WWF CANADA

CANADIAN ARCTIC MARINE PRIORITY AREAS FOR CONSERVATION

A systematic planning approach for identifying a network of priority areas for conservation in the Eastern Arctic

CONTENTS

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FOREWORD

Climate change is impacting the Arctic more rapidly than anywhere else on Earth. As Canada and the world step up to protect 30 per cent of marine areas by 2030, ensuring that we are getting it right with conservation action — protecting the most important things in the right places — has never been more urgent.

For three years, WWF-Canada worked to identify a potential network of protected areas in four of the five Arctic marine bioregions to guide conservation planning across the region. We analyzed more than 500 features of the Canadian Arctic marine bioregions: from the rich diversity of the floe edge to the depths of underwater canyons, and from coastal seabird colonies and offshore polynyas to a wide range of species and habitats. We looked at how key areas across the Arctic are connected to ocean currents and the wildlife that traverse this unique ecosystem, identifying the locations of the most productive ecosystems that support the entire Arctic food web.

Consolidating this wealth of information in the Arctic from both scientific and Indigenous knowledge sources has enabled us to identify where protection can best support the viability of this unique and globally significant ecosystem into the future.

WWF-Canada trusts that this work will act as impetus to governments and rightsholders to enact additional conservation measures in a fully integrated network plan. The Arctic marine bioregions in Canada must now be given priority to ensure they remain a place where people and nature thrive.

Megan Leslie,
WWF-Canada CEO and President

SUMMARY

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Robust conservation network planning and adaptive management are of paramount importance for maintaining a healthy ocean in the face of increasing human pressures and rapid climate change in the Arctic Ocean.

The Canadian Arctic Marine Priority Areas for Conservation (CanPAC) project is the first to design a network of ecologically connected Priority Areas for Conservation (PACs) in the Canadian Eastern Arctic, and the first to cover more than a single bioregion. This project shows how Canada can take the first steps toward network planning as it works to reach its international commitment to protect 30 per cent of Canadian waters by 2030.

The systematic conservation planning approach used in CanPAC contributes to ongoing efforts to establish Arctic Marine Protected Areas (MPAs[1]) and to inform future marine conservation and regional planning such as marine spatial planning (MSP) and ecosystem-based management, by identifying key components of marine biodiversity. CanPAC consolidates an enormous breadth and depth of available information from conventional scientific and Indigenous Knowledge (IK) sources about the marine Arctic environment, and is underpinned by expert support. CanPAC demonstrates that conservation planning is achievable, even in the relatively data-poor Canadian Arctic. It also establishes a baseline for developing future conservation plans.

[1] In this report, the acronym MPA is used in a generic sense, not specifically in reference to protected areas under the jurisdiction of Fisheries and Oceans Canada.

A CHANGING ARCTIC

The rate of climate warming in the Canadian Arctic is almost triple the global average — an alarming trend that is expected to continue into the future (Bush et al., 2019). The Last Ice Area, an area of the Arctic Archipelago that lies between Northern Canada and Greenland, is projected to be the place where Arctic summer sea ice will persist the longest (Huard and Tremblay, 2013). Current changes and predictions of largely ice-free summers in the Arctic Ocean by mid-century (IPCC, 2013) will have cascading effects on ecosystems: from algae, to fish, to marine mammals. Communities that rely on the Arctic and subarctic marine environment for subsistence, livelihoods and culture will experience major impacts to their ways of life.

Arctic marine ecosystems also play an important role in moderating global climate, contributing to overall marine biodiversity, and are central to providing food security, income and cultural identity for Northern communities. Establishing a network of conservation areas is one of the keys to building ecosystem resilience in the face of the climate crisis because networks create conservation measures that spread risk from climate change and other threats across more areas, and provide links needed for ecosystem processes and connectivity. The IUCN's definition of an MPA network identifies that networks "fulfill ecological aims more effectively and comprehensively than individual sites could alone" (IUCN, 2008). Connectivity and networks are important for marine conservation because many species are on the move, whether actively or carried by ocean currents. A stand-alone MPA can only capture a snapshot of the diversity of species and habitats, and the interconnections between them. Networks can holistically capture and protect the integrity of these dynamic ecosystems.

As a nation, Canada has the longest coastline in the world

— over 70 per cent of it in the Arctic. The Canadian Arctic is home to more than 80,000 people, including Inuit, First Nations and Métis. The majority of the Inuit population lives in 53 communities across Nunavut, Nunavik, Nunatsiavut and the Inuvialuit Settlement Region. Gwich'in live in the Western Arctic, while Cree, Dene and Métis reside in the subarctic regions of southern and western Hudson Bay. Indigenous territories and coastal communities within the study area and adjacent marine bioregions are identified in Figure 1.

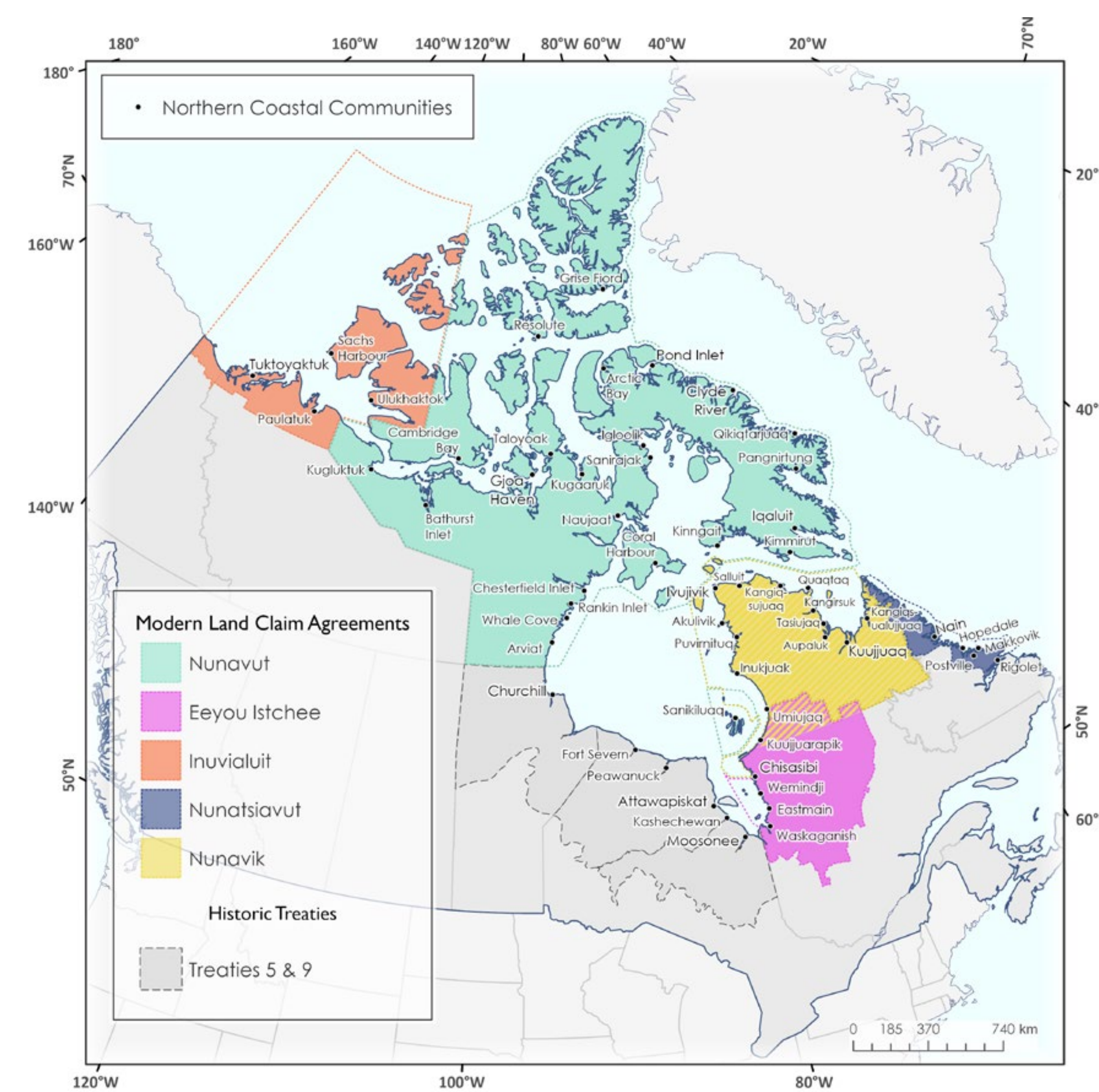

Figure 1. Indigenous communities and territories within the CanPAC study area.

PROTECTING MARINE WATERS IN THE ARCTIC REQUIRES NETWORK PLANNING

The Government of Canada defines an MPA network as a set of complementary and ecologically linked MPAs well as as other effective area-based conservation measures (OEABCMs — areas not designated as MPAs that still provide some benefits to conservation). These networks protect representative examples of ecosystems or habitat types in a region, as well as special or unique areas (Government of Canada, 2011). The government also recognizes five ecologically defined marine bioregions (Arctic Basin, Arctic Archipelago, Eastern Arctic, Hudson Bay Complex and Western Arctic) within the Canadian Arctic that underpin marine conservation planning efforts (Figure 2).

Networks for protection can be identified by systematic conservation planning — a framework that helps identify a set of candidate sites that contribute to enhanced marine biodiversity over a larger area than any standalone MPA.

Marine Protected Areas

The term Marine Protected Areas (MPAs) is used here to refer to a range of area-based protections in the marine environment, including MPAs designated under the Oceans Act, National Wildlife Areas, National Marine Conservation Areas and Indigenous Protected and Conserved Areas, among others.

Over the past few years, Canada has been actively engaged in designating marine areas for protection in order to meet the internationally agreed-upon Aichi Target 11 of protecting 10 per cent of coastal and marine areas by 2020 (CBD, 2011). With all MPAs and OEABCMs established by the end of 2020, Canada has protected approximately 793,906 km² (or 13.81 per cent) of Canada's marine waters, including 15 per cent of Canada's Arctic waters. However, to date, these Arctic MPAs have been designated without a broader network plan or design.

To be effective, these protected areas should be incorporated into a network that is ecologically connected — one that can drive the replenishment of biodiversity in areas damaged by natural or human drivers (Kenchington et al., 2016) and help safeguard species from the effects of climate change (Costello and Connor, 2019). Current ad hoc approaches miss the opportunity to achieve the enhanced conservation benefits that MPA network planning provides. In Canada's Arctic, which remains relatively intact, we still have a chance to get it right.

In December 2019, the Government of Canada committed to working toward a new target of protecting 25 per cent of Canada's oceans by 2025, and subsequently 30 per cent by 2030. This will need to be consistent with IUCN's 2030 global target to protect 30 per cent of each marine habitat in a network of highly protected MPAs[2] and OEABCMs that are free of extraction, in order to achieve a sustainable ocean (WCC, 2016). Indigenous Protected and Conserved Areas (IPCAs) are also gaining recognition as an important tool for biodiversity conservation and meeting national and international targets. **CanPAC is designed to identify the priority areas for protection as we work towards meeting these targets, using a range of conservation tools such as IPCAs.**

Indigenous Protected and Conserved Areas (IPCAs)

comprise "lands and waters where Indigenous governments have the primary role in protecting and conserving ecosystems through Indigenous laws, governance and knowledge systems." IPCAs include a variety of land protection initiatives including Tribal Parks, Indigenous Protected Areas, Indigenous Conserved Areas and Indigenous Cultural Landscapes, some of which count towards Canada's protected area targets. While IPCAs vary with respect to their governance approaches and management objectives, they generally have three key elements in common: The are Indigenous-led; they represent a long-term commitment to conservation; and they elevate Indigenous rights and responsibilities.

The most comprehensive MPA planning undertaken for marine conservation in the Arctic thus far was developed in Russia by WWF-Russia, where the entire Russian Exclusive Economic Zone (EEZ) was analyzed based on comprehensive geophysical data and historical biological records (Solovyev et al., 2017; Spiridonov et al., 2017). That process is similar to the one undertaken here by WWF-Canada.

CanPAC HELPS TO IDENTIFY A WAY TO MEET CANADA'S 30 PER CENT MARINE PROTECTION TARGET WHILE DELIVERING THE BEST CONSERVATION OUTCOMES FOR THE ARCTIC.

