	Parks Canada	222	The park includes tundra, glacier, wetland, coastal, marine, and freshwater ecosystems, and much of the park is covered by high mountain peaks and glaciers. The park also has habitat for numerous aquatic species such as polar bear, whale, and fish, and includes the Bylot Island Migratory Bird Sanctuary.	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted. Cruise ships come into this area for wildlife viewing.
	Hatton Basin Conservation Area	Marine Refuge	Fisheries and Oceans Canada	42,459	To conserve sensitive benthic areas containing significant concentrations of small and large gorgonian corals, sponges, and non-aggregating species such as black coral, stony coral, and hydrocoral. The area is also home to benthic species of commercial importance, such as Greenland halibut, northern shrimp and striped shrimp and is the only known overwintering area for northern Hudson Bay narwhal.	Prohibits all bottom-contact fishing activities. Does not have the authority to manage other activities so mining or oil and gas activities could potentially be allowed in the future.

Hudson Bay Complex (0.62% Protected)	East Bay Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	287	Protects nesting populations of lesser snow geese, Atlantic brants, and cackling geese. Many other shore and seabirds use this area during fall migration. Polar bear and beluga whale also use this area.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Dewey Soper Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	1,592	Protects feeding and nesting habitat for a large portion of the Canadian breeding population of lesser snow geese. Cackling geese, Atlantic brant, long-tailed ducks, and king and common eiders also nest in the area.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Ukkusiksalik National Park	Marine extension of National Park	Parks Canada	3,074	The park is home to polar bear congregations in the summer, is important habitat for many species of migratory birds, and is also home to bearded and ringed seal, and beluga whale.	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted. Recreational boating is permitted.
	Wapusk National Park	Marine extension of National Park	Parks Canada	803	The park lies in the transition zone between taiga and tundra. It protects one of the largest concentrations of polar bear maternity dens in the world and is important habitat for migratory and breeding birds.	Unknown if traditional harvest is permitted but is likely. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted.
	Hannah Bay Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	61	Protects extensive tidal flats and coastal marshes that represent important feeding grounds for migrating birds each autumn, including	Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit. It is

					hundreds of thousands of ducks, geese, and shorebirds. It is also a molting area for ducks in summer.	possible traditional harvest is permitted but is not explicitly stated.
	Boatswain Bay Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	67	Protects important nesting and staging area for numerous water birds during spring and fall migration, including Canada geese, lesser snow geese, brants, and black ducks. Between August and October significant numbers of shorebirds use the area for feeding and staging.	Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit. It is possible traditional harvest is permitted but is not explicitly stated.
	McConnell River (Kuugaarjuk) Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	132	Protects a nesting population representing more than 5% of the Canadian population of lesser snow geese, and nesting habitat for many other species such as Ross's geese and Canada geese.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Harry Gibbons Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	191	Protects the main nesting areas of lesser snow geese.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Akimiski Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	1,472	Protects nesting areas for lesser snow geese, Canada geese, common eiders, herring gulls, and Arctic terns. Other waterfowl that use the area for nesting,	Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit. It is

					molting, and/or staging include the American black duck, mallard, black scoter, and red-breasted merganser.	possible traditional harvest is permitted but is not explicitly stated.
	Moose River Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	5	Protects an important staging area for the lesser snow goose. Canada geese also use the area to feed. It also provides habitat for migrating shorebirds such as yellowlegs and plovers. The area provides a large, undisturbed feeding and resting area for migrating geese in an area of heavy hunting pressure.	Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit. It is possible traditional harvest is permitted but is not explicitly stated.
	Kuururjuaq National Park (Québec)	Quebec national park	Ministère des Forêts, de la Faune et des Parcs	34	The marine portion of the park protects the mouth of the George and Koroc rivers where abundant fish provide feeding for seals and beluga. Arctic charr are especially common, as are ringed seals.	Industrial pressures, such as oil and gas exploration/extraction are not allowed. Traditional indigenous harvest is permitted, as well as general hunting and angling (subject to provincial/ federal regulations).
	Tursujuq National Park (Québec)	Quebec National Park	Ministère des Forêts, de la Faune et des Parcs	17	The marine portion of the park protects the mouth of the Goulet river which is an important feeding area for fauna and is the site of a polynya used by belugas and seal species. The area is also an important stopover site for snow goose.	Industrial pressures, such as oil and gas exploration/extraction, are not allowed. Traditional indigenous harvest is permitted, as well as general hunting and angling (subject to provincial/federal regulations).
Western Arctic (0.25% Protected)	Cape Parry Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	1	Protects habitat for 23 bird species, including 17 breeding species. This includes a nesting colony of thick-billed murres, and one of the two known black guillemot colonies in the Western Canadian Arctic. The area is also an	Traditional harvest is permitted by Inuvialuit beneficiaries. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.

					important staging area for king and common eiders, long-tailed ducks, glaucous gulls, and Pacific and red-throated loons. Bowhead whale and polar bear also use the area.	
	Banks Island Migratory Bird Sanctuary No. 1	Migratory Bird Sanctuary	Environment and Climate Change Canada	826	Protects feeding habitat for black brants and 15% of the Canadian population of lesser snow geese, and nesting habitat for 25,000 king eiders, several thousand long-tailed ducks in addition to tundra swans, Ross's geese, and sandhill cranes.	Traditional harvest is permitted by Inuvialuit beneficiaries. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Banks Island Migratory Bird Sanctuary No. 2	Migratory Bird Sanctuary	Environment and Climate Change Canada	33	Protects molting area for black brants and 25,000 lesser snow geese.	Traditional harvest is permitted by Inuvialuit beneficiaries. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Kendall Island Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	133	Protects staging areas for lesser snow geese, white-fronted geese, black brants, Canada geese, and tundra swans.	Traditional harvest is permitted by Inuvialuit beneficiaries. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.
	Anderson River Delta Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	161	Protects spring and fall feeding habitat for many migratory species such as: long-tailed ducks, white-winged scoters and red-breasted mergansers; summer feeding grounds for sandpipers, plovers, phalaropes, and other shore birds; and breeding	Traditional harvest is permitted by Inuvialuit beneficiaries. For others, hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit.

					grounds for numerous geese and duck species.	
	Polar Bear Pass National Wildlife Area	National Wildlife Area	Environment and Climate Change Canada	215	Protects Wetlands of International Importance under the RAMSAR Convention, hosts numerous breeding waterfowl and shorebird species including the red phalarope. The area is an important spring and summer feeding area for polar bear who eat the walrus and ringed seal they find there.	Access to the NWA is restricted except for beneficiaries of the Nunavut Land Claims Agreement, for whom traditional harvest is permitted. For others, access to the NWA is by permit only, and most activities, including hunting, fishing, swimming, boating, dumping, commercial, or industrial activities, are not permitted.
	Queen Maud Gulf (Ahiak) Migratory Bird Sanctuary	Migratory Bird Sanctuary	Environment and Climate Change Canada	6,553	Protects nesting habitat for over 90% of the world's population of Ross's goose and 8% of the Canadian population of snow goose. Other species, such as Canada goose, greater white-fronted goose, brant and tundra swan, nest, and molt in the area. Ringed seals are abundant in the area, as are Arctic charr.	Traditional harvest is permitted by beneficiaries of the Nunavut Land Claims Agreement. For others, access to the MBS is by permit only. Hunting, disturbing, destroying, or taking the nest of migratory birds is prohibited. Possessing a live migratory bird, carcass, skin, nest, or egg of a migratory bird is also prohibited unless by permit. Unknown if mining, oil and gas, commercial fishing, or recreational fishing are permitted, though it is mentioned that Arctic charr are harvested in the area.
	Anguniaqvia niqiqyuam	*Oceans Act* MPA	Fisheries and Oceans Canada	2,358	Protects polynya and sea ice habitats that are home to species such as polar bear, and ringed and bearded seal. It is also feeding and migration habitat for Arctic charr, and migratory bird feeding habitat. Also protects kelp beds within Darnley Bay.	Traditional and recreational fishing are permitted. Commercial fishing and oil and gas activities are prohibited.
	Tarium Niryutait	*Oceans Act* MPA	Fisheries and Oceans Canada	1,750	Protects a portion of the Eastern Beaufort Sea beluga and its habitat. This	Fishing is allowed in all of the MPA, including subsistence harvesting and recreational and commercial

					area is also seasonal habitat for bowhead whale, ringed and bearded seal, and many fish and waterfowl species.	fishing. Shipping occurs through the area, including dredging to maintain access for ships. The MPA contains two significant discovery licenses for oil and gas exploration. While there is currently a moratorium on oil and gas in the Arctic, there is potential for drilling to occur within the MPA in the future, including the laying of oil and gas pipelines through the MPA.
	Aulavik National Park	Marine extension of National Park	Parks Canada	97	High Arctic seacoast that is habitat for polar bear, ringed and bearded seal, beluga, and bowhead whale. Nesting site for many species of waterfowl and other birds, and also important molting habitat for geese.	Traditional harvest is permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted. Recreational boating is permitted.
	Ivvavik National Park	Marine extension of National Park	Parks Canada	78	Located in the Beaufort Sea, there are three main marine habitats near the park: lagoons and estuaries, open beaches, and the continental shelf. Species found in the area include Dolly Varden trout, Arctic grayling, bowhead whale, beluga whale, polar bear, and ringed and bearded seal.	Traditional harvest and recreational fishing are permitted. Managed for enjoyment and education of visitors. Mining and oil and gas activities are prohibited. Unknown if commercial fishing is permitted. Recreational Boating is permitted.
	Pingo Canadian Landmark	National Historic Site	Parks Canada	5	Protects ice-cored hills called pingos, which are a unique Arctic landform. Waterfowl such as tundra swans, snow geese, common and Pacific loons, sandhill cranes, and a variety of ducks and shorebirds use the area seasonally.	Traditional harvest is permitted. Recreational and commercial fishing is prohibited. Recreational boating is permitted. Mining and oil and gas activities are prohibited.

APPENDIX 2: CONSERVATION FEATURES SELECTED FOR MARXAN UNDER MECCEA STRATEGIC OBJECTIVES AND TARGET RANGES.

Conservation feature names in the following tables are constructed using: "Species, habitat type or area, population or management unit (bioregion)". Note: populations or management units are only used where applicable.

ID number is a MECCEA internal identification number for Marxan.

