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Scientific considerations of how Arctic Marine Protected Area (MPA) networks may reduce negative effects of climate change and ocean acidification

Report from the Third Expert Workshop on Marine Protected Area networks in the Arctic, organised by Sweden and Finland under the auspices of the PAME working group of the Arctic Council in Helsinki, Finland, 21-22 September 2017

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This report was edited by Jessica Nilsson (Swedish Agency for Marine and Water Management), Pauline Snoeijs-Leijonmalm (Stockholm University), Jon Havenhand (University of Gothenburg), and Per Nilsson (University of Gothenburg). The Editors have compiled, analysed and synthesized the discussions, presentations and conclusions communicated during the workshop by the workshop participants.

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Editors: Jessica Nilsson, Pauline Snoeijs-Leijonmalm, Jon Havenhand, and Per Nilsson

Workshop organization

This expert workshop was organized jointly by Sweden and Finland. The coordinating national authorities were the Swedish Agency for Marine and Water Management (Jessica Nilsson), the Finnish Environment Institute (Kirsi Kostamo and Leena Laamanen), the Finnish Ministry of the Environment (Kristiina Isokallio and Jan Ekebom), and Parks & Wildlife Finland under the auspices of the Protection of the Arctic Marine Environment (PAME) working group of the Arctic Council. The scientific content of the workshop was supported by Jon Havenhand, Per Nilsson (University of Gothenburg, Sweden), and Pauline Snoeijs-Leijonmalm (Stockholm University, Sweden).

Acknowledgements

The workshop received financial support from the Governments of Sweden and Finland and the Nordic Council of Ministers Arctic Cooperation Programme. The workshop was organized by the Swedish Agency for Marine and Water Management (SwAM), the Finnish Environment Institute (SYKE) and Parks & Wildlife Finland. The Swedish Embassy in Helsinki and the National Library of Finland kindly provided excellent hospitality during the workshop.

Website

https://pame.is/index.php/projects/marine-protected-areas/mpa-network-workshop-september-2017

Abbreviations

ABA = Arctic Biodiversity Assessment (published by CAFF in 2013)
ABNJ = Areas Beyond National Jurisdiction
AC = Arctic Council
AMAP = Arctic Monitoring and Assessment Program (a working group of the Arctic Council)
AOSB = Arctic Ocean Sciences Board
CAFF = Conservation of Arctic Flora and Fauna (a working group of the Arctic Council)
CAO = Central Arctic Ocean (one large marine ecosystem in the Arctic)
CBD = Convention on Biological Diversity (United Nations)
CBMP = Circumpolar Biodiversity Monitoring Programme (published by CAFF in 2017)
CCAMLR= Commission for the Conservation of Antarctic Marine Living Resources
EBM = Ecosystem-Based Management
EBSA = Ecologically or Biologically Significant Areas
ES = Ecosystem Services
IASC = International Arctic Science Committee
IPCC = Intergovernmental Panel on Climate Change
ISAC = International Study of Arctic Change
LME = Large Marine Ecosystem
MEMA = Meaningful Engagement of Indigenous Peoples and Local Communities in Marine Activities
MIZ = Marginal Ice Zone (edge of the sea ice)
MPA = Marine Protected Area
MSP = Marine/Maritime Spatial Planning
PAME = Protection of the Arctic Marine Environment (a working group of the Arctic Council)
SCAR = Scientific Committee on Antarctic Research
SDG = Sustainable Development Goals (United Nations)
SDWG = Sustainable Development Working Group (a working group of the Arctic Council)
TFAMC = Task Force on Arctic Marine Cooperation (a task force of the Arctic Council)
TLK = Traditional and Local Knowledge
UN = United Nations
WG = Working Group

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Report summary

Rapid environmental changes in the Arctic

During the last two decades, the Arctic region has become an area of international strategic importance for states, businesses, NGOs and other stakeholders. The rapid environmental changes in the Arctic create new opportunities for different actors that may impact negatively on ecological and social values. Global climate change and ocean acidification change the habitats of the cold-adapted organisms living in the Arctic, with the risk of exterminating unique biodiversity. Human-induced emissions of greenhouse gases (primarily carbon dioxide, methane and nitrous oxide) affect the balance between energy entering and leaving the Earth's system resulting in global warming, melting of sea-ice (which increases heat absorption by the Arctic Ocean), and associated climate change. Approximately 27 % of the carbon dioxide released to the atmosphere every year is absorbed by the oceans. This keeps the atmosphere from warming as much as it otherwise would, but creates ocean acidification. In the Arctic region climate change and ocean acidification take place 10-100 times faster than at any time in the last 65 million years.