[2] The IUCN's Guidelines for Applying Protected Area Management Categories describes best practices for management and governance for different categories of protected areas, setting criteria for what can be considered a protected area according to international standards.

GOALS

A 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 CONSERVED AREAS, AND OTHER EFFECTIVE AREA-BASED CONSERVATION MEASURES (OEABCMS).

To address the gap in MPA network planning in the Canadian Arctic, WWF-Canada assessed more than 500 features of the Arctic marine environment using information from Indigenous Knowledge (IK) and conventional scientific sources to identify a potential network of **priority areas for conservation (PACs)**. Spanning four Arctic marine bioregions from the coast of Ellesmere Island to James Bay, the results of this work are several potential network designs that capture key areas for Arctic marine conservation and account for patterns of ecological connectivity. The features include, among others, types of wildlife habitats, abiotic features and highly productive areas (Table 1).

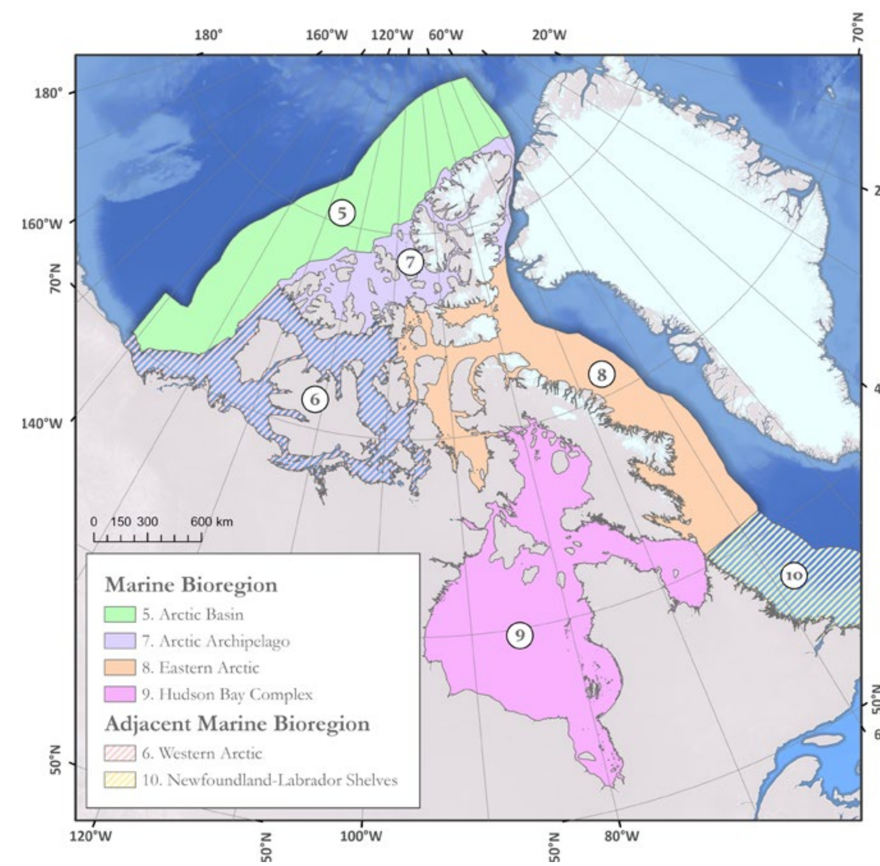

Figure 2. Scope of CanPAC: four of the five Canadian Arctic marine bioregions, as defined by the department of Fisheries and Oceans Canada (DFO, 2009). Areas included in the study are the Arctic Basin, Arctic Archipelago, Eastern Arctic and Hudson Bay Complex

The CanPAC results can help guide the Government of Canada and its partners as it works toward meeting the 25 per cent and 30 per cent targets in the coming years by identifying a process for network planning and individual candidate sites for protection. As a resource that consolidates diverse information about the Arctic marine environment into one tool, the network design can also contribute to ongoing marine planning activities in the Canadian Arctic — including the Nunavut Land Use Plan process, environmental assessments, fisheries management and more.

This marine conservation network planning exercise includes the Arctic Basin, Arctic Archipelago, Eastern Arctic and Hudson Bay Complex marine bioregions (Figure 2).[3] It is the first spatial conservation planning analysis in Canada to span multiple bioregions, and the first of its kind in the Canadian Arctic. The analysis also divided features according to their bioregion, which results in a network that can function at the scale of a single bioregion as well as across the full project area. Additionally, the analysis boundary extends about 20 km inland to capture coastal ecosystems and species, and to integrate the results with existing terrestrial protected areas.

[3] The Western Arctic and the Newfoundland and Labrador Shelves bioregions are the subject of separate studies undertaken by the Department of Fisheries and Oceans Canada (DFO) and were not included in CanPAC.

CONSERVATION OBJECTIVES

The CanPAC study draws on the principles of systematic conservation planning[4] (Ardron et al., 2010) to explore and assess several alternative network designs for a set of coherent PACs to achieve the following conservation objectives:

1. **To protect distinctive, unique, rare or endangered species and ecological features including:**
   - **A.** Key habitats[5] of Arctic priority species (e.g., polar bears, narwhals, belugas);
   - **B.** Ecologically sensitive areas (e.g., coral and sponge concentrations); and
   - **C.** Areas of high productivity (e.g., polynyas) and high species diversity/concentrations.
2. **To protect representative examples of identified ecosystems and habitat types to ensure various Arctic species will find ideal habitat conditions within the network.**
3. **To ensure that the PACs are integrated into the wider landscape and seascape by patterns of connectivity.**

These objectives guided the selection of the conservation features (see below) of the Arctic marine environment which form the backbone of the network design. The decision support tool Marxan[6] was then used to identify a coherent set of PACs that collectively include all conservation features.

[4] 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.

[5] For this analysis, "key habitat" is defined as a habitat associated with a specific life history stage of a species, other than habitat used exclusively by the species as a transit route during migration.

[6] Internationally, Marxan is the most widely used decision-support tool for MPA network design (Ardron et al. 2010).

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Marxan is a decision support tool used internationally

to guide systematic, multi-objective conservation planning using spatial analysis. It incorporates spatial data for a variety of features in a region, such as distributions of polar bear denning areas, locations of coral beds, or areas of high chlorophyll production to identify a set of potential sites that could function as a network to meet conservation objectives across the entire region (for example, protect habitats of key Arctic species). Marxan is a flexible tool — the set of areas it identifies results from a combination of the data selected for the analysis (the "conservation features" and a target for each type of data [e.g., 40 per cent of polar bear denning areas, 75 per cent of coral beds and 50 per cent of areas of high chlorophyll production]), which can both be changed to meet different objectives and create unique arrangements of potential protected areas.

THE PROCESS

The CanPAC process, illustrated in Figure 3, was undertaken between May 2017 and December 2019. Experts were recruited for data assessment, participation in expert workshops and completion of a vulnerability assessment of priority species for conservation target setting.

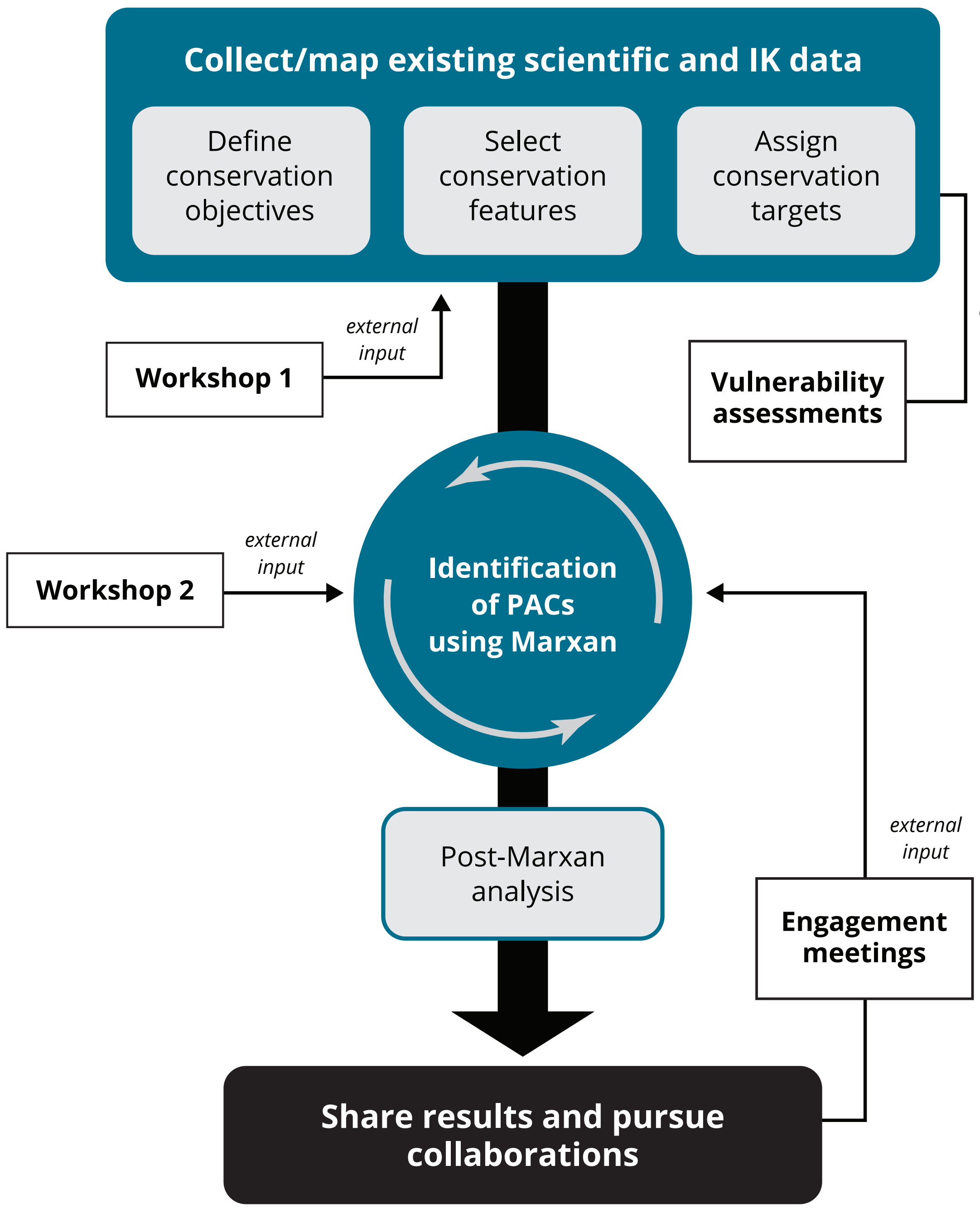

Figure 3. The CanPAC process.[7]

[7] For full description of the study and methodologies, see CanPAC Technical Report: *Marine ecological conservation for the Canadian eastern arctic (MECCEA) – a Systematic Planning Approach for Identifying Priority Areas for Conservation* (link).