Bioregion abbreviations are:

AA – Arctic Archipelago

AB – Arctic Basin

EA – Eastern Arctic

HBC – Hudson Bay Complex

Conservation Objectives are:

Objective 1A – Protect Key Habits of Arctic Priority Species

Objective 1B – Protect Ecologically Sensitive Areas

Objective 1C – Protect Areas of High Productivity and High Species Diversity / Concentrations

Objective 2 – Protect Representative Examples of Identified Ecosystems and Habitat Types

APPENDIX 2.1. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—POLAR BEAR KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: *Life history traits*	Vulnerability: *Fragility*	Vulnerability: *Functional significance*	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1000	Polar bear denning, Baffin Bay (EA)	1	3	2	3	3	1	1.91	40-60%
1001	Polar bear denning, Davis Strait (HBC)	1	3	2	3	3	2	2.16	40-60%
1002	Polar bear denning, Davis Strait (EA)	1	3	2	3	3	2	2.16	40-60%
1003	Polar bear denning, Foxe Basin (HBC)	1	3	2	3	3	2	2.16	40-60%
1004	Polar bear denning, Foxe Basin (EA)	1	3	2	3	3	2	2.16	40-60%
1005	Polar bear denning, Gulf of Boothia (EA)	1	3	2	3	3	2	2.16	40-60%
1006	Polar bear denning, Kane Basin (EA)	1	3	2	3	3	1	1.91	40-60%
1007	Polar bear denning, Kane Basin (AA)	1	3	2	3	3	1	1.91	40-60%
1008	Polar bear denning, Lancaster Sound (EA)	1	3	2	3	3	1	1.91	40-60%
1009	Polar bear denning, Lancaster Sound (AA)	1	3	2	3	3	1	1.91	40-60%
1010	Polar bear denning, M'Clintock Channel (EA)	1	3	2	3	3	2	2.16	40-60%
1011	Polar bear denning, Norwegian Bay (EA)	1	3	2	2	2	2	1.73	20-40%
1012	Polar bear denning, Norwegian Bay (AA)	1	3	2	2	2	2	1.73	20-40%
1013	Polar bear denning, Southern Hudson Bay (HBC)	1	3	2	3	3	2	2.16	40-60%
1014	Polar bear denning, Viscount Melville Sound (AA)	1	3	1	2	2	2	1.73	20-40%
1015	Polar bear denning, Western Hudson Bay (HBC)	1	3	2	3	3	2	2.16	40-60%
1025	Polar bear locally identified habitat, Baffin Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1026	Polar bear locally identified habitat, Davis Strait (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1027	Polar bear locally identified habitat, Foxe Basin (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1028	Polar bear locally identified habitat, Gulf of Boothia (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1029	Polar bear locally identified habitat, Lancaster Sound (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1030	Polar bear locally identified habitat, Norwegian Bay (AA)	1	3	n/a	n/a	3	1	1.91	40-60%

APPENDIX 2.2. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—BELUGA KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: *Life history traits*	Vulnerability: *Fragility*	Vulnerability: *Functional significance*	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1100	Beluga overwintering, Cumberland Sound (EA)	2	3	3	3	3	3	2.71	80-100%
1101	Beluga foraging, Eastern High Arctic-Baffin Bay (EA)	1	3	2	3	3	2	2.16	40-60%
1102	Beluga foraging, Eastern Hudson Bay/Western Hudson Bay (HBC)	3	3	2	3	3	3	3.00	80-100%
1103	Beluga foraging, Western Hudson Bay (EA)	1	3	2	3	3	2	2.16	40-60%
1104	Beluga calving, Cumberland Sound (EA)	2	3	3	3	3	3	2.71	80-100%
1105	Beluga calving, Eastern High Arctic-Baffin Bay (EA)	1	3	2	3	3	2	2.16	40-60%
1106	Beluga calving, Eastern Hudson Bay (HBC)	3	3	2	3	3	2	2.71	80-100%
1107	Beluga calving, Western Hudson Bay (HBC)	1	3	2	3	3	2	2.16	40-60%
1125	Beluga summer range, Eastern Beaufort Sea (AB)	0	3	2	3	3	2	2.08	40-60%
1126	Beluga winter range, Western Hudson Bay (HBC)	1	3	2	3	3	2	2.16	40-60%
1127	Beluga year-round high-density areas (HBC)	1	3	2	3	3	3	2.52	60-80%
1128	Beluga summer high density areas, Western Hudson Bay (HBC)	1	3	3	3	3	2	2.16	40-60%
1129	Beluga summer range, Eastern High Arctic-Baffin Bay (EA)	1	3	1	2	2	1	1.41	20-40%
1130	Beluga summer range, Ungava Bay (HBC)	3	3	1	2	2	2	2.38	60-80%
1131	Beluga summer range, Western Hudson Bay (HBC)	1	3	1	2	2	1	1.41	20-40%
1132	Beluga summer range, Eastern High Arctic-Baffin Bay (HBC)	1	3	1	2	2	1	1.41	20-40%
1133	Beluga winter range, Western Hudson Bay (EA)	1	3	2	3	3	2	2.16	40-60%
1134	Beluga winter range, Eastern High Arctic-Baffin Bay (EA)	1	3	2	3	3	2	2.16	40-60%
1150	Beluga locally identified habitat, Coastal Baffin Island (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1151	Beluga locally identified habitat, Cumberland Sound (EA)	2	3	n/a	n/a	3	1	2.16	40-60%
1152	Beluga locally identified habitat, Eastern High Arctic Baffin Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1153	Beluga locally identified habitat, Eastern Hudson Bay (HBC)	3	3	n/a	n/a	3	1	2.52	60-80%
1154	Beluga locally identified winter habitat, Cumberland Sound (EA)	2	3	n/a	n/a	3	1	2.16	40-60%

1155	Beluga locally identified winter habitat, Eastern High Arctic-Baffin Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1156	Beluga locally identified habitat, Western Hudson Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1157	Beluga locally identified habitat, Eastern Hudson Bay/Western Hudson Bay	3	3	n/a	n/a	3	1	2.52	60-80%
1158	Beluga locally identified habitat, Eastern High Arctic-Baffin Bay (HBC)	1	3	n/a	n/a	3	3	2.52	60-80%
1159	Beluga locally identified habitat, Western Hudson Bay	1	3	n/a	n/a	3	1	1.91	40-60%

APPENDIX 2.3. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—BOWHEAD KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: Life history traits	Vulnerability: Fragility	Vulnerability: Functional significance	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1200	Bowhead overwintering, East Canada-West Greenland (EA)	1	3	2	2	2	2	1.73	20-40%
1201	Bowhead spring foraging/calving (HBC)	1	3	2	3	3	2	2.16	40-60%
1202	Bowhead summer foraging/calving, East Canada-West Greenland (Lancaster Sound/Gulf of Boothia - EA)	1	3	2	3	3	2	2.16	40-60%
1203	Bowhead summer foraging/calving, East Canada-West Greenland (Coastal Baffin Island - EA)	1	3	2	3	3	2	2.16	40-60%
1204	Bowhead summer foraging/calving (HBC)	1	3	2	3	3	2	2.16	40-60%
1205	Bowhead summer foraging, East Canada-West Greenland (Cumberland Sound- EA)	1	3	2	3	3	2	2.16	40-60%
1225	Bowhead summer distribution, Bering-Chukchi-Beaufort (AB)	1	3	2	3	3	1	1.91	40-60%
1226	Bowhead summer distribution, East Canada-West Greenland (EA)	1	3	2	3	3	1	1.91	40-60%
1227	Bowhead summer distribution, East Canada-West Greenland (HBC)	1	3	2	3	3	1	1.91	40-60%
1228	Bowhead winter distribution, East Canada-West Greenland (HBC)	1	3	2	2	2	1	1.41	20-40%
1229	Bowhead winter distribution, East Canada-West Greenland (North Baffin Bay - EA)	1	3	2	2	2	1	1.41	20-40%
1230	Bowhead winter distribution, East Canada-West Greenland (Davis Strait - EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1250	Bowhead locally identified habitat, Davis Strait (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1251	Bowhead locally identified habitat, Davis Strait (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1252	Bowhead locally identified habitat, Coastal Baffin Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1253	Bowhead locally identified habitat, East Canada-West Greenland (EA)	1	3	n/a	n/a	3	1	1.91	40-60%

APPENDIX 2.4. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—NARWHAL KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: Life history traits	Vulnerability: Fragility	Vulnerability: Functional significance	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1300	Narwhal summer calving, Jones Sound (EA)	1	3	2	2	2	1	1.41	20-40%
1301	Narwhal summer calving, Somerset Island (EA)	1	3	2	3	3	2	2.16	40-60%
1302	Narwhal summer foraging/calving, Admiralty Inlet (EA)	1	3	2	3	3	2	2.16	40-60%
1303	Narwhal summer foraging/calving, East Baffin Island (EA)	1	3	3	3	3	2	2.16	40-60%
1304	Narwhal summer foraging/calving, Eclipse Sound (EA)	1	3	3	3	3	3	2.52	60-80%
1305	Narwhal summer foraging/calving, Northern Hudson Bay (HBC)	1	3	2	3	3	3	2.52	60-80%
1306	Narwhal summer foraging/calving, Somerset Island (AA)	1	3	2	3	3	3	2.52	60-80%
1307	Narwhal summer foraging/calving, Somerset Island (EA)	1	3	2	3	3	3	2.52	60-80%
1325	Narwhal summer range, Baffin Bay stocks (HBC)	1	3	2	2	2	2	1.73	20-40%
1326	Narwhal summer range, Baffin Bay stocks (Lancaster Sound area - EA)	1	3	2	2	2	2	1.73	20-40%
1327	Narwhal summer range, Baffin Bay stocks (AA)	1	3	2	2	2	2	1.73	20-40%
1328	Narwhal winter high density areas, Baffin Bay stocks (EA)	1	3	2	2	2	2	1.73	20-40%
1329	Narwhal summer range, Northern Hudson Bay (HBC)	1	3	2	2	2	2	1.73	20-40%
1330	Narwhal summer range, Baffin Bay stocks, South (EA)	1	3	2	2	2	2	1.73	20-40%
1331	Narwhal winter range, Northern Hudson Bay (HBC)	1	3	2	2	2	2	1.73	20-40%
1332	Narwhal winter range, Northern Hudson Bay (EA)	1	3	2	2	2	2	1.73	20-40%
1333	Narwhal summer high density, East Baffin Island (EA)	1	3	2	3	3	2	2.16	40-60%
1350	Narwhal locally identified habitat, Baffin Bay (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1351	Narwhal locally identified habitat (East Baffin Island - EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1352	Narwhal locally identified habitat (Lancaster Sound Area/Baffin Bay - EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1353	Narwhal locally identified habitat, Northern Hudson Bay (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1354	Narwhal locally identified habitat, South Baffin Bay (EA)	1	3	n/a	n/a	3	1	1.91	40-60%

APPENDIX 2.5. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—PINNIPEDS KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: Life history traits	Vulnerability: Fragility	Vulnerability: Functional significance	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1400	Walrus haulout sites, Canadian Central Arctic (EA)	1	3	3	3	3	2	2.16	40-60%
1401	Walrus haulout sites, Canadian Central Arctic (HBC)	1	3	3	3	3	2	2.16	40-60%
1402	Walrus haulout sites, Canadian High Arctic (AA)	1	3	3	3	3	2	2.16	40-60%
1403	Walrus haulout sites, Canadian High Arctic (EA)	1	3	3	3	3	2	2.16	40-60%
1404	Walrus haulout sites, Canadian Low Arctic (HBC)	1	3	3	3	3	2	2.16	40-60%
1410	Walrus distribution, Canadian High Arctic	1	3	2	2	2	2	1.73	20-40%
1411	Walrus distribution, Canadian Central Arctic	1	3	2	2	2	2	1.73	20-40%
1412	Walrus distribution, Canadian Low Arctic	1	3	2	2	2	1	1.41	20-40%
1413	Walrus wintering areas, Canadian Low Arctic (HBC)	1	3	3	3	3	2	2.16	40-60%
1414	Walrus wintering areas, Central Arctic (EA)	1	3	3	3	3	2	2.16	40-60%
1415	Walrus wintering areas, Canadian High Arctic (EA)	1	3	2	3	2	2	1.73	20-40%
1420	Walrus locally identified all year habitat, Canadian Central Arctic (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1421	Walrus locally identified habitat, Canadian Central Arctic (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1422	Walrus locally identified habitat, Canadian Central Arctic (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1423	Walrus locally identified habitat, Canadian High Arctic (AA)	1	3	n/a	n/a	3	1	1.91	40-60%
1424	Walrus locally identified habitat, Canadian High Arctic (EA)	1	3	n/a	n/a	3	1	1.91	40-60%
1425	Walrus locally identified habitat, Canadian Low Arctic (HBC)	1	3	n/a	n/a	3	1	1.91	40-60%
1430	Hooded seal whelping patch (EA)	0	3	2	3	3	2	2.08	40-60%
1431	Hooded seal feeding area (EA)	0	3	2	3	3	2	2.08	40-60%
1432	Hooded seal locally identified habitat (EA)	0	3	n/a	n/a	3	2	2.08	40-60%
1433	Hooded seal locally identified habitat (HBC)	0	3	n/a	n/a	3	2	2.08	40-60%
1441	Harp seal feeding area	0	3	2	3	3	2	2.08	40-60%