Intention of the workshop

This third expert workshop on Marine Protected Area (MPA) networks in the Arctic, organised by Sweden and Finland, was held in Helsinki (Finland) and its outcome is a contribution to the "PAME MPA-network toolbox" project. An MPA, as defined by PAME, 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". An MPA network is 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. During this third expert workshop the scientific basis of how MPA networks may reduce negative effects of climate change and ocean acidification in the Arctic region was discussed. Workshop participants were mainly scientists with expertise on Arctic marine ecosystems, climate change, ocean acidification and/or MPAs. The intention of the workshop was not to reach consensus and provide a fixed list of recommendations, but rather to summarize: (1) the best available knowledge that can already be applied to the planning of a pan-Arctic MPA network, and (2) the primary uncertainties and, hence, what necessary scientific knowledge is still lacking. As such, the six main outcomes from the workshop below contribute to the scientific basis for the potential of MPAs as a tool to meet the threats posed by climate change and ocean acidification to Arctic ecosystems and livelihoods.

A paradigm shift for establishing MPAs is necessary

Given the rapid environmental changes and unprecedented rate of loss of Arctic sea ice there is an urgency to protect habitats that are essential for ecosystem functioning and to link MPAs in an international network. Humanity has now the opportunity of a pro-active and precautionary approach vis-à-vis the largely intact, highly sensitive and unique cold-adapted Arctic marine ecosystems. The current paradigm for the creation of MPAs seems to be that a direct regional or local threat needs to be proven before an MPA can be designated. However, climate change and ocean acidification are global processes that operate across the whole Arctic, and therefore this paradigm should be shifted towards one that establishes MPA networks to protect what is valued and cherished before it is harmed. This calls for applying the precautionary principle and creating Arctic MPA networks that will support resilience of biodiversity and ecosystem services to climate change and ocean acidification. Scientists are aware that not all desired knowledge for planning such networks is available at this time. This includes uncertainty associated with projecting the consequences of climate change across the physical (e.g. climate models), ecological (e.g. species diversity, ecosystem processes) to the human domain (e.g. ecosystem services, human well-being). Uncertainty about the effects of climate change and ocean acidification grows when moving from physical processes to ecology and finally to human well-being. Nonetheless, general ecological principles and additional experience from other regions (e.g. Antarctica, Baltic Sea) provide sufficient basic understanding to start designing a robust pan-Arctic MPA network already now and to develop and implement the necessary connected management measures.

Existing MPA criteria need to be adapted to Arctic conditions

Creating an MPA network for the Arctic will require adaptation of established criteria to the unique, and rapidly changing, character of the region. For example, optimal MPA locations for some MPAs in the Arctic Ocean may not be stationary in space and time; e.g. high-biodiversity marginal ice zone (MIZ) ecosystems will become more dynamic in time and space, contracting in winter and expanding in summer, with climate change. In order to account for the migration of species with moving physico-chemical conditions (so-called 'climate tracking') creating dynamic MPAs along oceanographic and climatic gradients may be a feasible and effective approach. Such focus on ocean features, the integration of other effective area-based measures next to MPAs, as well as the systematic integration of traditional and local knowledge (TLK), will be essential in the process of designating MPA networks. In so doing, the vulnerability and status of Arctic ecosystems to cumulative drivers and pressures from not only regional and local scales (fishing, tourism, pollution, etc.) but also global scales (climate change and ocean acidification) should be monitored and reviewed on a regular basis.