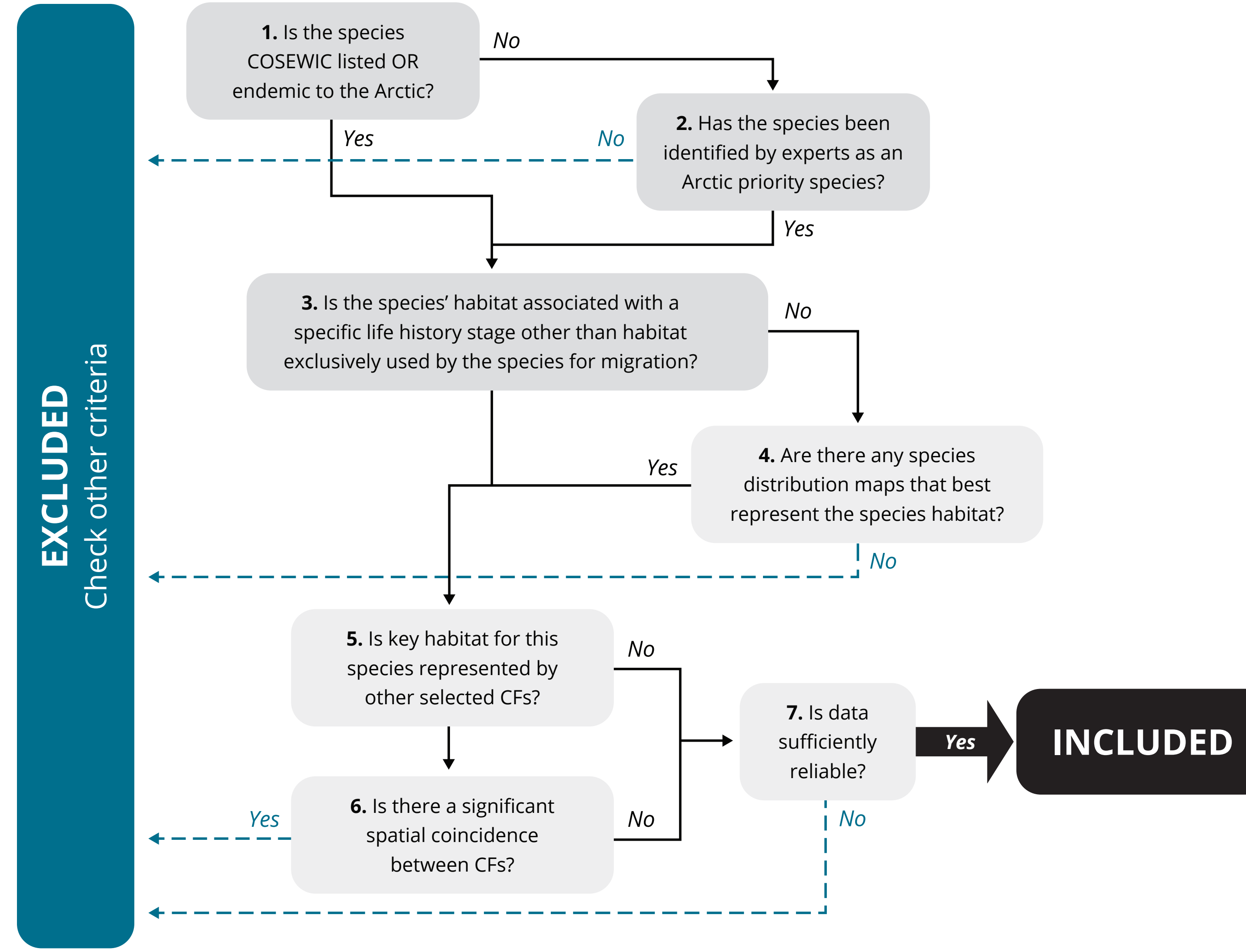

Figure 4. Criteria decision tree for Conservation Objective 1A: protect key habitats of Arctic priority species. Decision trees were also developed for conservation objectives 1B and 1C, for a total of three.

CONSERVATION FEATURES

A **conservation feature** (CF) is a component of biodiversity related to the conservation objectives for which data were available and included in the analyses. For example, beluga calving areas were selected as a CF under the conservation objective "To protect **distinctive**, **unique**, **rare** or **endangered** species and ecological features including: key habitats[8] of Arctic priority species."

CFs comprising the most essential aspects of the Arctic marine environment were selected using a set of criteria specific to each of the three CanPAC conservation objectives in the form of decision trees (see Figure 4 for an example of a decision tree). The selection criteria were also based on assessing available data, given that even with available documented IK and conventional scientific information, many features of the Arctic are data-poor. To compensate for data gaps, data was "split" by the marine bioregion boundaries to create conservation features that were specific to each bioregion. This ensured that the resulting network identifies PACs in each bioregion rather than a network that is concentrated in one part of the study area, but also results in a network design that functions both as a network across the four bioregions and at the scale of a single bioregion. If the analysis were conducted on just a single bioregion, the pattern of PACs for the selected bioregion would be very similar to the PACs found in the complete set of results. Essentially, the results function at both the scale of a single bioregion and all four bioregions originally included in the study area.

In total, **513 CFs** were used in the Marxan analysis.

[8] For this analysis, "key habitat" is defined as a habitat associated with a specific life history stage of a species, other than habitat used exclusively by the species as a transit route during migration.

DATA: INDIGENOUS KNOWLEDGE SOURCES AND CONVENTIONAL SCIENCE

A Marxan analysis requires mapping the distribution of each CF. All available spatial data were collected for a variety of biological and geophysical features in the Canadian Arctic across two broad categories: *distinctive features* (relating to Conservation Objective 1) and *representative features* (relating to Conservation Objective 2) (Figure 5). These two groups can be summarized as data representing specific species habitat usage versus data representing examples of different habitat types that could be suitable for multiple species and ecosystem processes.

With CanPAC's conservation objectives defined, and distinctive and representative CFs identified, the next stage was to collect the spatial data required to map the features.

Spatial data for each selected conservation feature was obtained using a broad survey, resulting in datasets from diverse sources, methodologies and formats. In general, datasets collected to represent distinctive CFs came from species-specific studies/surveys or compilations of information from IK sources. Most of the information from IK used in CanPAC came from the Nunavut Coastal Resources Inventory (Government of Nunavut, 2008) and included both information relating to marine ecology/ecosystems (e.g., species distributions) and information about areas of importance for Inuit uses (e.g., cultural sites, hunting areas). Information from IK also underpins several of the marine mammal conservation features that came from sources drawing on both conventional scientific and IK data. In comparison, data assembled for representative CFs was obtained mainly from oceanographic databases, remote sensing and models *(see WWF-Canada's CanPAC Project: Data and Metadata Guide : add link).*

Distinctive features

are spatially discrete and are important for specific marine taxa. Functionally, this means that distinctive features represent things such as cetacean foraging areas, walrus haulout sites, or bird colony locations, for example. Generally, data representing distinctive features are based on observations of species distributions and life-history traits.

Representative features include information on the attributes used

to define the seascapes of the Canadian marine Arctic environment, such as salinity, temperature, ice cover and ocean currents. The combination of these attributes in specific areas of the marine environment combine to create different types of marine habitats that support uniquely adapted species. For example, one type of representative habitat could be an area with high salinity, low temperatures and weak ocean currents compared to surrounding areas, whereas another could be lower salinity, higher temperature and strong currents. Different species are suited to each set of conditions, and so for species that are not well-studied or where there are data gaps, representative features help ensure the full range of ecosystem types in the four bioregions are captured in the network.

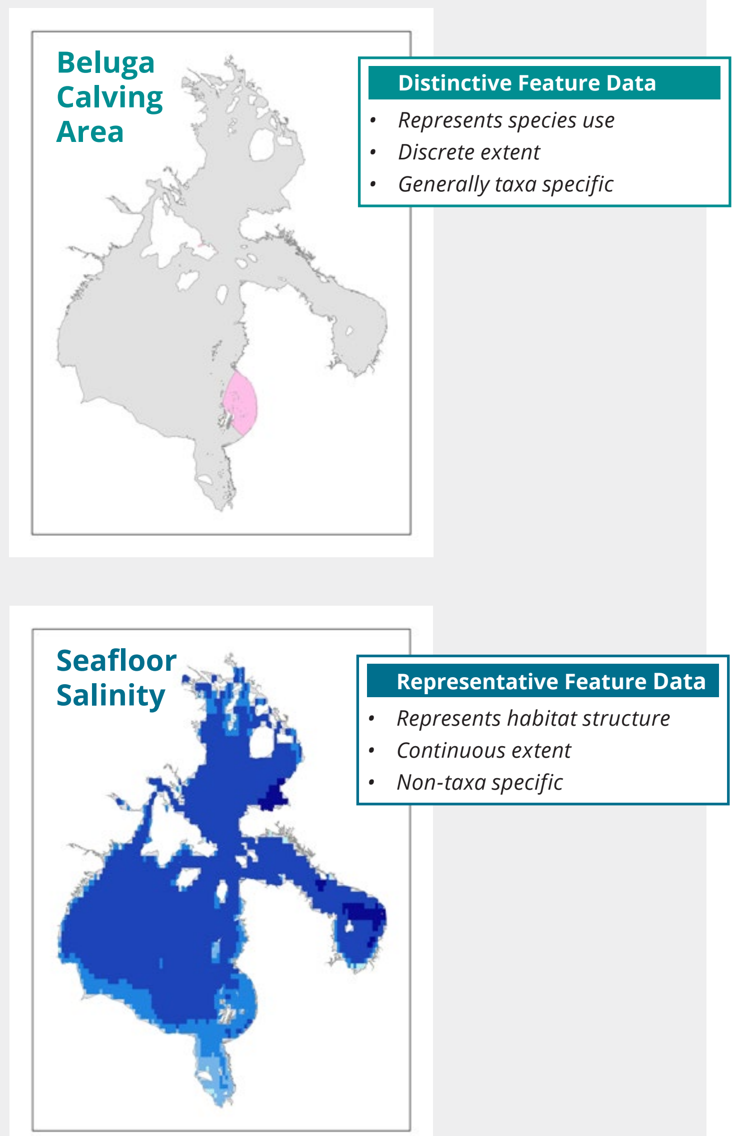

Figure 5. Examples of the differences between distinctive and representative data.

THE CFs INCLUDED IN THE MARXAN ANALYSIS CONSIST OF:

- **120** marine mammal key habitat features
- **45** fish habitat features
- **8** significant benthic area features
- **2** areas of high benthic family richness features
- **18** hotspot features (i.e., marine mammals, polar bears and seabirds)
- **9** seabird colony features
- **18** seabird key habitats features
- **12** Important Bird Areas (IBAs) features
- **31** coastal habitat features (i.e., cliffs, wetlands, inlets, intertidal areas)
- **32** seafloor geomorphic feature types
- **9** areas of high productivity and primary production features
- **3** polynyas features
- **1** eelgrass area feature
- **205** seascape features

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FROM CONSERVATION FEATURES TO CONSERVATION TARGETS

Having defined and mapped all possible CFs, we determined how much of each feature needed to be included in the set of PACs in order to meet the conservation objectives.

Marxan requires that each CF be assigned a conservation target. This target is the percentage of the total area of each CF that should be captured in the set of PACs in order to meet the conservation objectives. Marxan then attempts to design an MPA network in which the target for each conservation feature is met.

Distinctive and representative features were treated differently in the target-setting exercise: (See CanPAC Technical Report):

1) For distinctive features (i.e., key habitats), targets were assigned based on the advice of species specialists and based on specific traits such as habitat type, life history and rate of reproduction.

2) For representative features (i.e., physical habitats), targets were generally set quantitatively following a formula based on their areal coverage.

For each CF, the target-setting process resulted in a target range (e.g., 10–20%, 20–40%, etc.). Using target ranges enabled the creation of different protection scenario options. Higher targets resulted in scenarios with fewer — but larger — PACs and more total area; targets from the lower end of the range resulted in scenarios with more — but smaller — PACs and less total area. Table 1 lists the CFs with associated target ranges and examples of specific CFs.

Table 1. Groups of Conservation Features and their conservation targets used in Marxan[9].