1442	Harp seal locally identified habitat (HBC)	0	3	n/a	n/a	3	1	1.83	40-60%
1443	Harp seal locally identified habitat (Lancaster-Boothia area - EA)	0	3	n/a	n/a	3	1	1.83	40-60%
1444	Harp seal locally identified habitat (South Baffin Bay – EA)	0	3	n/a	n/a	3	1	1.83	40-60%
1450	Bearded seal locally identified habitat (HBC)	0	3	n/a	n/a	3	1	1.83	40-60%
1451	Bearded seal locally identified habitat (Lancaster-Boothia area – EA)	0	3	n/a	n/a	3	1	1.83	40-60%
1452	Bearded seal locally identified habitat (South Baffin Bay- EA)	0	3	n/a	n/a	3	1	1.83	40-60%
1460	Ringed seal locally identified habitat (AA)	0	2	n/a	n/a	2	1	1.29	10-20%
1461	Ringed seal locally identified habitat (HBC)	0	2	n/a	n/a	2	1	1.29	10-20%
1462	Ringed seal locally identified habitat (Lancaster-Boothia area - EA)	0	2	n/a	n/a	2	1	1.29	10-20%
1463	Ringed seal locally identified habitat (AA)	0	2	n/a	n/a	2	1	1.29	10-20%

APPENDIX 2.6. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—FISH KEY HABITATS

ID	Conservation Feature	Current Status	Vulnerability: *Life history traits*	Vulnerability: *Fragility*	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1557, 1558,1559	Arctic charr habitat (HBC, EA, AA)	0	3	2	3	1	1.83	40-60%
1577, 1578, 1579	Lumpfish habitat (HBC, EA, AA)	2	2	1	2	1	1.73	20-40%
1580	Rock grenadier habitat	3	2	3	3	2	2.71	80-100%
1596, 1597, 1598, 1599	Arctic cod habitat (HBC, EA, AA, AB)	0	2	1	2	1	1.29	10-20%
1600, 1601,	Spotted wolffish habitat (HBC, EA)	2	3	3	3	1	2.16	40-60%
1602, 1603	Atlantic wolffish habitat (HBC, EA)	1	3	3	3	1	1.91	40-60%
1604, 1605	Northern wolffish habitat (HBC, EA)	2	2	2	2	1	1.73	20-40%
1650, 1651, 1652, 1653	Rajiformes (order) habitat (HBC, EA, AA, AB)	0	3	2	3	1	1.83	40-60%
1654, 1655, 1656, 1657	Coregonus (genus) habitat (HBC, EA, AA, AB)	0	2	2	2	1	1.29	10-20%
1658, 1659, 1660, 1661	Glacier Lantern habitat (HBC, EA, AA, AB)	0	2	1	2	1	1.29	10-20%
1662, 1663, 1664, 1665	Arctic skate habitat (HBC, EA, AA, AB)	0	2	3	3	1	1.83	40-60%
1666, 1667	skate habitat (HBC, EA)	0	3	3	3	2	2.08	40-60%
1668, 1669, 1670, 1671	Fourhorn sculpin habitat (HBC, EA, AA, AB)	0	2	1	2	1	1.29	10-20%
1675	Arctic charr locally identified habitat (HBC)	0	3	2	3	1	1.83	40-60%
1676	Arctic charr locally identified habitat (Lancaster-Boothia area - EA)	0	3	2	3	1	1.83	40-60%
1677	Arctic charr locally identified habitat (South Baffin Bay - EA)	0	3	2	3	1	1.83	40-60%
1680, 1681	Arctic cod locally identified habitat (EA, HBC)	0	1	1	1	1	0.82	10-20%
1685	Greenland shark locally Identified habitat (EA)	0	3	3	3	3	2.45	60-80%

APPENDIX 2.7. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1A—SEABIRD COLONIES

ID	Conservation Feature	Current Status	Vulnerability: Life history traits	Vulnerability: Fragility	Vulnerability: Functional significance	Vulnerability Score	Rarity/ Uniqueness	Overall Score	Target Range
1700, 1701	Black guillemot colonies (AA, AB)	0	2	2	2	2	2	1.63	20-40%
1705, 1706	Black-legged kittiwake colonies (EA, HBC	0	2	1	2	2	2	1.63	20-40%
1710	Dovekie colonies (EA)	0	2	1	1	1	2	1.41	20-40%
1715	Thick-billed murre colonies (EA)	0	2	3	3	3	2	2.08	40-60%
1716	Thick-billed murre colonies (HBC	0	2	2	2	2	2	1.63	20-40%
1720	Ivory gull colonies (AA)	3	3	1	3	3	3	3.00	80-100%
1725	Ross's gull colonies (EA)	2	3	1	3	3	3	2.71	80-100%

APPENDIX 2.8. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1B—SIGNIFICANT BENTHIC AREAS

		Vulnerability							
ID	**Conservation Feature**	*Life history traits*	*Fragility*	*Functional significance*	*Structural complexity*	**Vulnerability Score**	**Rarity/ Uniqueness**	**Overall Score**	**Target Range**
1510	Large gorgonian coral concentrations, Davis Strait (EA)	3	3	3	3	3	3	3.00	80-100%
1511	Large gorgonian coral concentrations, Labrador Sea (EA)	3	3	3	3	3	3	3.00	80-100%
1512	Small gorgonian coral concentrations (EA)	3	3	2	3	3	3	2.89	80-100%
1513	Seapen concentrations, Davis Strait (EA)	3	3	3	2	3	1	2.09	40-60%
1514	Seapen concentrations, Coastal Baffin Island (EA)	3	3	3	2	3	1	2.09	40-60%
1515	Seapen concentrations, Lancaster Sound (EA)	3	3	3	2	3	1	2.09	40-60%
1516	Sponge concentrations (HBC)	3	3	3	3	3	2	2.55	60-80%
1517	Sponge concentrations (EA)	3	3	3	3	3	2	2.55	60-80%

APPENDIX 2.9. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—BENTHIC FAMILY RICHNESS

		Vulnerability						
ID	**Conservation Feature**	*Fragility*	*Functional significance*	*Structural complexity*	**Vulnerability Score**	**Rarity/ Uniqueness**	**Overall Score**	**Target Range**
1500	Benthic Family Richness (>40 families) (HBC)	3	3	3	3	2	2.55	60-80%
1501	Benthic Family Richness (>40 families) (EA)	3	3	3	3	2	2.55	60-80%

APPENDIX 2.10. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—SEABIRD KEY HABITATS (MULTIPLE SPECIES)

		Vulnerability						
ID	Conservation Feature	*Fragility*	*Functional significance*	*Structural complexity*	**Vulnerability Score**	**Rarity/ Uniqueness**	**Overall Score**	**Target Range**
2200	Foraging/breeding areas, Barrow Strait/Prince Regent Inlet (EA)	2	3	2	2	2	2.00	40-60%
2201	Wintering site, Central Davis Strait (EA)	1	3	2	2	2	2.00	40-60%
2202	Foraging/breeding areas, Cornwallis Island (EA)	2	3	2	2	2	2.20	40-60%
2203	Foraging/breeding areas, Cornwallis Island (AA)	2	3	2	2	2	2.20	40-60%
2204	Breeding areas, East Baffin Island (EA)	2	2	2	2	2	2.00	40-60%
2205	Foraging/breeding areas, Frobisher Bay (HBC)	2	2	2	2	2	2.00	40-60%
2206	Foraging/breeding areas, Frobisher Bay (EA)	2	2	2	2	2	2.00	40-60%
2207	Foraging/breeding areas, Lancaster Sound	2	3	3	3	2	2.55	60-80%
2208	Foraging/breeding areas, North Baffin Bay (EA)	2	3	3	3	3	3.00	80-100%
2209	Foraging/breeding areas, North Baffin Bay (AA)	2	3	3	3	3	3.00	80-100%
2210	Breeding areas, Northern Hudson Bay/Hudson Strait (HBC)	2	3	3	3	2	2.55	60-80%
2211	Foraging/molting areas, Northern Ontario coastline (HBC)	2	2	2	2	2	2.00	40-60%
2212	Foraging/breeding areas, Qaqulluit and Akpait (EA)	2	3	2	2	2	2.00	40-60%
2213	Foraging/breeding areas, Seymour Island (AA)	2	3	1	2	2	2.00	40-60%
2214	Year-round eider habitat, Sleeper Islands (HBC)	2	2	2	2	2	2.00	40-60%
2215	Staging/breeding areas, Ungava Bay (HBC)	1	3	2	2	2	2.00	40-60%
2216	Sea-ducks staging/foraging areas, Western Arctic (AA)	1	2	2	2	2	2.00	40-60%
2217	Sea-ducks staging/foraging areas, Western Arctic (AB)	1	2	2	2	2	2.00	40-60%

APPENDIX 2.11. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—IMPORTANT BIRD AREAS

ID	Conservation Feature	Globally Significant	Continentally Significant	Nationally Significant	Overall Score	Target Range
2300	Eastern Prince Patrick Island IBAs (AA)	2	0	0	1.15	10-20%
2301	Hudson Bay west coast IBAs (HBC)	3	1	1	1.91	40-60%
2302	Barrow Strait IBAs (EA)	2	3	2	2.38	60-80%
2303	Eastern Baffin Island IBAs (EA)	3	0	1	1.83	40-60%
2304	Foxe Basin IBAs (HBC)	3	1	1	1.91	40-60%
2305	Jones Sound IBAs (EA)	2	0	2	1.63	20-40%
2306	Lancaster Sound IBAs (EA)	3	1	0	1.83	40-60%
2307	North Baffin Bay IBAs (EA)	2	0	2	1.63	20-40%
2308	Northern Hudson Bay IBAs (HBC)	2	1	1	1.41	20-40%
2309	Northern Ontario coastline IBAs (HBC)	3	1	1	1.91	40-60%
2310	Ungava/Frobisher Bay IBAs (HBC)	2	0	0	1.15	10-20%
2311	Western Quebec coastline & Belcher Islands IBAs (HBC)	2	1	1	1.41	20-40%

APPENDIX 2.12. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—EELGRASS

ID	Conservation Feature	Vulnerability: *Fragility*	Vulnerability: *Functional significance*	Vulnerability: *Structural complexity*	**Vulnerability Score**	**Rarity/ Uniqueness**	**Overall Score**	**Target Range**
2999	Eelgrass beds (HBC)	2	3	3	3	2	2.38	60-80%