Arctic MPAs should be located in areas that are expected to become refugia

Climate change and ocean acidificationdo not operate in isolation but combine with regional and local environmental stressors to affect Arctic species, habitats, and ecosystems. It is possible to lessen the total stress burden and increase the resilience of biodiversity to the impacts of climate change and ocean acidification by mitigating stresses from direct anthropogenic pressures, such as habitat destruction, fishing, shipping, discharges of hazardous substances, etc., through establishing MPA networks. This will not 'solve' the underlying problems of climate change and ocean acidification, which can only be done by reducing atmospheric greenhouse gas emissions, but it will 'buy time' during which the underlying problems are addressed globally.

Additional stresses should be targeted

A key aspect is how to identify the location of prospective MPAs within a network. Since the effects of climate change and ocean acidification are unevenly distributed across the Arctic Ocean, it would be recommended to protect habitats that will act as refugia for Arctic biodiversity. For example, protecting the areas north of Greenland, where summer sea ice is projected to be most long-lasting, or parts of the Arctic Ocean where the supply of organic matter through permafrost melt, glacier melt, higher precipitation and higher river runoff (with increasing coastal CO_2 concentrations through microbial activity) will be lowest. The 18 Arctic large marine ecosystems (LMEs) reflect the marine ecosystem variability in the region, and should be used to draft plans for MPA networks to more effectively consider representativeness.

The scientific knowledge basis must be improved

The workshop highlighted the need for a dedicated group to compile relevant geophysical and biological data for the purpose of MPA network planning. These data should include the changing environment, 'spatial adaptation planning', biochemical gradients, and identification of areas of high and low impact of climate change and ocean acidification. There is a wealth of information available (both reviews and analyses of knowledge gaps from CAFF, AMAP and others), that can be used for MPA planning but this information is highly scattered and needs to be collated and made spatially explicit, when possible. While the planning for MPA networks can start already now, there remains a large need for monitoring and relevant scientific research. This would require not only improved scientific cooperation between countries but also truly integrated international monitoring and research to decrease fragmentation and duplication of research.

Identification of research priorities

Gaps in knowledge identified by the workshop participants mainly concern the winter season, the vulnerability and resilience of the Arctic marine ecosystems and the need to support sustainable development. With respect to climate change much more is known about species higher up in the food web (seabirds, marine mammals, some fish) than about species lower in food web. For ocean acidification, most of the experimental work has been done on lower trophic levels. Much uncertainty surrounds the fate of Arctic ecosystems in a future world and how to deal with uncertainties is an issue that should be addressed in scientific studies. For example, the disappearance of strongly ice-associated species in many places will likely lead to a state-change in the associated ecosystem, yet the timing and nature of that change is currently unpredictable. While the basic drivers of the Arctic shelf-sea ecosystems are quite well understood, there is a massive lack of information at all trophic levels for the Central Arctic Ocean LME, i.e. the deep central basin, and key species are difficult to identify. Presently, this high-latitude ecosystem is ice-bound, but climate projections indicate that it will become ice-free during summer within decades; the projected spatial and temporal variability is however very large and is likely not predictable. It is not known if native species will be able to adapt to the very rapid rates of change. It is also not known if more southern species that may migrate into the new ice-free areas will be able to adapt to certain local conditions that are not likely to change, e.g. the low nutrient availability in the Central Arctic Ocean . While many coastal areas may become more productive as melting terrestrial ice and snow transports nutrients to the sea, the Central Arctic Ocean is expected to remain nutrient-poor since no new nutrients are projected to reach this remote area with climate change.

Clear is that the ecosystems of the Arctic Ocean, and especially the Central Arctic Ocean, face critical changes, which will be large and unprecedented, and that there is an urgent need for food-web studies and ecosystem modelling to inform the establishment of marine protection regimes in the Arctic.