Conservation feature groups	Example	Target range
Examples of features used to identify distinctive areas		
Beluga key habitats	Beluga calving areas, Western Hudson Bay subpopulation	40–60%
	Beluga locally identified habitat, Cumberland Sound subpopulation	40–60%
Bowhead key habitats	Bowhead summer foraging and calving, East Canada-West Greenland population	40–60%
	Bowhead locally identified habitat (NCRI), Davis Strait	40–60%
Narwhal key habitats	Narwhal summer foraging and calving, Northern Hudson Bay population	60–80%
	Narwhal locally identified habitat (NCRI), Baffin Bay stocks	40–60%
Polar bear key habitats	Polar bear denning areas, Baffin Bay subpopulation	40–60%
	Polar bear locally identified habitat (NCRI), Davis Strait subpopulation	40–60%
	Polar bear hot spot areas, winter, Hudson Bay bioregion	5–10%
Seals (hooded, harp, bearded, ringed) key habitats	Hooded seal whelping patch	60–80%
	Harp seal feeding area	60–80%
	Bearded seal locally identified habitat (NCRI), Hudson Bay bioregion	40–60%
Walrus key habitat	Walrus haulout sites, Canadian Central Arctic subpopulation	40–60%
	Walrus locally identified habitat, Canadian Low Arctic subpopulation (NCRI)	40–60%
Species hotspots	Marine mammal hotspots, winter, Hudson Bay bioregion	10–25%
	Seabird hotspots, summer, Arctic Basin bioregion	20–40%
Fish key habitat	Arctic char habitat, Hudson Bay bioregion	40–60%
	Greenland shark locally identified habitat (NCRI), Eastern Arctic bioregion	60–80%
Important Bird Areas[2] (IBAs)	Important Bird Areas, Western Quebec Coastline and Belcher Islands	20–40%
Seabird key habitats[10]	Black guillemot colonies, Arctic Archipelago bioregion	20–40%
	Seabird breeding areas, Northern Hudson Bay and Hudson Strait	60–80%
Polynyas	Polynyas, Arctic Archipelago bioregion	25–50%
Significant benthic areas	Large gorgonian coral concentrations, Davis Strait	80–100%
Benthic family richness	Benthic family richness, >40 families, Hudson Bay	60–80%
Examples of features used to identify representative areas		
Maximum chlor a production	*Areas of high chlorophyll production identified in each bioregion*	15–50%
Primary production	*Areas of high sustained primary productivity identified in each of the three bioregions across two intervals*	10–100%
Benthic and pelagic seascape types	*205 features based on distinct seascape types identified*	5–100%
Benthic geomorphology	*e.g., Abyss, bank, canyons, escarpment, fan, rise, plateau, rise, shelf, sill, slope, valley, and terrace*	5–100%
Coastal habitat types	*e.g., intertidal habitat types, inlets, cliffs, and wetlands*	5–100%

[9] A full list of conservation features and associated targets is available in the CanPAC Technical Report.

[10] Seabird key habitats include seabird colonies and other areas such as breeding, foraging and overwintering sites. Important Bird Areas are defined according to international criteria as part of an international conservation initiative coordinated by Birdlife International, and include all types of birds, as opposed to only seabirds.

MARXAN ANALYSIS AND SCENARIOS

From the different scenarios, the CanPAC team selected three that used different target levels across the target range (minimum, median or high). Presenting various scenarios provides flexibility to governments, rightsholders and other stakeholders when examining how different targets within the assigned ranges affect overall network devsign while always ensuring a minimum requirement (i.e., the lower end of the target range) is met.

Selected scenarios

Figures 6, 7 and 8 present the PACs generated from the minimum-, median- and high-target scenarios, respectively. All scenarios were designed to include existing MPAs (with the exception of the High Arctic Basin/Tuvaijuittuq MPA, which was established after the CanPAC analysis).

The results from these scenarios require that 31 per cent (75 PACs), 39 per cent (45 PACs) and 47 per cent (44 PACs) of the total study area is protected to meet the minimum, median and high targets, respectively. Each of the selected Marxan scenarios meets a minimum of 99 per cent of its conservation targets for the CFs.

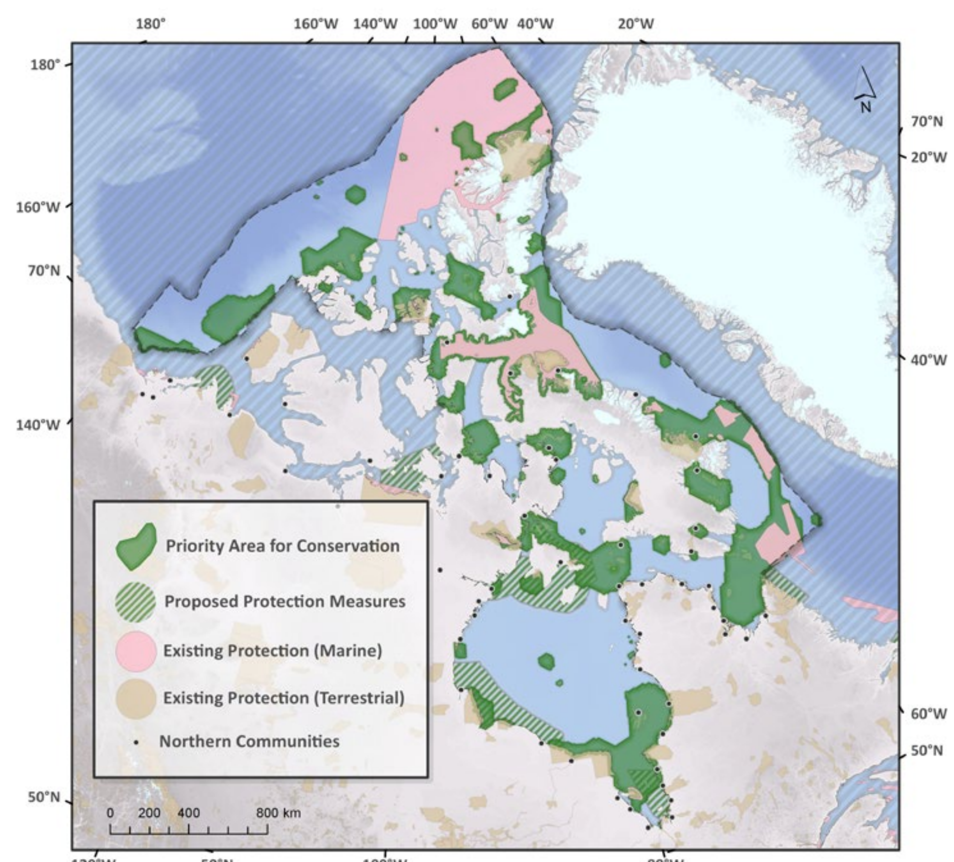

Figure 6. Marxan PAC network generated using the minimum-target scenario.

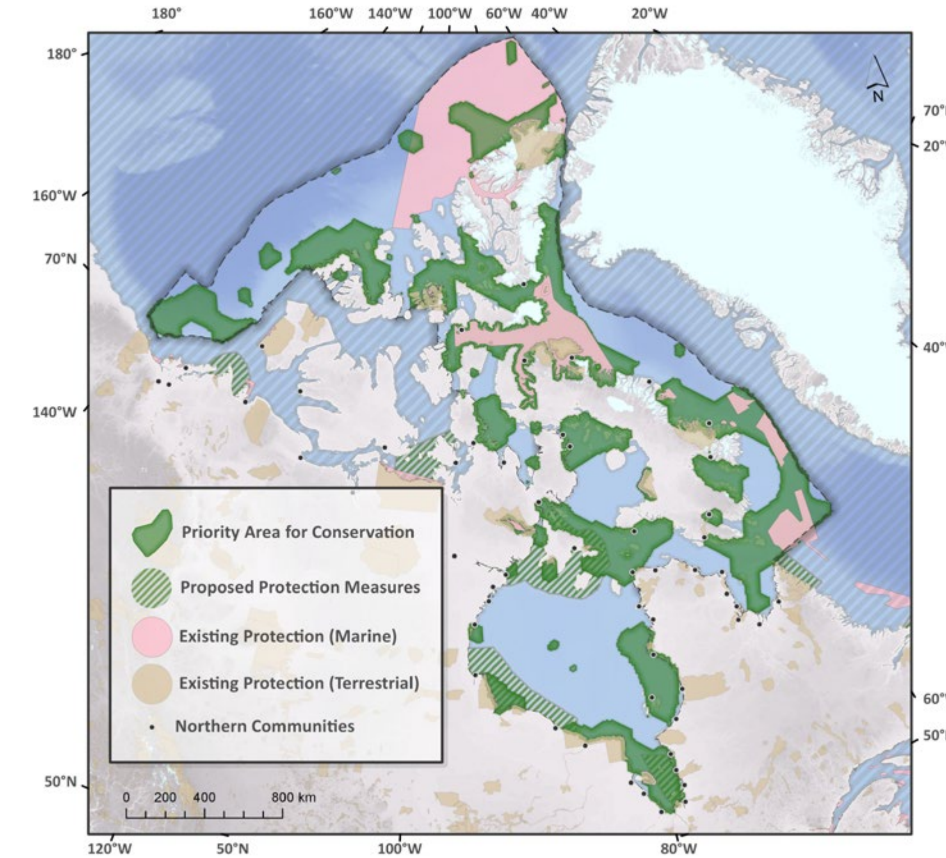

Figure 7. Marxan PAC network generated using the median-target scenario.

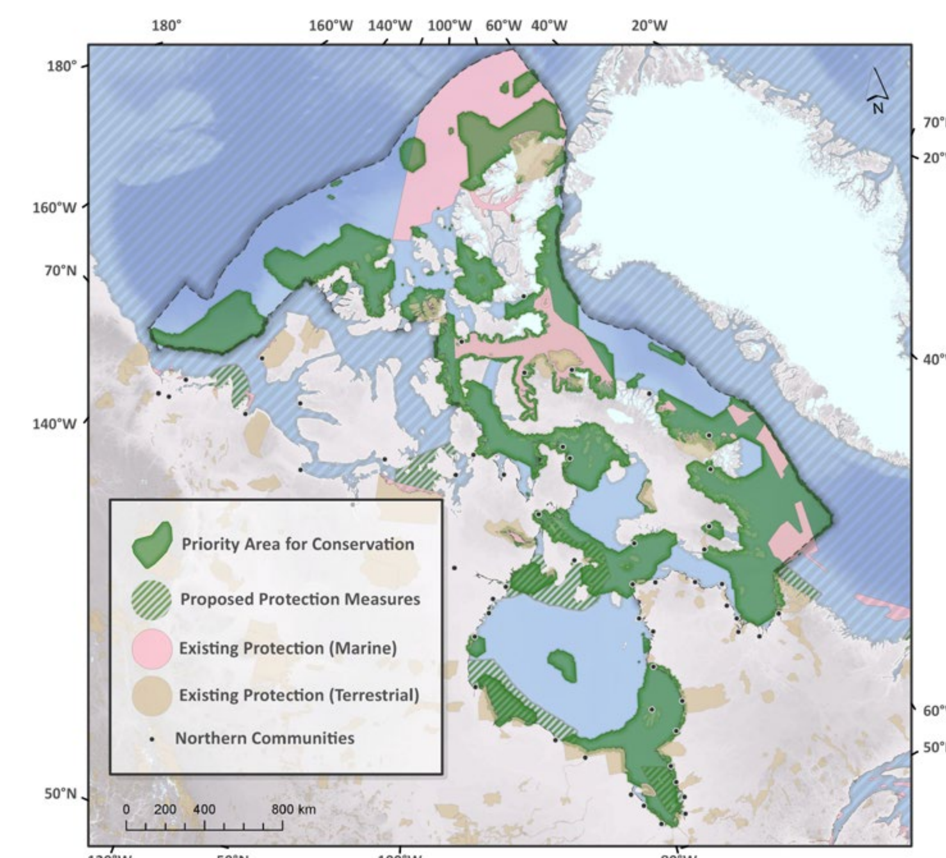

Figure 8. Marxan PAC network generated using the high-target scenario.