APPENDIX 2.13. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—HOTSPOTS

ID	Conservation Feature	Area (km²)	*Target in Km²* Target at 10%	Target at 5%	Target at 2%	*Target in Proportions* Prop. 10%	Prop. 5%	Prop. 2%	Target Range
2000	Polar bear hotspots, winter (HBC)	510263	51026	25513	10205	0.10	0.05	0.02	5-10%
2001	Polar bear hotspots, winter (EA)	143316	27042	13521	5408	0.19	0.09	0.04	10-20%
2002	Polar bear hotspots, winter (AB)	80125	20220	10110	4044	0.25	0.13	0.05	10-25%
2003	Polar bear hotspots, summer (HBC)	213856	33034	16517	6607	0.15	0.08	0.03	10-15%
2004	Polar bear hotspots, summer (EA)	253681	35978	17989	7196	0.14	0.07	0.03	10-15%
2005	Polar bear hotspots, summer (AA)	1978	3177	1589	635	1.00	0.80	0.32	80-100%
2006	Polar bear hotspots, summer (AB)	175991	29967	14983	5993	0.17	0.09	0.03	10-20%
2007	Marine mammal hotspots, winter (HBC)	81186	20353	10177	4071	0.25	0.13	0.05	10-25%
2008	Marine mammal hotspots, winter (EA)	94155	21919	10959	4384	0.23	0.12	0.05	10-25%
2009	Marine mammal hotspots, summer (HB)	214719	33100	16550	6620	0.15	0.08	0.03	10-15%
2010	Marine mammal hotspots, summer (EA)	211864	32880	16440	6576	0.16	0.08	0.03	10-15%
2011	Marine mammal hotspots, summer (AB)	43446	14889	7445	2978	0.34	0.17	0.07	20-35%
2012	Seabird hotspots, summer (HBC)	236715	34754	17377	6951	0.15	0.07	0.03	10-15%
2013	Seabird hotspots, summer (EA)	173663	29768	14884	5954	0.17	0.09	0.03	10-20%
2014	Seabird hotspots, summer (AB)	31408	12660	6330	2532	0.40	0.20	0.08	20-40%
2015	Seabird hotspots, winter (HBC)	223930	33803	16901	6761	0.15	0.08	0.03	10-15%
2016	Seabird hotspots, winter (EA)	149508	27620	13810	5524	0.18	0.09	0.04	10-15%
2017	Seabird hotspots, winter (AB)	4433	4756	2378	951	1.00	0.54	0.21	50-100%

APPENDIX 2.14. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—POLYNYAS

ID	Conservation Feature	Area (km²)	*Target in Km²* Target at 10%	Target at 5%	Target at 2%	*Target in Proportions* Prop. 10%	Prop. 5%	Prop. 2%	Target Range
2050	Polynya (HBC)	119675	11967.50	5983.75	2393.50	0.10	0.05	0.02	5-10%
2051	Polynya (EA)	45497.2	7378.94	3689.47	1475.79	0.16	0.08	0.03	10-15%
2052	Polynya (AA)	5113.76	2473.84	1236.92	494.77	0.48	0.24	0.10	25-50%

APPENDIX 2.15. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—CHLOROPHYLL PERSISTENCE

ID	Conservation Feature	Area (km^2)	*Target in Km^2* Target at 10%	Target at 5%	Target at 2%	*Target in Proportions* Prop. 10%	Prop. 5%	Prop. 2%	Target Range
2404	Maximum Chlor A, SD5 (HBC)	250735	25073.50	12536.75	5014.70	0.10	0.05	0.02	15-30%
2405	Maximum Chlor A, SD5 (EA)	117193	17141.87	8570.94	3428.37	0.15	0.07	0.03	20-40%
2406	Maximum Chlor A, SD5 (AA)	619.268	1246.08	623.04	249.22	1.00	1.00	0.40	35-50%
2407	Maximum Chlor A, SD5 (AB)	9279.39	4823.55	2411.78	964.71	0.52	0.26	0.10	35-50%

APPENDIX 2.16. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 1C—AREAS OF HIGH PRIMARY PRODUCTION

ID	Conservation Feature	Area (km^2)	*Target in Km^2* Target at 10%	Target at 5%	Target at 2%	*Target in Proportions* Prop. 10%	Prop. 5%	Prop. 2%	Target Range
3709	Primary Productivity (1500–2000) (HBC)	55999.8	5599.98	2799.99	1120.00	0.10	0.05	0.02	10-20%
3710	Primary Productivity (1500–2000) (EA)	22276.7	3531.98	1765.99	706.40	0.16	0.08	0.03	20-40%
3711	Primary Productivity (1500–2000) (AA)	833.094	683.03	341.52	136.61	1.00	1.00	0.16	50-100%
3712	Primary Productivity (>2000) (HBC)	19708	3322.11	1661.06	664.42	0.17	0.08	0.03	20-40%
3713	Primary Productivity (>2000) (EA)	9136.3	2261.93	1130.96	452.39	0.25	0.12	0.05	30-50%

APPENDIX 2.17. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—INLETS

ID	Conservation Feature	Area (km^2)	*Target in Km^2* Target at 10%	Target at 5%	Target at 2%	*Target in Proportions* Prop. 10%	Prop. 5%	Prop. 2%	Target Range
3607	Inlet (>1200 km^2) (HBC)	7556.15	2181.57	1090.78	436.31	0.29	0.14	0.06	5-15%
3608	Inlet (>1200 km^2) (EA)	62985.00	6298.50	3149.25	1259.70	0.10	0.05	0.02	2-10%
3609	Inlet (>1200 km^2) (AA)	35040.20	4697.88	2348.94	939.58	0.13	0.07	0.03	5-10%
3610	Inlet (0–32 km^2) (HBC)	2797.00	1327.29	663.64	265.46	0.47	0.24	0.09	10-25%
3611	Inlet (0–32 km^2) (EA)	2126.99	1157.45	578.72	231.49	0.54	0.27	0.11	10-30%
3612	Inlet (0–32 km^2) (AA)	896.14	751.29	375.64	150.26	0.84	0.42	0.17	20-40%
3613	Inlet (121–1200 km^2) (HBC)	2143.20	1161.85	580.92	232.37	0.54	0.27	0.11	10-30%
3614	Inlet (121–1200 km^2) (EA)	1195.04	867.58	433.79	173.52	0.73	0.36	0.15	15-35%
3615	Inlet (121–1200 km^2) (AA)	1769.66	1055.76	527.88	211.15	0.60	0.30	0.12	10-30%
3616	Inlet (121–1200 km^2) with 2nd order sub-inlets (HBC)	11514.00	2692.97	1346.49	538.59	0.23	0.12	0.05	5-10%
3617	Inlet (121–1200 km^2) with 2nd order sub-inlets (EA)	12151.90	2766.56	1383.28	553.31	0.23	0.11	0.05	5-10%
3618	Inlet (121–1200 km^2) with 2nd order sub-inlets (AA)	12858.30	2845.84	1422.92	569.17	0.22	0.11	0.04	5-10%
3619	Inlet (121–1200 km^2) with 2nd order sub-inlets (AB)	11.10	83.63	41.82	16.73	1.00	1.00	1.00	100%
3620	Inlet (32–121 km^2) (HBC)	335.31	459.56	229.78	91.91	1.00	0.69	0.27	30-70%
3621	Inlet (32–121 km^2) (EA)	655.59	642.59	321.30	128.52	0.98	0.49	0.20	20-50%
3622	Inlet (32–121 km^2) (AA)	463.81	540.49	270.25	108.10	1	0.58	0.23	25-60%
3623	Inlet (32–121 km^2) with 2nd order sub-inlets (HBC)	2659.24	1294.19	647.09	258.84	0.49	0.24	0.10	10-25%
3624	Inlet (32–121 km^2) with 2nd order sub-inlets (EA)	2600.78	1279.88	639.94	255.98	0.49	0.25	0.10	10-25%
3625	Inlet (32–121 km^2) with 2nd order sub-inlets (AA)	1586.15	999.52	499.76	199.90	0.63	0.32	0.13	10-30%

APPENDIX 2.18. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—COASTAL FEATURES: INTERTIDAL HABITATS

ID	Conservation Feature	Area (km^2)	Target in Km^2			Target in Proportions			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3600	Intertidal - Other (HBC)	14727.80	1472.78	736.39	294.56	0.10	0.05	0.02	2-10%
3601	Intertidal - Other (EA)	1600.79	485.55	242.78	97.11	0.30	0.15	0.06	5-15%
3602	Intertidal - Other (AA)	1279.91	434.17	217.08	86.83	0.34	0.17	0.07	10-20%
3603	Intertidal - Sandy (HBC)	960.27	376.07	188.03	75.21	0.39	0.20	0.08	10-20%
3604	Intertidal - Sandy (EA)	287.25	205.68	102.84	41.14	0.72	0.36	0.14	15-35%
3605	Intertidal - Sandy (AA)	42.72	79.32	39.66	15.86	1.00	0.93	0.37	40-90%

APPENDIX 2.19. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—COASTAL FEATURES: CLIFFS

ID	Conservation Feature	Area (km^2)	Target in Km^2			Target in Proportions			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3626	Cliffs (HBC)	102.65	53.74	26.87	10.75	0.52	0.26	0.10	25-50%
3627	Cliffs (EA)	2813.44	281.34	140.67	56.27	0.10	0.05	0.02	5-10%
3628	Cliffs (AA)	402.99	106.48	53.24	21.30	0.26	0.13	0.05	15-25%

APPENDIX 2.20. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—COASTAL FEATURES: WETLANDS

ID	Conservation Feature	Area (km^2)	Target in Km^2			Target in Proportions			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3629	Wetland (HBC)	17895.08	1789.51	894.75	357.90	0.10	0.05	0.02	15-30%
3630	Wetland (EA)	1029.04	429.12	214.56	85.82	0.42	0.21	0.08	20-40%
3631	Wetland (AA)	152.01	164.93	82.47	32.99	1.00	0.54	0.22	40-60%

APPENDIX 2.21. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—SEAFLOOR GEOMORPHOLOGY (BENTHIC HABITATS)