Background of the workshop

The Arctic Council and PAME

The Arctic Council is a leading intergovernmental forum that addresses issues faced by the Arctic governments (Canada, Finland, Iceland, Kingdom of Denmark, Norway, Russian Federation, Sweden and the United States of America) and the indigenous people of the Arctic region. Marine environmental issues are high on the agenda of the Arctic Council and one of its six Working Groups, PAME (Protection of the Arctic Marine Environment), focuses on a number of activities within the framework of the Arctic Marine Strategic Plan (2015-2025). PAME was established against a background of increased economic activity and significant change due to climatic processes, which together are increasing the use, opportunities, and threats to Arctic marine and coastal environments and livelihoods. These changes require integrated approaches to address existing and emerging challenges to Arctic marine and coastal environments. PAMEs mandate within the Arctic Council is "to address marine policy measures and other measures related to the conservation and sustainable use of the Arctic marine and coastal environment in response to environmental change from both land and sea-based activities, including non-emergency pollution prevention control measures".

The Arctic Marine Protected Areas (MPA) network project of PAME

PAME's MPA network project (www.pame.is) aims to develop guidance to assist countries in advancing MPA networks in the Arctic. The project produces this guidance in the form of a catalogue of examples of diverse existing area-based measures, including different types of marine protected areas and other effective area-based measures that contribute to the long-term conservation of important categories of Arctic marine biodiversity (e.g. important species and habitats). The "Framework for a Pan-Arctic Marine Protected Areas Network' document (PAME, 2015) recognizes that individual Arctic countries pursue MPA development based on their own authorities and priorities, and that MPA networks can be comprised of 'both MPAs and 'other' area-based measures that contribute to network objectives'.

This workshop was the third in a series of four workshops supporting PAME's project on MPAs, each of which deals with a specific aspect of MPA networks:

1. Science and tools for developing Arctic Marine Protected Area networks (Washington DC, USA, September 2016)
2. Understanding MPA networks as tools for resilience in a changing Arctic (Copenhagen, Denmark, February 2017)
3. Scientific considerations of how Arctic Marine Protected Area (MPA) networks may reduce negative effects of climate change and ocean acidification (Helsinki, Finland, September 2017)

4. Exploring best practices for supporting Indigenous involvement in, and Indigenous led, marine protection in the circumpolar Arctic Ocean (Canada, November, 2018)

These four workshops contribute with compilations of scientific knowledge to the 'PAME MPA-network toolbox'. This is a living document that is built, and refined, over time; its current version is the document 'PAME MPA-network toolbox (2015–2017): Area-based conservation measures and ecological connectivity' (PAME, 2017; www.pame.is).

Aim of the workshops

The aim of the two-day workshop was to take stock of the current scientific understanding, expert knowledge and experiences of how Marine Protected Areas (MPAs), and other effective area-based measures, may be used to reduce negative effects of climate change and ocean acidification and their interactions with other human-induced stressors in the Arctic marine environment. The intention of the workshop was not to reach consensus and provide a list of recommendations, but rather to summarize: (1) the best available knowledge that can already be applied to the planning of MPA networks in the Arctic; and (2) the primary uncertainties and, hence, what scientific knowledge is still lacking. As such, the outcomes from the workshop contributes to the scientific basis for the potential of MPAs as a tool to meet the threats posed by climate change and ocean acidification to Arctic ecosystems and livelihoods.