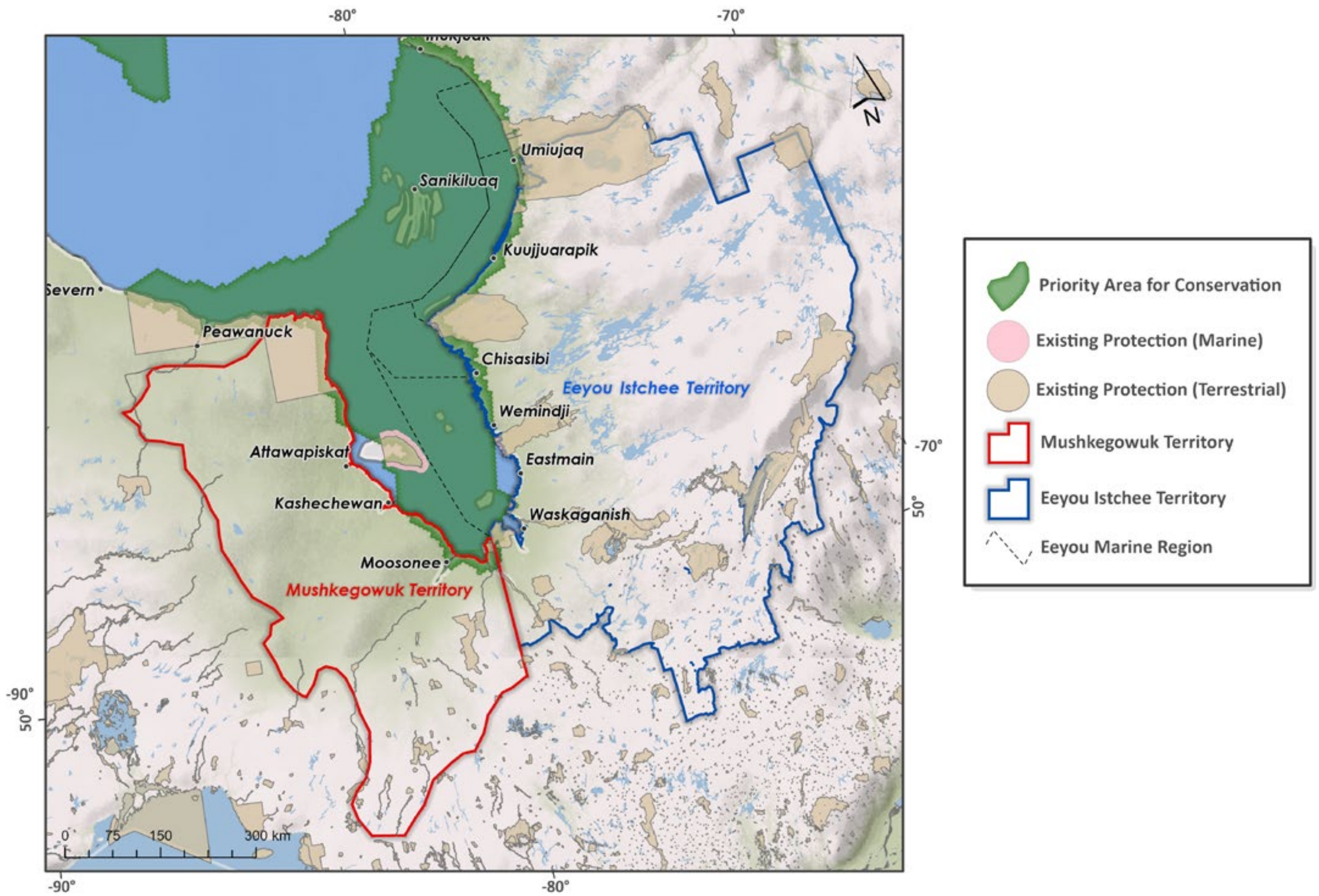

Figure 9. James Bay and Southeastern Hudson Bay PAC (high-target scenario). Conservation features contained within this area are listed in Table 2.

THE PAC NETWORK: A RESOURCE FOR CONSERVATION PLANNING

The CanPAC results include detailed information on the CFs found in each PAC. Each PAC was selected by Marxan due to a unique combination of underlying conservation features that can be used to guide planning processes. This PAC-specific information enables the results to feed into ongoing site-specific conservation efforts (for example, in determining appropriate boundaries for new MPAs) as well as guiding regional planning and identifying new candidate areas for protection. In the example in Figure 9 and Table 2, a candidate National Marine Conservation Area (NMCA) is currently under study in Eastern James Bay, but no protection plan is underway for adjacent regions.

The CanPAC results identify a PAC that extends into the western part of James Bay and southeastern Hudson Bay — information that suggests broader protection for this region could be needed.

The PACs and the assembled underlying data can also inform appropriate boundary setting of current candidate sites for marine conservation and the delineation of specific zones within future marine conservation areas. In the case of the James Bay candidate NMCA, Parks Canada and the Grand Cree Nation could use CanPAC geospatial data to inform their feasibility analysis and as an aid in selecting the final boundaries of the candidate NMCA.

The PAC analysis also documents how PACs identified in the four CanPAC bioregions vary considerably in terms of the combinations of conservation features they include. For example, in the Eastern Arctic, Tallurutiup Imanga is an important feeding area for several priority species. In the data-sparse Arctic Basin, geophysical features like canyons and sea ice are among the ecologically important features that may change dramatically with the seasons and in coming years. In Hudson Bay, the wetlands used for bird migration and eelgrass beds in James Bay are important features. In the Arctic Archipelago, ice-dependant species and polynyas are the key ecological features.

Table 2. Lists of conservation features within the James Bay and Southeastern Hudson Bay PAC (Figure 9) for the high-target scenario.

Species	Local	Geomorphic	Seascapes
• Arctic char *(Salvelinus alpinus)* habitat • Arctic cod *(Boreogadus saida)* habitat • Beluga areas of year-round high density • Beluga calving area • Beluga summer habitat • Benthic family richness, >40 families • Coregonus (genus) habitat • Eelgrass beds • Fourhorn sculpin *(Myoxocephalus quadricornis)* habitat • Lumpfish *(Cyclopterus lumpus)* habitat • Marine mammal hotspots, summer • Marine mammal hotspots, winter • Northern Ontario Coastline IBAs • Polar bear denning areas • Polar bear hotspots, winter • Seabird foraging/moulting areas • Walrus haulout sites • Walrus winter areas • Western Quebec Coastline & Belcher Islands IBAs • Year-round eider habitat	• Arctic char *(Salvelinus alpinus)* locally identified habitat • Arctic cod *(Boreogadus saida)* locally identified habitat • Bearded seal locally identified habitat • Beluga locally identified habitat • Ringed seal locally identified habitat • Walrus locally identified habitat	• Three types of unique seafloor geomorphic features • Coastal inlet • Coastal intertidal habitat • Coastal cliffs • Coastal wetland	• 15 unique classes of benthic seascapes • Three unique classes of pelagic seascapes • Chlorophyll hotspot • Primary productivity hotspot

POST-MARXAN ANALYSES

Marxan was used to identify areas that collectively meet the conservation targets, but additional analyses were required to identify patterns of connectivity among these areas to ensure the PACs could function as a network. Following the identification of PACs, the study team conducted post-Marxan analyses, looking at ecological connectivity, and also spatial overlays to specifically examine relationships between the PACs and human use.

Connectivity

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" (IUCN-WCPA, 2008). Understanding the links between different parts of species' ranges could drive the restoration of biodiversity in areas that have been damaged by natural or human causes (Cowen et al., 2006; IUCN-WCPA, 2008; Kenchington et al., 2016) and help safeguard species by increasing resilience to climate change (Costello and Connor, 2019). In addition to identifying a coherent set of PACs using Marxan, CanPAC also provides insight into patterns of connectivity in the Canadian Arctic by looking at the properties of the PACs as parts of a network.

Species seasonal uses, migration corridors and bottlenecks

CanPAC's PACs integrate different types of seasonal habitats for seabirds and marine mammals. Polynyas, shore leads and the ice edge represent overwintering and seasonal migration habitat for seabirds, and are captured by the "polynyas" conservation feature. For marine mammals, summer and winter habitats were included in the selection of conservation features. Polar bear and marine mammal key habitats also include both summer and winter hotspots.

In the CanPAC high-target scenario, PACs cover 57 per cent of the marine mammal migratory corridors (Figure 10 and Table 3) identified in DFO's Arctic Ecologically and Biologically Significant Areas (EBSAs; DFO, 2004; 2011; 2015). They have the potential to significantly contribute to the protection of migratory species.

CanPAC has also analyzed current and potential future narrow passages, or "bottlenecks" for species migrations between the islands and land masses in the four bioregions to highlight the locations of vulnerable areas for migration, some of which included in the network of PACs (see Figure 11).

DFO's Ecologically and Biologically Significant Areas

Ecologically and Biologically Significant Areas (EBSAs) are areas in Canada's oceans that have been identified, through formal scientific assessments, as having special biological or ecological significance. The identification of an EBSA is based on the biological and ecological properties of an area and does not consider threats and risks to those sites. Due to their biological or ecological significance, they are to be managed with a greater degree of risk aversion (DFO, 2004); EBSAs do not, however, have any specific legal status or associated protection measures. EBSAs differ from PACs in that they are independent from one another rather than comprising a cohesive network.

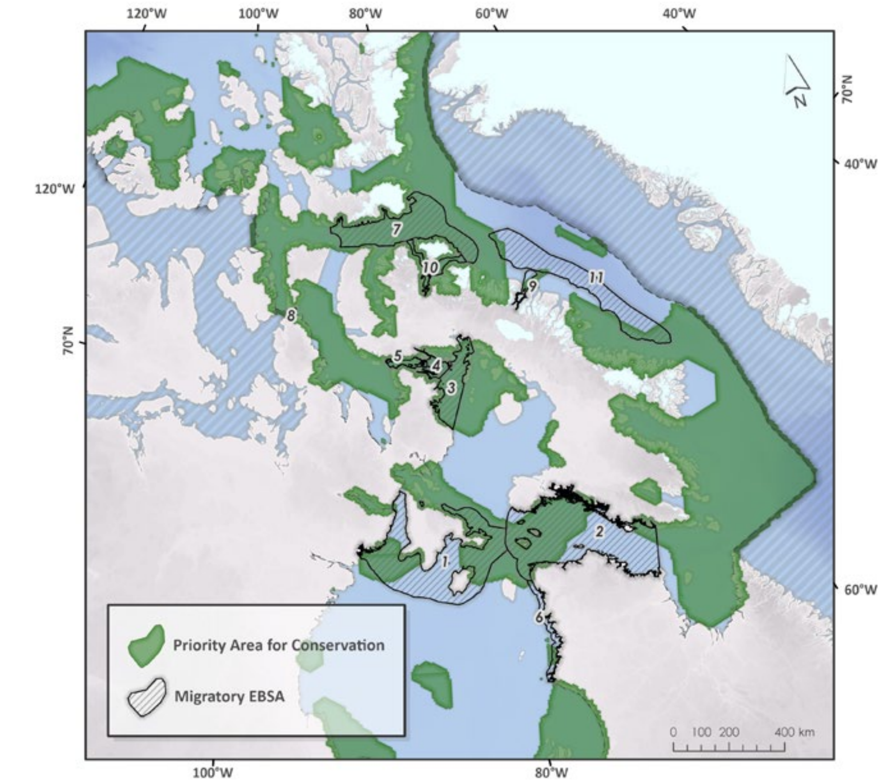

Figure 10. Overlay between PACs in the high-target scenario and migratory EBSAs.

Table 3. Arctic EBSAs important for wildlife migrations. Map ID No. corresponds to the labels in Figure 10.

Map ID No.	EBSA name	Migratory information
1	Southampton Island	The waters around the island are important spring and fall migration routes for beluga and eastern Arctic bowhead (COSEWIC Special Concern).
2	Western Hudson Strait	It is a major seasonal migration route for all marine mammals that spend the summer in Hudson Bay and Foxe Basin and beyond, and winter in either Hudson Strait, and/or Davis Bay, including beluga, narwhal and bowhead.
3	Rowley Island	Serves as a migratory corridor for several species of marine mammals, including belugas and narwhals.
4	Igloolik Island	The area 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	An 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	The 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	The area has a 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	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 bottleneck.
9	Scott Inlet	The extension out to the Baffin Bay shelf break captures a cross-section of the Baffin Bay narwhal migration corridor.
10	Eclipse Sound	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	IK identifies this area as an important migration route for bowhead whale as well as harp seal, hooded seal, ringed seal and bearded seal.