ID	Conservation Feature	Area (km²)	Target in Km²			Target in Proportions			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3500	Abyss (AB)	60,651.10	23687.22	11843.61	4737.44	0.39	0.20	0.08	10-20%
3501	Bank (EA)	3870.87	5984.10	2992.05	1196.82	1.00	0.77	0.31	30-80%
3502	Bank (AA)	179.11	1287.21	643.61	257.44	1.00	1.00	1.00	100%
3503	Basin (HBC)	197885.00	42785.96	21392.98	8557.19	0.22	0.11	0.04	5-10%
3504	Basin (EA)	296056.00	52333.74	26166.87	10466.75	0.18	0.09	0.04	5-10%
3505	Basin (AA)	54024.80	22355.86	11177.93	4471.17	0.41	0.21	0.08	10-20%
3506	Basin (AB)	125984.00	34139.13	17069.57	6827.83	0.27	0.14	0.05	5-15%
3507	Canyon (EA)	1362.31	3550.04	1775.02	710.01	1.00	1.00	0.52	50-100%
3508	Canyon (AB)	83386.80	27774.32	13887.16	5554.86	0.33	0.17	0.07	10-20%
3509	Escarpment (EA)	889.41	2868.45	1434.22	573.69	1.00	1.00	0.65	65-100%
3510	Escarpment (AB)	929.28	2932.02	1466.01	586.40	1.00	1.00	0.63	60-100%
3511	Fan (EA)	0.24	47.30	23.65	9.46	1.00	1.00	39.12	100%
3512	Fan (AB)	37419.10	18605.51	9302.75	3721.10	0.50	0.25	0.10	10-25%
3513	Plateau (AB)	67869.70	25057.21	12528.61	5011.44	0.37	0.18	0.07	10-20%
3514	Ridge (AB)	477.57	2101.90	1050.95	420.38	1.00	1.00	0.88	90-100%
3515	Rise (EA)	13699.30	11257.55	5628.78	2251.51	0.82	0.41	0.16	15-40%
3516	Rise (AB)	80166.50	27232.74	13616.37	5446.55	0.34	0.17	0.07	10-20%
3517	Shelf (HBC)	925102.00	92510.20	46255.10	18502.04	0.10	0.05	0.02	2-10%
3518	Shelf (EA)	265527.00	49562.04	24781.02	9912.41	0.19	0.09	0.04	5-10%
3519	Shelf (AA)	112520.00	32263.37	16131.68	6452.67	0.29	0.14	0.06	5-15%
3520	Shelf (AB)	116955.00	32893.05	16446.53	6578.61	0.28	0.14	0.06	5-15%
3521	Shelf Valley (HBC)	115024.00	32620.38	16310.19	6524.08	0.28	0.14	0.06	5-15%
3522	Shelf Valley (EA)	67013.80	24898.71	12449.36	4979.74	0.37	0.19	0.07	10-20%
3523	Shelf Valley (AA)	96050.10	29808.75	14904.37	5961.75	0.31	0.16	0.06	5-15%
3524	Shelf Valley (AB)	34709.00	17919.09	8959.54	3583.82	0.52	0.26	0.10	10-25%
3525	Sill (EA)	1259.43	3413.36	1706.68	682.67	1.00	1.00	0.54	55-100%
3526	Sill (AA)	25.15	482.33	241.17	96.47	1.00	1.00	1.00	100%
3527	Sill (AB)	1309.33	3480.32	1740.16	696.06	1.00	1.00	0.53	50-100%
3528	Slope (EA)	121933.00	33585.78	16792.89	6717.16	0.28	0.14	0.06	5-15%
3529	Slope (AB)	123529.00	33804.87	16902.44	6760.97	0.27	0.14	0.05	5-15%
3530	Terrace (EA)	4970.68	6781.14	3390.57	1356.23	1.00	0.68	0.27	30-70%
3531	Terrace (AB)	18701.20	13153.14	6576.57	2630.63	0.70	0.35	0.14	15-35%

APPENDIX 2.22. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—SEASCAPES, PELAGIC

ID	Conservation Feature	Area (km^2)	*Target in Km^2*			*Target in Proportions*			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3250	<4.13&PermenantlyIce&<0&<30.4_AB	154073.32	15407	7704	3081	0.10	0.05	0.02	5-10%
3251	<4.13&PermenantlyIce&<0&<31.8_AA	1333.63	1433	717	287	1.07	0.54	0.21	30-75%
3252	<4.13&PermenantlyIce&<0&<31.8_AB	189880.08	17104	8552	3421	0.09	0.05	0.02	5-10%
3253	<4.13&PermenantlyOpen&>2&>31.8_EA	4340.97	2586	1293	517	0.60	0.30	0.12	15-40%
3254	<4.13&SeasonallyOpen&<0&<30.4_AA	4779.39	2714	1357	543	0.57	0.28	0.11	20-40%
3255	<4.13&SeasonallyOpen&<0&<30.4_EA	1941.60	1730	865	346	0.89	0.45	0.18	25-60%
3256	<4.13&SeasonallyOpen&<0&<31.8_AA	10265.70	3977	1989	795	0.39	0.19	0.08	10-30%
3257	<4.13&SeasonallyOpen&<0&<31.8_EA	4378.01	2597	1299	519	0.59	0.30	0.12	15-40%
3258	<4.13&SeasonallyOpen&<0&>31.8_AA	1686.98	1612	806	322	0.96	0.48	0.19	30-70%
3259	<4.13&SeasonallyOpen&<0&>31.8_EA	3200.37	2221	1110	444	0.69	0.35	0.14	20-50%
3260	<4.13&SeasonallyOpen&<2&<30.4_EA	7171.07	3324	1662	665	0.46	0.23	0.09	10-30%
3261	<4.13&SeasonallyOpen&<2&<31.8_EA	21820.02	5798	2899	1160	0.27	0.13	0.05	10-20%
3262	<4.13&SeasonallyOpen&<2&<31.8_HBC	49273.62	8713	4357	1743	0.18	0.09	0.04	5-10%
3263	<4.13&SeasonallyOpen&<2&>31.8_AA	1412.98	1475	738	295	1.04	0.52	0.21	30-70%
3264	<4.13&SeasonallyOpen&<2&>31.8_EA	178292.14	16574	8287	3315	0.09	0.05	0.02	5-10%
3265	<4.13&SeasonallyOpen&<2&>31.8_HBC	91206.38	11854	5927	2371	0.13	0.06	0.03	5-10%
3266	<4.13&SeasonallyOpen&>2&<31.8_HBC	19853.16	5531	2765	1106	0.28	0.14	0.06	10-20%
3267	<4.13&SeasonallyOpen&>2&>31.8_EA	113046.82	13198	6599	2640	0.12	0.06	0.02	5-10%
3268	<4.13&SeasonallyOpen&>2&>31.8_HBC	19022.37	5414	2707	1083	0.28	0.14	0.06	10-20%
3269	>8.55&PermenantlyIce&<0&<30.4_AA	8875.73	3698	1849	740	0.42	0.21	0.08	10-30%
3270	>8.55&PermenantlyIce&<0&<30.4_AB	70034.01	10388	5194	2078	0.15	0.07	0.03	5-10%
3271	>8.55&PermenantlyIce&<0&<31.8_AA	38376.16	7689	3845	1538	0.20	0.10	0.04	5-15%
3272	>8.55&PermenantlyIce&<0&<31.8_AB	13435.04	4550	2275	910	0.34	0.17	0.07	10-25%
3273	>8.55&PermenantlyIce&<2&<30.4_AA	5394.82	2883	1442	577	0.53	0.27	0.11	15-40%
3274	>8.55&PermenantlyIce&<2&<30.4_AB	4181.18	2538	1269	508	0.61	0.30	0.12	20-40%
3275	>8.55&PermenantlyIce&<2&<31.8_AA	21313.65	5731	2865	1146	0.27	0.13	0.05	10-20%
3276	>8.55&PermenantlyIce&<2&<31.8_AB	5098.68	2803	1401	561	0.55	0.27	0.11	15-40%
3277	>8.55&SeasonallyOpen&<0&<30.4_AA	15097.55	4823	2411	965	0.32	0.16	0.06	10-20%
3278	>8.55&SeasonallyOpen&<0&<30.4_AB	37871.82	7639	3819	1528	0.20	0.10	0.04	5-15%
3279	>8.55&SeasonallyOpen&<0&<30.4_EA	17253.89	5156	2578	1031	0.30	0.15	0.06	10-20%
3280	>8.55&SeasonallyOpen&<0&<31.8_AA	22049.16	5829	2914	1166	0.26	0.13	0.05	10-20%
3281	>8.55&SeasonallyOpen&<0&<31.8_EA	9734.48	3873	1936	775	0.40	0.20	0.08	10-30%
3282	>8.55&SeasonallyOpen&<0&<31.8_HBC	720.53	1054	527	211	1.46	0.73	0.29	40-100%

3283	>8.55&SeasonallyOpen&<2&<30.4_AA	1625.28	1582	791	316	0.97	0.49	0.19	30-70%
3284	>8.55&SeasonallyOpen&<2&<30.4_AB	38056.47	7657	3829	1531	0.20	0.10	0.04	5-15%
3285	>8.55&SeasonallyOpen&<2&<30.4_EA	15076.92	4820	2410	964	0.32	0.16	0.06	10-20%
3286	>8.55&SeasonallyOpen&<2&<30.4_HBC	117996.17	13483	6742	2697	0.11	0.06	0.02	5-10%
3287	>8.55&SeasonallyOpen&<2&<31.8_EA	36900.51	7540	3770	1508	0.20	0.10	0.04	5-15%
3288	>8.55&SeasonallyOpen&<2&<31.8_HBC	22934.87	5944	2972	1189	0.26	0.13	0.05	10-20%
3289	>8.55&SeasonallyOpen&<2&>31.8_EA	1729.56	1632	816	326	0.94	0.47	0.19	25-65%
3290	>8.55&SeasonallyOpen&>2&<30.4_HBC	289658.93	21126	10563	4225	0.07	0.04	0.01	2-10%
3291	>8.55&SeasonallyOpen&>2&<31.8_HBC	19535.56	5486	2743	1097	0.28	0.14	0.06	10-20%
3292	4.13-8.55&PermenantlyIce&<0&<30.4_AA	1113.05	1310	655	262	1.18	0.59	0.24	35-85%
3293	4.13-8.55&PermenantlyIce&<0&<30.4_AB	179596.08	16635	8317	3327	0.09	0.05	0.02	5-10%
3294	4.13-8.55&PermenantlyIce&<0&<31.8_AA	50259.64	8800	4400	1760	0.18	0.09	0.04	5-10%
3295	4.13-8.55&PermenantlyIce&<0&<31.8_AB	82051.70	11244	5622	2249	0.14	0.07	0.03	5-10%
3296	4.13-8.55&PermenantlyIce&<0&>31.8_AA	1194.59	1357	678	271	1.14	0.57	0.23	30-80%
3297	4.13-8.55&PermenantlyIce&<2&<30.4_AB	228.31	593	297	119	2.60	1.30	0.52	70-100%
3298	4.13-8.55&PermenantlyIce&<2&<31.8_AA	4863.41	2737	1369	547	0.56	0.28	0.11	15-40%
3299	4.13-8.55&PermenantlyIce&<2&<31.8_AB	6336.76	3125	1562	625	0.49	0.25	0.10	15-35%
3300	4.13-8.55&PermenantlyIce&<2&>31.8_AA	764.07	1085	543	217	1.42	0.71	0.28	40-100%
3301	4.13-8.55&PermenantlyIce&>2&>31.8_AA	157.14	492	246	98	3.13	1.57	0.63	90-100%
3302	4.13-8.55&SeasonallyOpen&<0&<30.4_AA	2244.11	1859	930	372	0.83	0.41	0.17	25-60%
3303	4.13-8.55&SeasonallyOpen&<0&<30.4_AB	1245.49	1385	693	277	1.11	0.56	0.22	30-80%
3304	4.13-8.55&SeasonallyOpen&<0&<30.4_EA	24803.00	6182	3091	1236	0.25	0.12	0.05	10-20%
3305	4.13-8.55&SeasonallyOpen&<0&<31.8_AA	14435.53	4716	2358	943	0.33	0.16	0.07	10-20%
3306	4.13-8.55&SeasonallyOpen&<0&<31.8_EA	46240.44	8441	4220	1688	0.18	0.09	0.04	5-10%
3307	4.13-8.55&SeasonallyOpen&<0&>31.8_AA	521.62	896	448	179	1.72	0.86	0.34	50-100%
3308	4.13-8.55&SeasonallyOpen&<2&<30.4_AB	811.52	1118	559	224	1.38	0.69	0.28	40-95%
3309	4.13-8.55&SeasonallyOpen&<2&<30.4_EA	10010.81	3927	1964	785	0.39	0.20	0.08	10-30%
3310	4.13-8.55&SeasonallyOpen&<2&<31.8_EA	88288.01	11663	5832	2333	0.13	0.07	0.03	5-10%
3311	4.13-8.55&SeasonallyOpen&<2&<31.8_HBC	30665.43	6874	3437	1375	0.22	0.11	0.04	5-15%
3312	4.13-8.55&SeasonallyOpen&<2&>31.8_AA	130.67	449	224	90	3.43	1.72	0.69	100%
3313	4.13-8.55&SeasonallyOpen&<2&>31.8_EA	64374.48	9959	4980	1992	0.15	0.08	0.03	5-10%
3314	4.13-8.55&SeasonallyOpen&<2&>31.8_HBC	14247.87	4685	2343	937	0.33	0.16	0.07	10-20%
3315	4.13-8.55&SeasonallyOpen&>2&<30.4_HBC	96032.53	12164	6082	2433	0.13	0.06	0.03	5-10%
3316	4.13-8.55&SeasonallyOpen&>2&<31.8_HBC	136228.60	14488	7244	2898	0.11	0.05	0.02	5-10%
3317	4.13-8.55&SeasonallyOpen&>2&>31.8_EA	271.04	646	323	129	2.38	1.19	0.48	65-100%