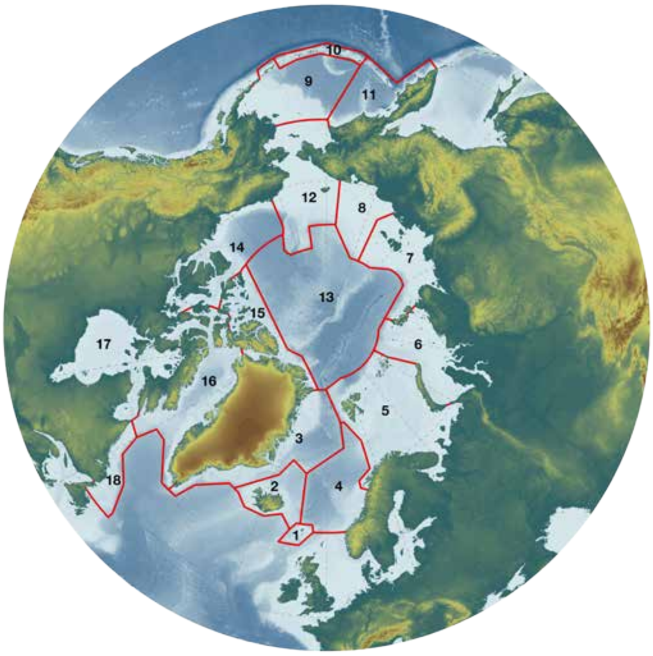
Workshop participants

Given the multifaceted subject of MPA networks in relation to global environmental change, the 63 workshop participants (Fig. 1; names and affiliations listed in Appendix I) were experts with relevant but diverse knowledge backgrounds, mainly scientists performing research in the fields of Arctic marine ecosystems, climate change, ocean acidification, and MPAs in the Arctic region, and elsewhere (e.g. Antarctica and Baltic Sea), as well as representatives of relevant governmental and non-governmental organizations involved in Arctic marine management.

Figure 1: Group photo of the participants in the Helsinki workshop.

Relevant maps

To aid the discussions during the workshop, three maps of the Arctic region were on the table, showing the 18 large marine ecosystems (Fig. 2), the Marine Protected Areas in 2017 (Fig. 3), and Ecologically or Biologically Significant Areas (EBSAs; Fig. 4).



1 Faroe-Islands LME
2 Iceland Shelf LME
3 Greenland Sea - East-Greenland LME
4 Norwegian Sea LME
5 Barents Sea LME
6 Kara Sea LME
7 Laptev Sea LME
8 East Siberian Sea LME
9 East Bering Sea LME
10 Aleutian Islands LME
11 West Bering Sea LME
12 Northern Bering Chukchi Sea LME
13 Central Arctic Ocean LME
14 Beaufort Sea LME
15 Canadian High Arctic North Greenland LME
16 Canada East Arctic - West Greenland LME
17 Hudson Bay LME
18 Labrador Newfoundland LME

Figure 2: The 18 large marine ecosystems (LMEs) within the area considered the Arctic region by the Arctic Council (indicated by the red line). Image: © NaturalEarth, CAFF

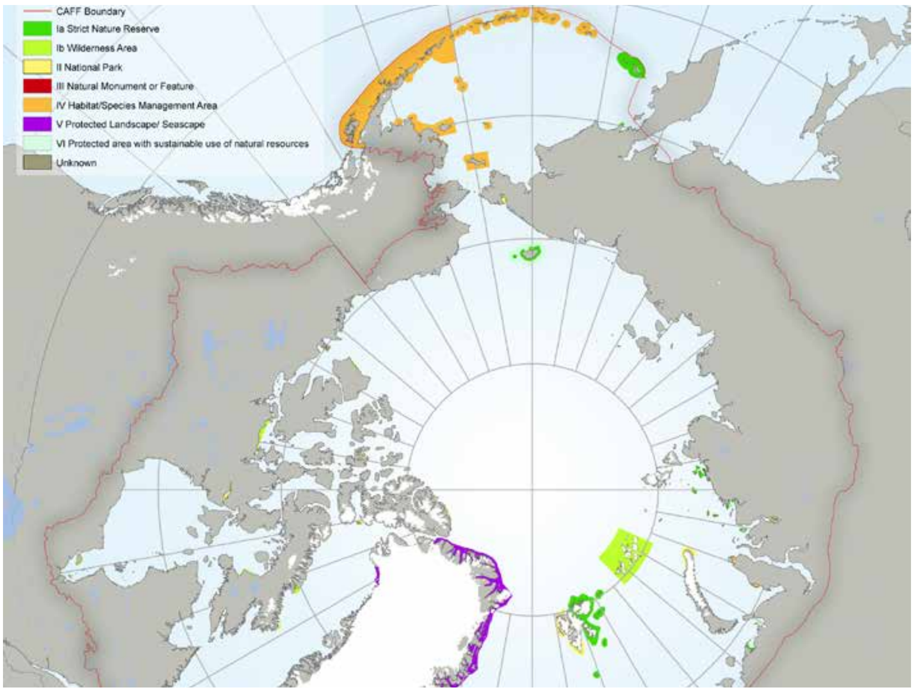


Figure 3: Marine Protected areas in the Arctic within the area considered the arctic region by the Arctic Council (indicated by the red line), except for Canada's newest MPA.
Image: © NaturalEarth, CAFF 2016