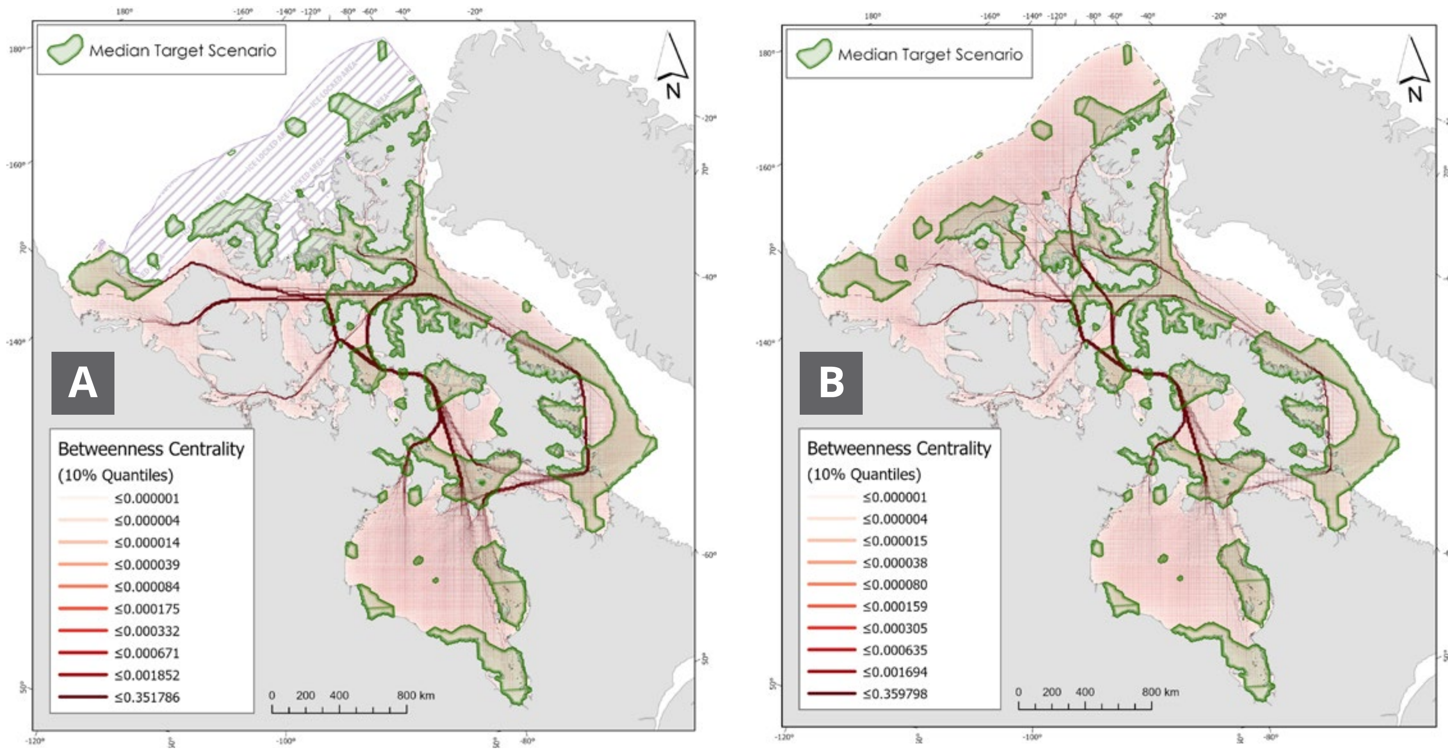

Figure 11. Betweenness centrality analysis results showing potential corridors and bottlenecks to migration (A) with and (B) without ice cover overlaid with PACs from median scenario.

Marine-freshwater connections

Extending the CanPAC analysis boundary up to 20 km into coastal areas ensured that important coastal habitat was captured for species like polar bears, seabirds and anadromous fish (e.g., Arctic char), and helped connect PACs with existing terrestrial protected areas. Figure 12 shows an example of a PAC adjacent to an existing terrestrial protected area where one of the main conservation features within the PAC is a beluga calving area (Eastern Hudson Bay beluga listed under the Species at Risk Act [SARA, 2002]). This calving area is connected to the Nastapoka River and Estuary within Tursujuq National Park but is not included in the national park or protected by any other means. There is a need for collaboration between federal, provincial and territorial governments as well as rightsholders (e.g., James Bay Cree on Eeyou Istchee and Omushkegowuk on Mushkegowuk Aski territories in Southern Hudson Bay and James Bay) when setting conservation objectives for MPAs adjacent to national parks.

Oceanographic connectivity: Particle drift simulations

CanPAC undertook a series of particle drift simulations to estimate the connectivity among the PACs by producing a baseline of structural connectivity — direct physical connection through ocean currents and topography — across space. A particle drift simulation shows how marine "drifters" like fish larvae (as opposed to "swimmers" like marine mammals and fish) move between marine areas under the influence of currents, winds and other factors, to identify how these areas are connected. Modelled following Kenchington et al. (2019), this is the first analysis of its kind in the Canadian marine Arctic and included more than 70 simulations over 14, 30 and 90 days at five and 110 metre depths in all four seasons for all three PAC scenarios, providing insight into the interconnections between the PACs in each one.

Figure 13 shows the maximum connections that were recorded throughout the 90-day simulations over four seasons and gives an overall picture of annual connectivity.

The analysis found that the PACs are generally well connected both within marine bioregions and between neighbouring marine bioregions. Some important separations/isolations were observed, such as a strong East-West divide and isolated offshore PACs in the Arctic Basin (see CanPAC Technical Report). The Hudson Bay complex PACs are well connected around its perimeter, but not beyond. The Lancaster/Jones Sound PAC is a hub of connectivity for the Eastern Arctic and Arctic Archipelago bioregions for all scenarios.

CanPAC's initial exploration of connectivity provides a contextual framework for connectivity in Canada's Eastern Arctic to which species-specific data may be applied in the future.

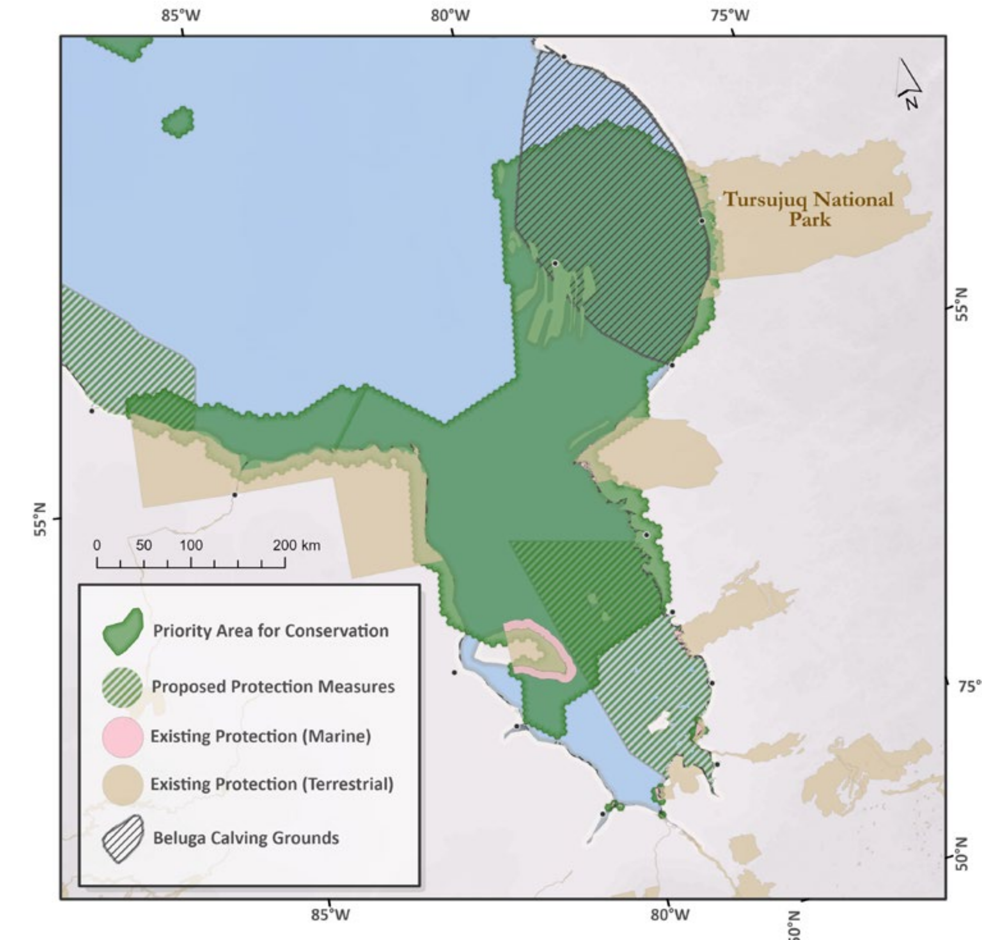

Figure 12. James Bay/Eastern Hudson Bay PAC and adjacent terrestrial protected areas.

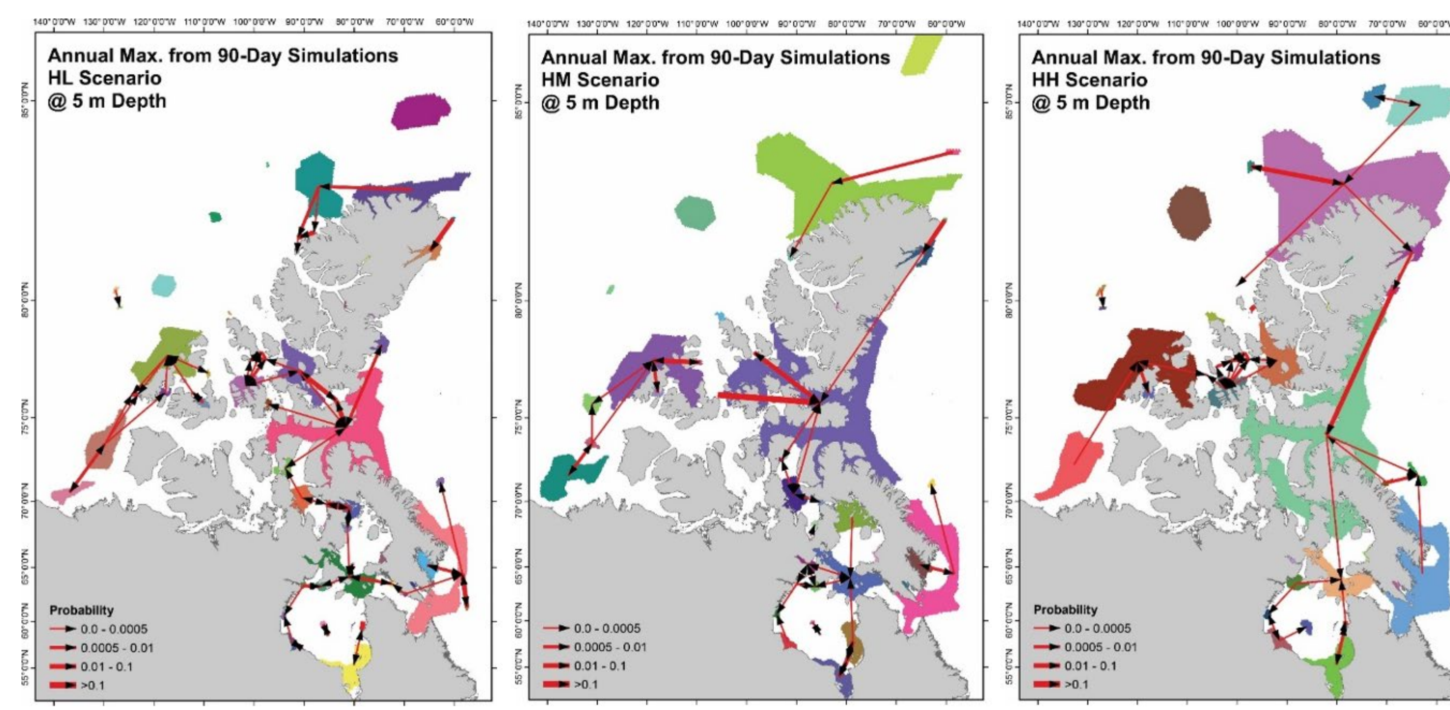

Figure 13. Annual maximum connections at the surface between CanPAC PACs for the three scenarios (minimum, median and high). Red lines denote connections between PACs, not actual particle drift tracks. Line thickness represents the relative strength of the connection expressed as a probability. Black arrow heads indicate the direction of the connection, which can be bi-directional.