APPENDIX 2.23. CONSERVATION FEATURES AND TARGETS FOR OBJECTIVE 2—SEASCAPES, BENTHIC

ID	Conservation Feature	Area (km²)	Target in Km²			Target in Proportions			Target Range
			Target at 10%	Target at 5%	Target at 2%	Prop. 10%	Prop. 5%	Prop. 2%	
3000	0-50m&<0.13&<0&<34.7_AA	75.71	599.76	299.88	119.95	1.00	1.00	1.00	100%
3001	0-50m&<0.13&<0&<34.7_AB	30.78	382.39	191.20	76.48	1.00	1.00	1.00	100%
3002	0-50m&<0.13&<0&<34.7_EA	37.37	421.33	210.66	84.27	1.00	1.00	1.00	100%
3003	0-50m&<0.13&<2&<34.7_AA	57.76	523.83	261.92	104.77	1.00	1.00	1.00	100%
3004	0-50m&<0.36&<0&<31.8_AA	1040.31	2223.15	1111.57	444.63	1.00	1.00	0.43	40-60%
3005	0-50m&<0.36&<0&<31.8_AB	34.30	403.69	201.84	80.74	1.00	1.00	1.00	100%
3006	0-50m&<0.36&<0&<31.8_EA	96.29	676.35	338.17	135.27	1.00	1.00	1.00	100%
3007	0-50m&<0.36&<0&<31.8_HBC	175.75	913.75	456.88	182.75	1.00	1.00	1.00	100%
3008	0-50m&<0.36&<0&<34.7_AA	866.31	2028.72	1014.36	405.74	1.00	1.00	0.47	50-70%
3009	0-50m&<0.36&<0&<34.7_AB	31.20	384.99	192.49	77.00	1.00	1.00	1.00	100%
3010	0-50m&<0.36&<0&<34.7_EA	854.57	2014.93	1007.47	402.99	1.00	1.00	0.47	50-70%
3011	0-50m&<0.36&<0&<34.7_HBC	97.47	680.49	340.25	136.10	1.00	1.00	1.00	100%
3012	0-50m&<0.36&<0&>34.7_AA	22.03	323.48	161.74	64.70	1.00	1.00	1.00	100%
3013	0-50m&<0.36&<2&<31.8_AA	187.15	942.92	471.46	188.58	1.00	1.00	1.00	100%
3014	0-50m&<0.36&<2&<31.8_EA	157.00	863.65	431.82	172.73	1.00	1.00	1.00	100%
3015	0-50m&<0.36&<2&<31.8_HBC	899.00	2066.65	1033.32	413.33	1.00	1.00	0.46	50-70%
3016	0-50m&<0.36&<2&<34.7_AA	941.28	2114.68	1057.34	422.94	1.00	1.00	0.45	50-70%
3017	0-50m&<0.36&<2&<34.7_HBC	78.54	610.83	305.41	122.17	1.00	1.00	1.00	100%
3018	0-50m&<0.36&>2&<31.8_HBC	590.56	1675.01	837.51	335.00	1.00	1.00	0.57	60-80%
3019	0-50m&>0.36&<0&<31.8_AA	407.64	1391.63	695.82	278.33	1.00	1.00	0.68	70-90%
3020	0-50m&>0.36&<0&<31.8_EA	867.35	2029.94	1014.97	405.99	1.00	1.00	0.47	50-70%
3021	0-50m&>0.36&<0&<31.8_HBC	3382.76	4008.86	2004.43	801.77	1.00	0.59	0.24	20-40%
3022	0-50m&>0.36&<0&<34.7_AA	352.93	1294.89	647.45	258.98	1.00	1.00	0.73	70-90%
3023	0-50m&>0.36&<0&<34.7_EA	2369.82	3355.40	1677.70	671.08	1.00	0.71	0.28	30-50%
3024	0-50m&>0.36&<0&<34.7_HBC	5639.37	5176.08	2588.04	1035.22	0.92	0.46	0.18	20-40%
3025	0-50m&>0.36&<2&<31.8_AA	141.05	818.59	409.29	163.72	1.00	1.00	1.00	100%
3026	0-50m&>0.36&<2&<31.8_EA	5751.05	5227.08	2613.54	1045.42	0.91	0.45	0.18	20-40%
3027	0-50m&>0.36&<2&<31.8_HBC	38658.56	13552.16	6776.08	2710.43	0.35	0.18	0.07	10-20%
3028	0-50m&>0.36&<2&<34.7_AA	709.46	1835.91	917.95	367.18	1.00	1.00	0.52	50-70%
3029	0-50m&>0.36&<2&<34.7_EA	1090.65	2276.29	1138.15	455.26	1.00	1.00	0.42	40-60%
3030	0-50m&>0.36&<2&<34.7_HBC	64742.40	17538.00	8769.00	3507.60	0.27	0.14	0.05	5-10%
3031	0-50m&>0.36&>_2&<31.8_EA	40.99	441.31	220.65	88.26	1.00	1.00	1.00	100%
3032	0-50m&>0.36&>_2&<31.8_HBC	57205.86	16485.65	8242.82	3297.13	0.29	0.14	0.06	5-10%

3033	0-50m&>0.36&>_2&<34.7_EA	23.54	334.40	167.20	66.88	1.00	1.00	1.00	100%
3034	0-50m&>0.36&>_2&<34.7_HBC	3014.65	3784.46	1892.23	756.89	1.00	0.63	0.25	30-50%
3035	200-1000m&<0.13&<0&<31.8_AB	81.50	622.24	311.12	124.45	1.00	1.00	1.00	100%
3036	200-1000m&<0.13&<0&<34.7_AA	1855.27	2968.86	1484.43	593.77	1.00	0.80	0.32	30-50%
3037	200-1000m&<0.13&<_0&<34.7_AB	4601.80	4675.73	2337.87	935.15	1.00	0.51	0.20	20-40%
3038	200-1000m&<0.13&<0&<34.7_EA	672.20	1787.04	893.52	357.41	1.00	1.00	0.53	50-70%
3039	200-1000m&<0.13&<0&>_34.7_AB	3686.77	4185.13	2092.56	837.03	1.00	0.57	0.23	20-40%
3040	200-1000m&<0.13&<2&<34.7_AA	5302.92	5019.30	2509.65	1003.86	0.95	0.47	0.19	20-40%
3041	200-1000m&<0.13&<2&34.7_AB	146.73	834.92	417.46	166.98	1.00	1.00	1.00	100%
3042	200-1000m&<0.13&<2&<34.7_EA	723.18	1853.57	926.79	370.71	1.00	1.00	0.51	50-70%
3043	200-1000m&<0.13&<2&>34.7_AA	7310.74	5893.41	2946.70	1178.68	0.81	0.40	0.16	20-40%
3044	200-1000m&<0.13&<2&>34.7_AB	12325.46	7652.22	3826.11	1530.44	0.62	0.31	0.12	10-30%
3045	200-1000m&<0.13&<2&>34.7_EA	35.60	411.23	205.61	82.25	1.00	1.00	1.00	100%
3046	200-1000m&<0.36&<0&<31.8_AA	427.87	1425.74	712.87	285.15	1.00	1.00	0.67	70-90%
3047	200-1000m&<0.36&<0&<31.8_AB	219.99	1022.33	511.17	204.47	1.00	1.00	0.93	90-100%
3048	200-1000m&<0.36&<0&<34.7_AA	21864.69	10191.95	5095.98	2038.39	0.47	0.23	0.09	10-20%
3049	200-1000m&<0.36&<0&<34.7_AB	23088.64	10473.33	5236.67	2094.67	0.45	0.23	0.09	10-20%
3050	200-1000m&<0.36&<0&<34.7_EA	22845.01	10417.93	5208.97	2083.59	0.46	0.23	0.09	10-20%
3051	200-1000m&<0.36&<0&<34.7_HBC	6795.60	5681.98	2840.99	1136.40	0.84	0.42	0.17	20-40%
3052	200-1000m&<0.36&<0&>34.7_AA	7924.90	6135.96	3067.98	1227.19	0.77	0.39	0.15	20-40%
3053	200-1000m&<0.36&<0&>34.7_AB	6127.58	5395.48	2697.74	1079.10	0.88	0.44	0.18	20-40%
3054	200-1000m&<0.36&<2&<31.8_EA	93.12	665.13	332.57	133.03	1.00	1.00	1.00	100%
3055	200-1000m&<0.36&<2&<34.7_AA	16357.28	8815.38	4407.69	1763.08	0.54	0.27	0.11	10-30%
3056	200-1000m&<0.36&<2&<34.7_AB	21078.85	10007.12	5003.56	2001.42	0.47	0.24	0.09	10-20%
3057	200-1000m&<0.36&<2&<34.7_EA	70063.92	18244.54	9122.27	3648.91	0.26	0.13	0.05	5-10%
3058	200-1000m&<0.36&<2&<34.7_HBC	25.43	347.60	173.80	69.52	1.00	1.00	1.00	100%
3059	200-1000m&<0.36&<2&>34.7_AA	38177.55	13467.59	6733.79	2693.52	0.35	0.18	0.07	10-20%
3060	200-1000m&<0.36&<2&>34.7_AB	147580.60	26478.93	13239.46	5295.79	0.18	0.09	0.04	5-10%
3061	200-1000m&<0.36&<2&>34.7_EA	528.20	1584.11	792.05	316.82	1.00	1.00	0.60	60-80%
3062	200-1000m&<0.36&>2&<34.7_EA	321.06	1235.03	617.51	247.01	1.00	1.00	0.77	80-100%
3063	200-1000m&<0.36&>2&>34.7_EA	6553.30	5579.76	2789.88	1115.95	0.85	0.43	0.17	20-40%
3064	200-1000m&>0.36&<0&<34.7_AA	9666.33	6776.67	3388.34	1355.33	0.70	0.35	0.14	10-30%
3065	200-1000m&>0.36&<0&<34.7_AB	2264.86	3280.24	1640.12	656.05	1.00	0.72	0.29	30-50%
3066	200-1000m&>0.36&<0&<34.7_EA	88842.24	20544.50	10272.25	4108.90	0.23	0.12	0.05	5-10%
3067	200-1000m&>0.36&<0&<34.7_HBC	113284.22	23199.06	11599.53	4639.81	0.20	0.10	0.04	5-10%
3068	200-1000m&>0.36&<0&>34.7_AA	1535.59	2700.99	1350.50	540.20	1.00	0.88	0.35	40-60%
3069	200-1000m&>0.36&<2&<31.8_EA	68.48	570.38	285.19	114.08	1.00	1.00	1.00	100%
3070	200-1000m&>0.36&<2&<34.7_AA	581.51	1662.13	831.07	332.43	1.00	1.00	0.57	60-80%