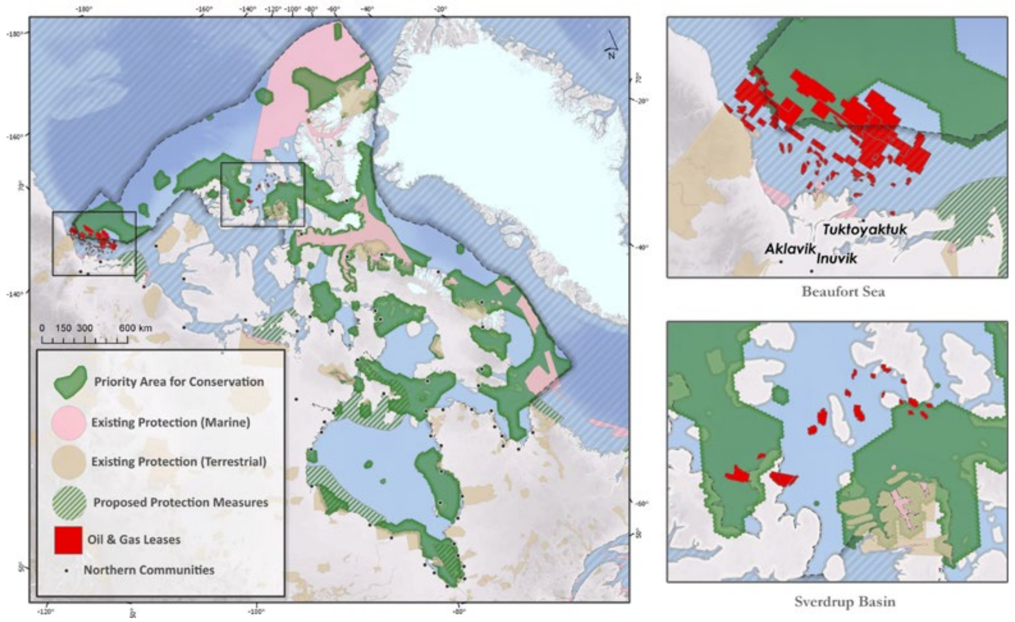

Figure 14. Overlay of current oil and gas leases and the PACs in the median-target scenario.

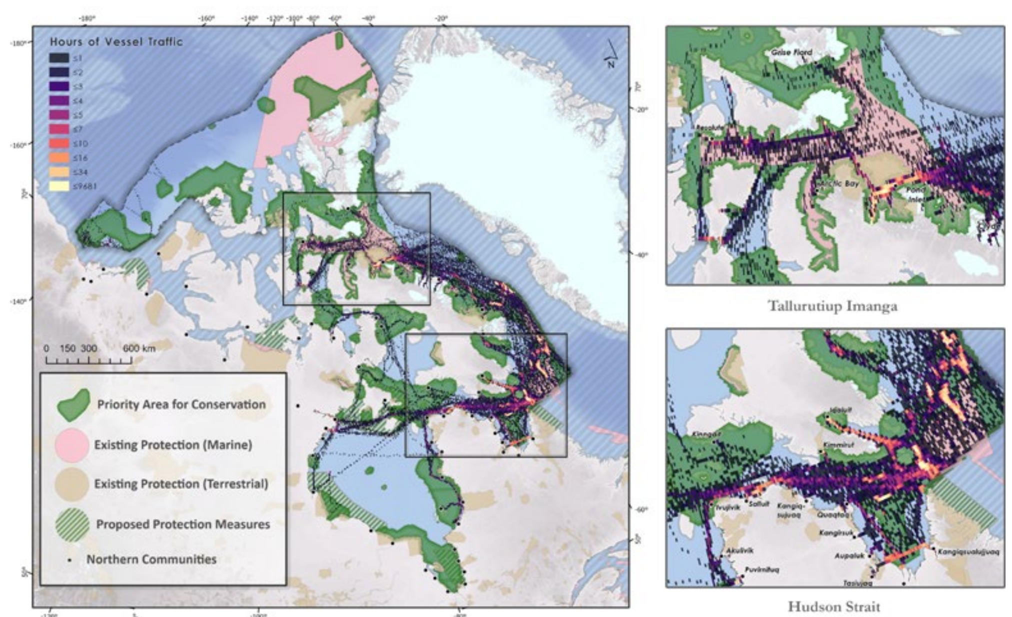

Figure 15. Overlay between ship tracks (2017) and the PACs in the median scenario.

OVERLAYING CanPAC PACS WITH HUMAN USES

There are three major commercial activities taking place within the CanPAC bioregions: shipping, mining and offshore fisheries. While there is currently no oil and gas exploration or extraction within the Canadian Arctic, existing Exploration and Significant Discovery licences overlap with the CanPAC study area (Figure 14). In particular, licences in the Arctic Basin bioregion overlap with PACs selected partly for the presence of underwater canyons, which are likely to become increasingly significant habitat as sea ice patterns change in a warming climate.

These overlaps are one indicator of the importance of marine conservation planning for informing the management of development opportunities in the Arctic and ensuring that marine ecosystems are protected.

Marine traffic

Marine shipping in Nunavut almost tripled from 1990 to 2015, with the majority of the increase occurring since 2005. Cargo ships bringing supplies to communities and servicing mines, as well as government vessels, including icebreakers, account for the largest share of traffic. Pleasure craft (primarily private yachts) represent the fastest growing type of craft, increasing by a factor of 20 over the 26-year period (Dawson et al., 2018).

Mining also generates significant marine traffic. The highest density of shipping activity within Arctic MPAs occurs within the Tallurutiup Imanga National Marine Conservation Area and Hudson Strait »

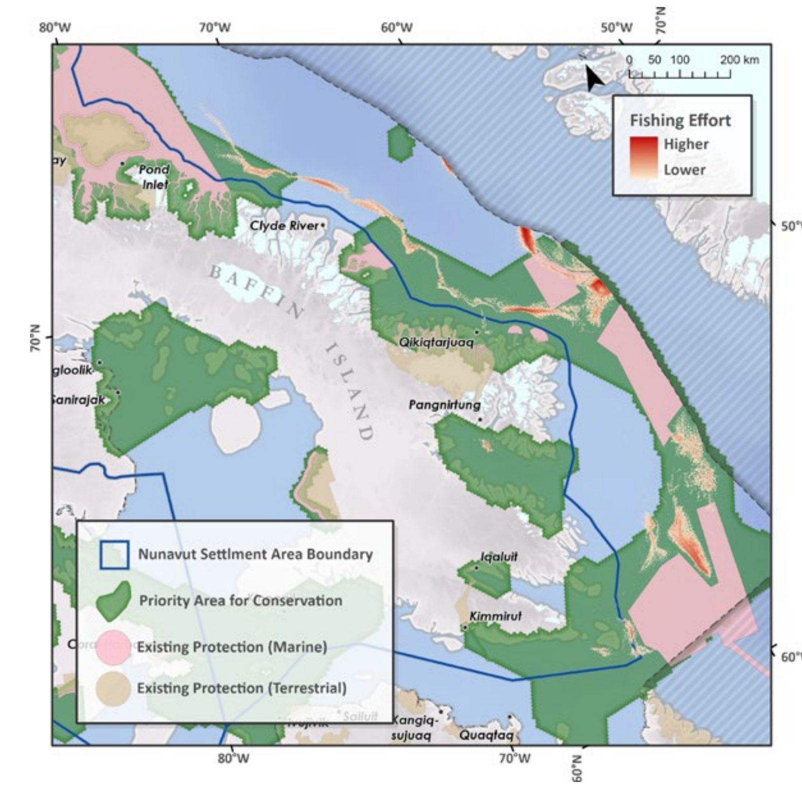

Figure 16. Overlay between offshore fishing intensity (Greenland halibut and shrimp) and PACs in the median-target scenario.

(Figure 15) 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 travelled approximately 725,000 km within the CanPAC study region. The portion of this travel that took place within the identified PACs ranged between 56 to 71 per cent for the minimum- and high-target scenarios, respectively. The results of this analysis can inform localized navigation recommendations and can act as a helpful basis for regional marine planning to manage the ecological impacts of commercial shipping and other marine activities.

Commercial Fishing

Offshore commercial fisheries occur only in the waters of Baffin Bay and Davis Strait and are a major contributor to the economy of Nunavut. The offshore fishery in these waters mainly targets Greenland halibut (*Reinhardtius hippoglossoides*, also known as turbot) and Northern shrimp (*Pandalus borealis*).

As shown in Figure 16, the median-target scenario PAC overlaps significantly with combined fishing intensity data for the halibut and shrimp fisheries. Within the footprint of fishing activity in Northwest Atlantic Fisheries Organization (NAFO) Areas 0A and 0B, 83 per cent of the actively fished region (DFO, 2017) overlaps with PACs. The same environmental and oceanographic factors that drive fisheries productivity in Baffin Bay and Davis Strait also drive the important concentrations of marine mammals and overall biodiversity found there. Identifying areas of overlap can inform fisheries management to enhance sustainability and protect ecological integrity.

PACs and Nunavut Inuit use areas

Most Canadian Arctic communities are coastal. Local marine ecosystems contribute to livelihoods in these communities through hunting and travel and are inherently linked to cultural identity. Recent marine conservation initiatives, such as the designation of Tallurutiup Imanga National Marine Conservation Area show how conservation can be directly linked to community well-being and development (QIA, 2019). As a starting point to addressing this dimension of marine planning, the CanPAC study examined how PACs within Nunavut intersect with areas identified as important for hunting, fishing, travel, cultural significance or other local uses, based on information from the Nunavut Coastal Resource Inventory (NCRI). Figure 17 shows that 63 per cent of NCRI Inuit use areas coincide with CanPAC's PACs. Local priorities and uses are a key element for identifying areas for protection and developing management measures. Guidance from local communities and Indigenous leadership on how conservation can support local needs and priorities is essential to advancing conservation of the PACs. Direct engagement with interested communities to identify how CanPAC can support local level initiatives is the next step in this work.

PACs and the Draft Nunavut Land Use Plan (DNLUP)

Nunavut is working towards implementing a land use plan for the Nunavut Settlement Area. The current DNLUP (Nunavut Planning Commission, 2016) includes the "protected area" designation, which is oriented towards wildlife habitat »

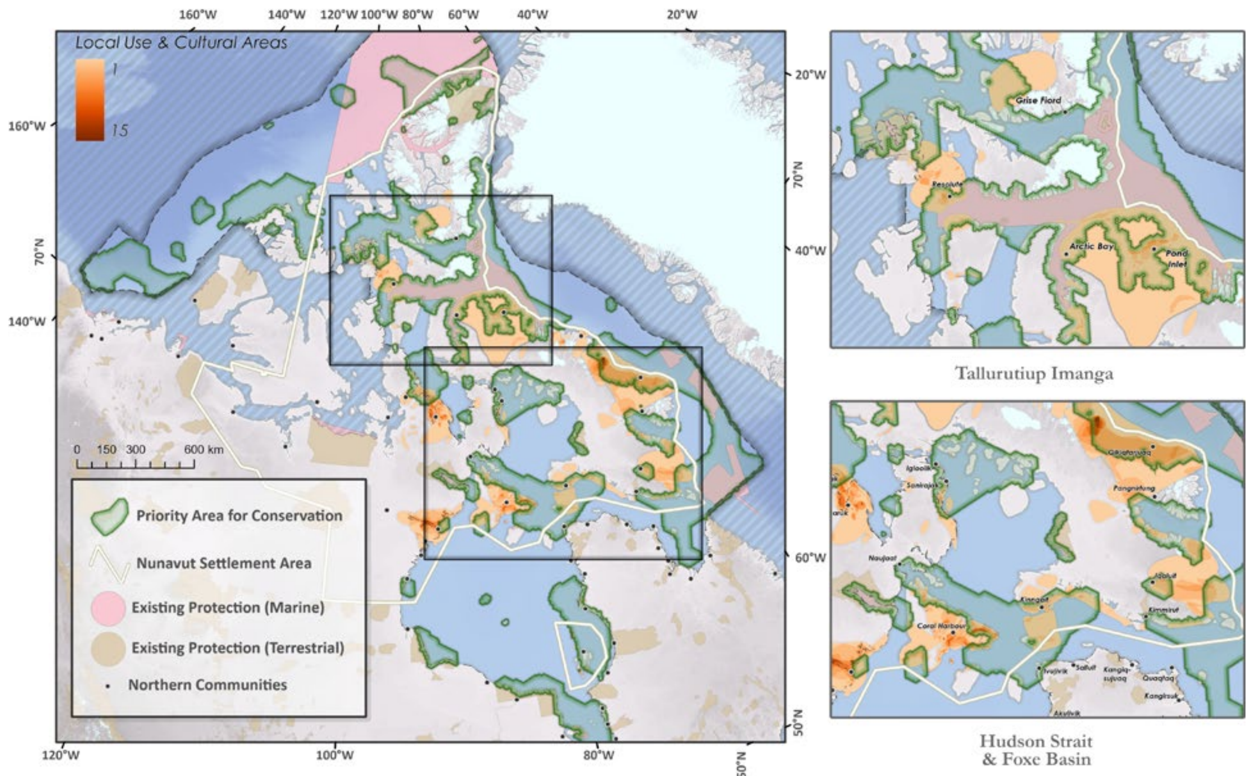

Figure 17. Overlap between the PACs of the median-target scenario and NCRI Nunavut Inuit use areas.

protection and stewardship, and "special management area" designations, which is more flexible, but in many cases is also focused on stewardship and conservation. Overlap between DNLUP protected areas and CanPAC PACs ranges between 70 to 77 per cent, while overlap with DNLUP special management areas ranges between 80 to 94 per cent from minimum- to high-target scenarios, respectively (see Figure 18 for an example).