3071	200-1000m&>0.36&<2&<34.7_AB	118.93	751.68	375.84	150.34	1.00	1.00	1.00	100%
3072	200-1000m&>0.36&<2&<34.7_EA	73207.20	18649.31	9324.65	3729.86	0.25	0.13	0.05	5-10%
3073	200-1000m&>0.36&<2&<34.7_HBC	18558.39	9389.79	4694.90	1877.96	0.51	0.25	0.10	10-30%
3074	200-1000m&>0.36&<2&>_34.7_AA	2256.84	3274.43	1637.22	654.89	1.00	0.73	0.29	30-50%
3075	200-1000m&>0.36&<2&>34.7_AB	727.24	1858.76	929.38	371.75	1.00	1.00	0.51	50-70%
3076	200-1000m&>0.36&>2&<34.7_EA	32744.74	12472.59	6236.29	2494.52	0.38	0.19	0.08	10-20%
3077	200-1000m&>0.36&2&<34.7_HBC	3761.86	4227.53	2113.77	845.51	1.00	0.56	0.22	20-40%
3078	200-1000m&>0.36&>2&>_34.7_EA	41650.30	14066.78	7033.39	2813.36	0.34	0.17	0.07	10-20%
3079	50-200m&<0.13&<0&<31.8_AA	88.29	647.67	323.83	129.53	1.00	1.00	1.00	100%
3080	50-200m&<0.13&<0&<34.7_AA	1459.72	2633.42	1316.71	526.68	1.00	0.90	0.36	40-60%
3081	50-200m&<0.13&<0&<34.7_AB	2757.36	3619.37	1809.68	723.87	1.00	0.66	0.26	30-50%
3082	50-200m&<0.13&<0&<34.7_EA	58.72	528.19	264.09	105.64	1.00	1.00	1.00	100%
3083	50-200m&<0.13&<2&<34.7_AA	1230.48	2417.82	1208.91	483.56	1.00	0.98	0.39	40-60%
3084	50-200m&<0.13&<2&<34.7_EA	40.22	437.12	218.56	87.42	1.00	1.00	1.00	100%
3085	50-200m&<0.13&<2&>34.7_AA	103.02	699.58	349.79	139.92	1.00	1.00	1.00	100%
3086	50-200m&<0.13&<2&>34.7_AB	136.65	805.74	402.87	161.15	1.00	1.00	1.00	100%
3087	50-200m&<0.36&<0&<31.8_AA	1334.68	2518.11	1259.05	503.62	1.00	0.94	0.38	40-60%
3088	50-200m&<0.36&<0&<31.8_AB	173.02	906.64	453.32	181.33	1.00	1.00	1.00	100%
3089	50-200m&<0.36&<0&<31.8_EA	249.62	1088.99	544.50	217.80	1.00	1.00	0.87	90-100%
3090	50-200m&<0.36&<0&<31.8_HBC	10107.83	6929.70	3464.85	1385.94	0.69	0.34	0.14	10-30%
3091	50-200m&<0.36&<0&<34.7_AA	18927.76	9482.77	4741.39	1896.55	0.50	0.25	0.10	10-30%
3092	50-200m&<0.36&<0&<34.7_AB	7822.66	6096.25	3048.13	1219.25	0.78	0.39	0.16	20-40%
3093	50-200m&<0.36&<0&<34.7_EA	13839.45	8108.59	4054.29	1621.72	0.59	0.29	0.12	10-30%
3094	50-200m&<0.36&<0&<34.7_HBC	145449.08	26287.01	13143.51	5257.40	0.18	0.09	0.04	5-10%
3095	50-200m&<0.36&<0&>34.7_AA	360.57	1308.82	654.41	261.76	1.00	1.00	0.73	70-90%
3096	50-200m&<0.36&<2&<31.8_AA	230.13	1045.62	522.81	209.12	1.00	1.00	0.91	90-100%
3097	50-200m&<0.36&<2&<31.8_EA	280.61	1154.61	577.30	230.92	1.00	1.00	0.82	80-100%
3098	50-200m&<0.36&<2&<31.8_HBC	3264.22	3938.00	1969.00	787.60	1.00	0.60	0.24	20-40%
3099	50-200m&<0.36&<2&<34.7_AA	10644.85	7111.41	3555.70	1422.28	0.67	0.33	0.13	10-30%
3100	50-200m&<0.36&<2&<34.7_AB	383.03	1348.97	674.49	269.79	1.00	1.00	0.70	70-90%
3101	50-200m&<0.36&<2&<34.7_EA	874.90	2038.76	1019.38	407.75	1.00	1.00	0.47	50-70%
3102	50-200m&<0.36&<2&<34.7_HBC	835.99	1992.90	996.45	398.58	1.00	1.00	0.48	50-70%
3103	50-200m&<0.36&<2&>34.7_AA	880.63	2045.42	1022.71	409.08	1.00	1.00	0.46	50-70%
3104	50-200m&<0.36&<2&>34.7_AB	272.84	1138.52	569.26	227.70	1.00	1.00	0.83	80-100%
3105	50-200m&<0.36&>2&<31.8_HBC	1284.44	2470.26	1235.13	494.05	1.00	0.96	0.38	40-60%
3106	50-200m&>0.36&<0&<31.8_AA	1543.45	2707.90	1353.95	541.58	1.00	0.88	0.35	40-60%
3107	50-200m&>0.36&<0&<31.8_EA	1790.96	2916.95	1458.48	583.39	1.00	0.81	0.33	30-50%
3108	50-200m&>0.36&<0&<31.8_HBC	53924.42	16005.84	8002.92	3201.17	0.30	0.15	0.06	10-20%

3109	50-200m&>0.36&<0&<34.7_AA	17306.33	9067.52	4533.76	1813.50	0.52	0.26	0.10	10-30%
3110	50-200m&>0.36&<0&<34.7_AB	507.81	1553.23	776.61	310.65	1.00	1.00	0.61	60-80%
3111	50-200m&>0.36&<0&<34.7_EA	65322.55	17616.41	8808.20	3523.28	0.27	0.13	0.05	5-10%
3112	50-200m&>0.36&<0&<34.7_HBC	423085.56	44833.21	22416.61	8966.64	0.11	0.05	0.02	2-10%
3113	50-200m&>0.36&<0&>34.7_AA	28.44	367.60	183.80	73.52	1.00	1.00	1.00	100%
3114	50-200m&>0.36&<2&<31.8_AA	91.25	658.44	329.22	131.69	1.00	1.00	1.00	100%
3115	50-200m&>0.36&<2&<31.8_EA	7743.31	6065.25	3032.63	1213.05	0.78	0.39	0.16	20-40%
3116	50-200m&>0.36&<2&<31.8_HBC	35784.87	13038.73	6519.37	2607.75	0.36	0.18	0.07	10-20%
3117	50-200m&>0.36&<2&<34.7_AA	2012.35	3091.99	1545.99	618.40	1.00	0.77	0.31	30-50%
3118	50-200m&>0.36&<2&<34.7_EA	16089.93	8743.05	4371.52	1748.61	0.54	0.27	0.11	10-30%
3119	50-200m&>0.36&<2&<34.7_HBC	31749.33	12281.55	6140.77	2456.31	0.39	0.19	0.08	10-20%
3120	50-200m&>0.36&<2&>34.7_AA	81.88	623.68	311.84	124.74	1.00	1.00	1.00	100%
3121	50-200m&>0.36&>2&<31.8_EA	64.97	555.56	277.78	111.11	1.00	1.00	1.00	100%
3122	50-200m&>0.36&>2&<31.8_HBC	18736.26	9434.68	4717.34	1886.94	0.50	0.25	0.10	10-30%
3123	50-200m&>0.36&>2&<34.7_EA	193.23	958.13	479.07	191.63	1.00	1.00	0.99	100%
3124	50-200m&>0.36&>2&<34.7_HBC	3635.32	4155.82	2077.91	831.16	1.00	0.57	0.23	20-40%
3125	Gr1000m&<0.13&<0&>34.7_AB	475085.21	47508.52	23754.26	9501.70	0.10	0.05	0.02	2-10%
3126	Gr1000m&<0.13&<2&>34.7_AB	5396.06	5063.19	2531.59	1012.64	0.94	0.47	0.19	20-40%
3127	Gr1000m&<0.36&<0&<34.7_EA	65517.30	17642.65	8821.32	3528.53	0.27	0.13	0.05	5-10%
3128	Gr1000m&<0.36&<0&>34.7_AB	25457.12	10997.41	5498.70	2199.48	0.43	0.22	0.09	10-20%
3129	Gr1000m&<0.36&<2&<34.7_EA	19303.22	9576.36	4788.18	1915.27	0.50	0.25	0.10	10-30%
3130	Gr1000m&<0.36&<2&>34.7_AB	3319.87	3971.43	1985.71	794.29	1.00	0.60	0.24	20-40%
3131	Gr1000m&<0.36&<2&>34.7_EA	219.22	1020.53	510.27	204.11	1.00	1.00	0.93	90-100%
3132	Gr1000m&<0.36&>2&>34.7_EA	36408.43	13151.85	6575.92	2630.37	0.36	0.18	0.07	10-20%
3133	Gr1000m&>0.36&<0&<34.7_EA	51022.10	15569.15	7784.58	3113.83	0.31	0.15	0.06	10-20%
3134	Gr1000m&>0.36&<2&<34.7_EA	9369.72	6671.89	3335.95	1334.38	0.71	0.36	0.14	10-30%
3135	Gr1000m&>0.36&>2&<34.7_EA	68.78	571.61	285.81	114.32	1.00	1.00	1.00	100%
3136	Gr1000m&>0.36&>2&>34.7_EA	2069.76	3135.78	1567.89	627.16	1.00	0.76	0.30	30-50%

APPENDIX 3: GEOGRAPHIC POSITIONS OF THE PRIORITY AREAS FOR CONSERVATION (PACS) IDENTIFIED IN THE MECCEA STUDY.

The locations and reference number of each PAC are shown below in Figures A3.1, A3.2, and A3.3, for minimum, median, and high conservation targets, respectively.

For each PAC, a full listing of the conservation features it contains is on record with WWF-Canada. Because these are very lengthy lists they are not included in this report. However, access to this data is available by request to WWF-Canada citing the reference number for any of the three target scenarios. Note that these PACs are not given names since they constitute proposals not established sites.

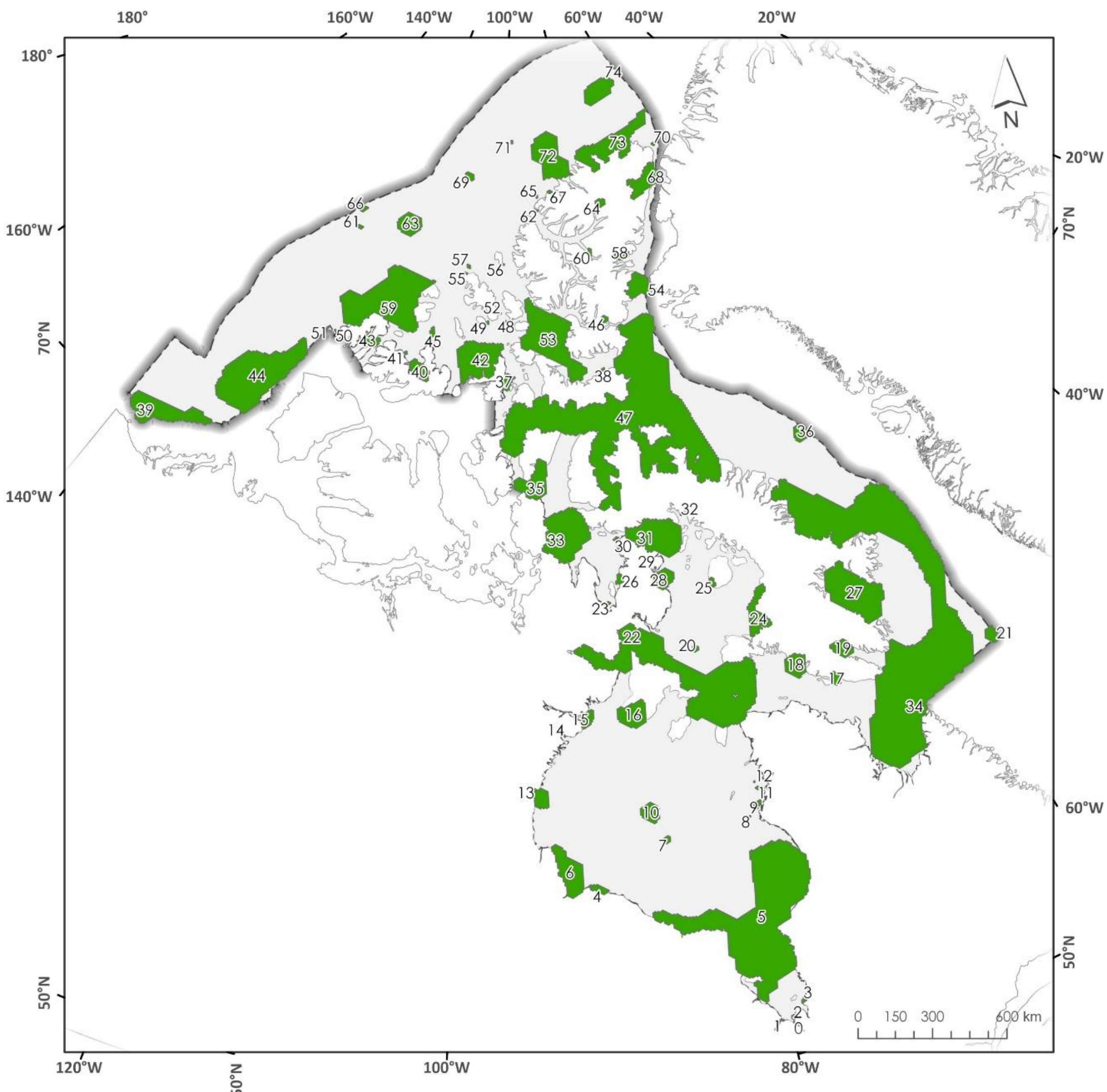

Figure A3.1. Locations and identification numbers of the MECCEA PACs for the minimum target scenario.

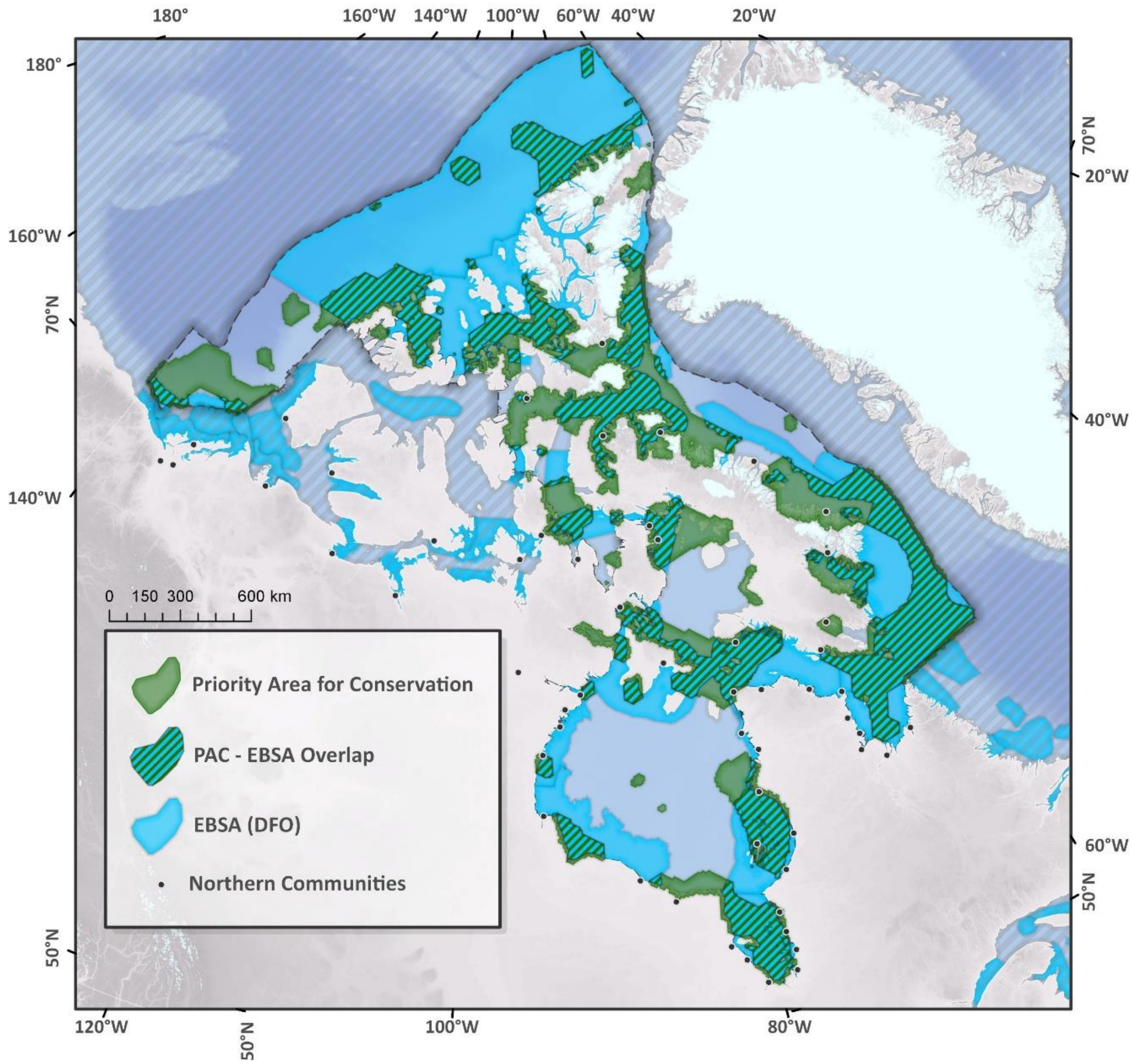

Figure A3.2. Locations and identification numbers of the MECCEA PACs for the median target scenario.

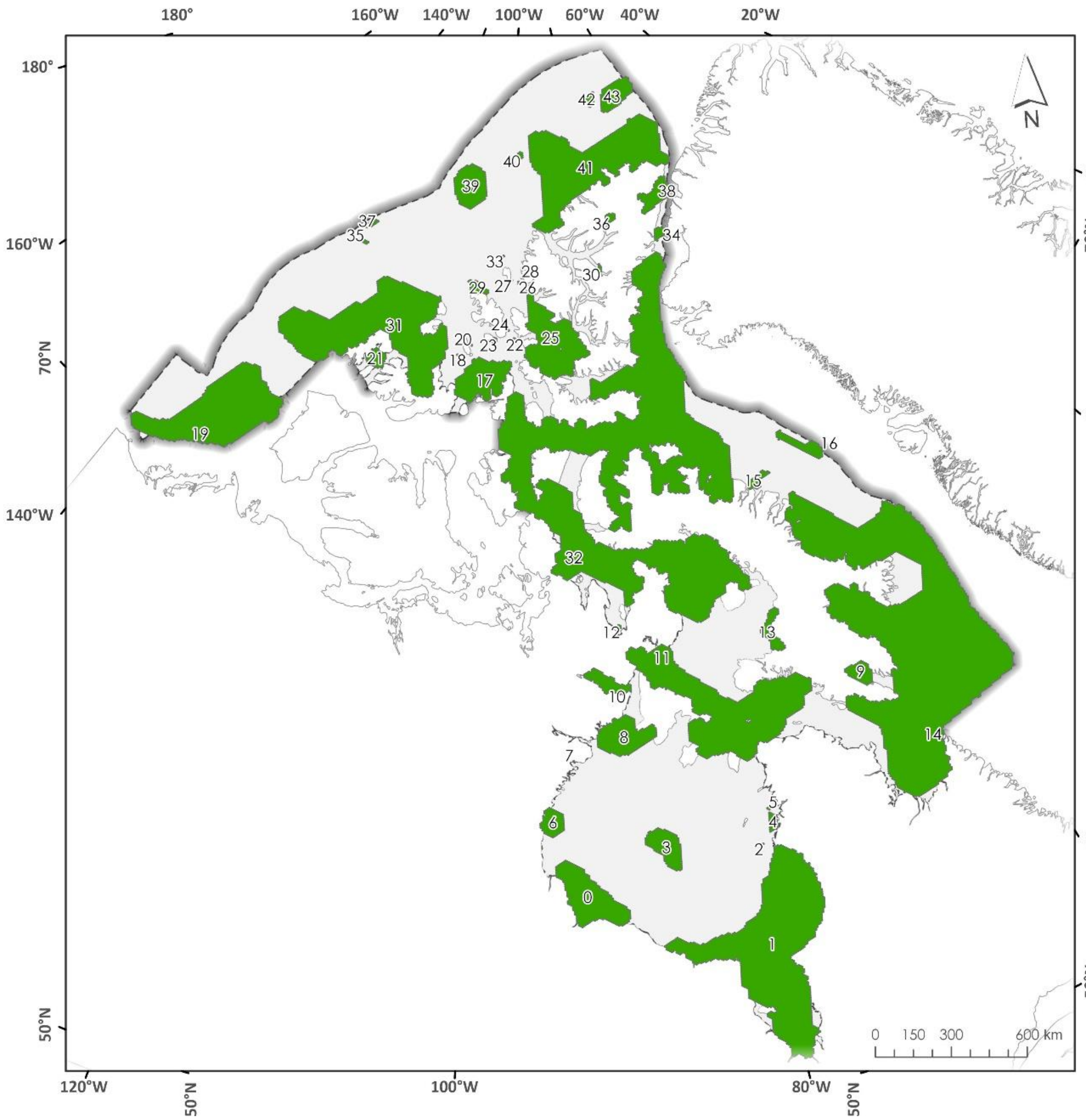

Figure A3.3. Locations and identification numbers of the MECCEA PACs for the high target scenario.

Photo: Arctic sunset near Pond Inlet, Canada. Image used under license from Shutterstock.com