Most areas identified by the DNLUP were chosen for an objective relating to a single species or species group. CanPAC PACs, on the other hand, are driven by a diverse range of features and can guide the identification of additional marine areas, and additional considerations in already identified areas, in the current draft and future iterations of the NLUP. The ongoing NLUP process represents a unique opportunity to implement a network of protected areas within the marine components of the Nunavut Settlement Area, which falls within the CanPAC geographic scope. The overlaps between the DNLUP protected areas and PACs indicates that CanPAC is capturing areas that are already known to be important, while also taking our current understanding to the next level by identifying the additional areas required to build a network that provides conservation benefits throughout the Canadian Arctic and investigating the connectivity between them.

CanPAC and Pan-Arctic PACs

A process parallel to CanPAC is taking place at the pan-Arctic scale. The WWF Arctic Programme is undertaking a similar marine conservation planning effort called 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 that are integrated in an ecosystem approach to the wider seascape (PAME, 2015). The ArcNet initiative is meant to complement regional analyses such as CanPAC by highlighting areas across the Arctic that are important for maintaining circumpolar biodiversity from a whole-ocean perspective.

While the ArcNet and CanPAC initiatives share a similar methodology, differences in scale (e.g., national versus pan-Arctic) and other technical details (e.g., the way conservation targets were set), mean that alignment in terms of the areas identified by these two studies is not guaranteed. Unlike CanPAC, ArcNet also included the Western Arctic bioregion and Tuvaijuittuq MPA (which was established after the completion of the CanPAC analysis), leading to differences in the arrangement of PACs in these two areas.

With this in mind, comparisons between the ArcNet results and the corresponding CanPAC median scenario still indicate a 61 per cent agreement in the areas identified (Figure 19). Although some differences in spatial arrangement exist, in general, ArcNet and CanNPAC support one another well, indicating that the CanPAC network supports broader conservation planning at the pan-Arctic scale.

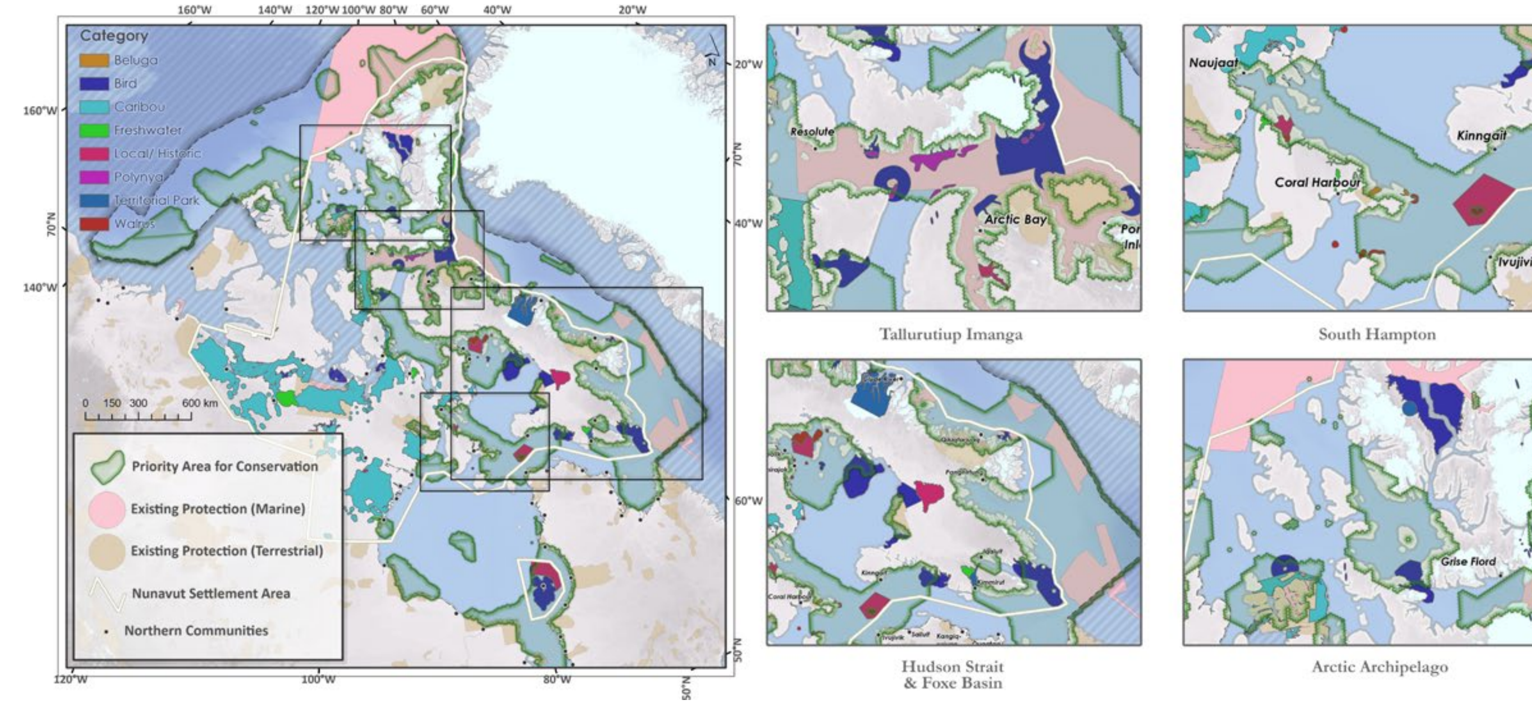

Figure 18. Overlap between the PACs of the median-target scenario and the Draft Nunavut Land Use Plan proposed protected areas and special management areas.

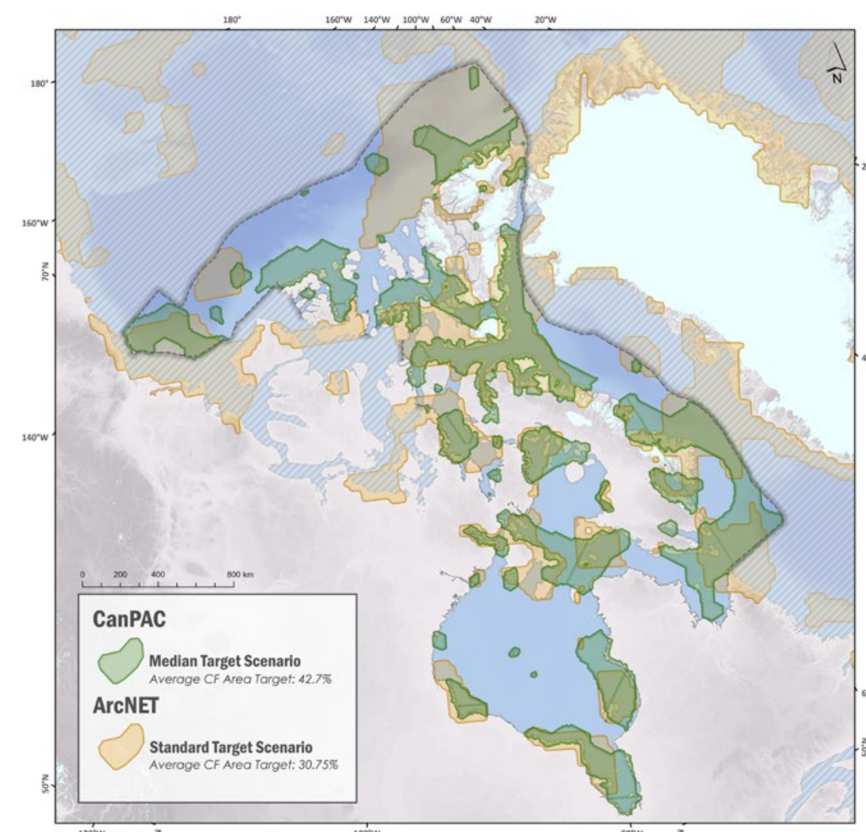

Figure 19. Overlap between CanPAC and the ArcNet PACs.

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LOOKING FORWARD

CanPAC demonstrates that spatial planning for an Arctic network of MPAs is valuable and feasible. It constitutes a powerful tool to ensure that Canada is truly protecting the most important areas for marine biodiversity in the Canadian Arctic in reaching the 25 per cent and 30 per cent protection targets.

KEY RECOMMENDATIONS:

1. **The Government of Canada should work with Indigenous Peoples and relevant stakeholders, as appropriate, to develop a Marine Protected Area (MPA) network in the Canadian Arctic and begin Marine Spatial Planning to enable Integrated Oceans Management;**

2. **A "toolbox" of marine conservation and management measures should be used for MPA network implementation, including:**
    - Federal, provincial and territorial legislation
    - Indigenous Protected and Conserved Areas (IPCAs)
    - Other Effective Area-Based Conservation Measures (OEABCMs); and

3. **A stepwise approach to marine conservation should be adopted, beginning with the 30 per cent minimum target by 2030, and increasing to 50 per cent by 2050.**

Best-management practices

- Each PAC, whether it becomes an MPA, IPCA or is managed though OEABCM, requires a unique management plan driven by environmental features, ecological processes, seasonal biological usage, and regulating authorities' and rightsholders' priorities.
- The CanPAC results show that PACs span jurisdictions, emphasizing the need for collaborative conservation management.

Toward adaptive conservation

In a region where the climate is changing more rapidly than anywhere else in the world, attempts should be made to anticipate environmental changes and consequent ecological responses as the basis for ongoing conservation efforts.

This means supporting Indigenous knowledge, engaging local leaders, and utilizing the best available information as a foundation for:

- Monitoring changes in species and habitats as well as human activities that may impact features of conservation importance;
- Assessing the current status and potential role of the CanPAC PACs;
- Identifying which species and habitats within PACs are vulnerable to change and which are resistant to change, and why;
- Understanding current food webs and expected changes; and
- Planning for the changes envisioned by adaptive management.

Because the Arctic marine environment is changing rapidly, the analysis of both vulnerability and resilience is a fundamental requirement for management.

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CONCLUSION

In light of the current dual crises of climate change and biodiversity loss, and the high likelihood of an increase in human activities in the Canadian Arctic, there is an urgent need for a systematic conservation plan to effectively protect marine biodiversity and increase and enhance ecosystem resilience. CanPAC has shown that effective conservation can be achieved by targeting priority areas that cover 30–50 per cent of the Canadian Arctic marine bioregions as shown in the three Marxan PAC scenarios. Canada's commitment to the 25 per cent and 30 per cent marine protection targets, the ongoing NLUP process, and other Arctic marine management initiatives are an opportunity to start implementing an effective marine protection network that leads to meaningful conservation outcomes for Arctic wildlife and the communities that rely on them into the future.

The PACs from this study, together with post-Marxan analyses, consolidate an enormous breadth and depth of available information about the Arctic marine environment. By bringing this information together into a comprehensive analysis, the results serve as an important resource for all marine conservation planning stakeholders. More specifically, the CanPAC results can be used to inform various marine conservation and management efforts as well as marine planning processes such as:

- Supporting Indigenous and local communities' marine conservation priorities
- Selecting new sites for protection (including a range of tools, such as Indigenous Protected and Conserved Areas, federal, provincial and territorial legislation, or for marine spatial planning)
- Environmental assessments for industrial marine activities, such as shipping and commercial fisheries
- Identifying research and management priorities
- Pan-Arctic marine protected areas network development as part of the Arctic Marine Protected Areas Network (ArcNet) development.

The data used in this study, including shapefiles and inventories of conservation features for each PAC, are available from WWF-Canada upon request. More information is available in the CanPAC Technical Report.

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