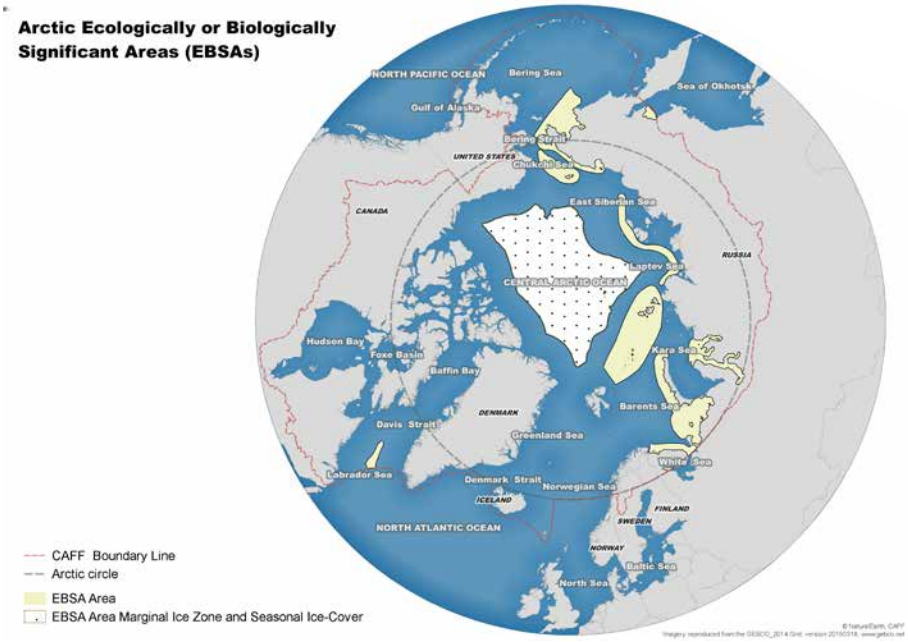


Figure 4: Ecologically or Biologically Significant Areas (EBSAs, as defined by the Convention on Biological Diversity of the United Nations) within the area considered the Arctic region by the Arctic Council (indicated by the red line), except for Canada's newest MPA.
Image: © NaturalEarth, CAFF

Introduction to the workshop on behalf of the Finnish organizers

presented by **Paula Kankaanpää**, SYKE

The Finnish Environment Institute (SYKE) is the expert and research agency for the Finnish government and administration under the Ministry of the Environment with a staff of 550. SYKE is Finland's hub for environmental data and information and manages Finland's environmental laboratories on terrestrial, marine and freshwater environmental science, sustainable consumption and production, circulation economy and environmental policy.

During 2017-2019, Finland chairs the Arctic Council according to a two-year chairmanship rotation scheme. A film with presentation of the Finnish chairmanship of the Arctic Council: https://toolbox.finland.fi/videos/other-videos/arctic-council-chairmanship-finland-long-version/ Chairing countries can trigger new projects or emphasize certain existing processes. This workshop, organized together with Sweden, is one of the activities Finland contributes with during its chairmanship.

The Arctic Council brings together policy leaders (Ministers), representatives of indigenous people, diplomats, officers, experts, and scientists. Within the Arctic Council there are five permanent environmental working groups: AMAP (monitoring), ACAP (actions), CAFF (nature), EPPR (emergencies) and PAME (marine), one sustainable development working group for ad hoc projects and Task Forces for ad hoc tasks. The Arctic Council is a success story of information production for over 20 years through assessment reports, best practices, recommendations and compilations of existing information. As such the Arctic Council has influence as the Arctic Voice in global fora such as the Intergovernmental Panel on Climate Change (IPCC), the Convention on Biological Diversity (CBD) and Sustainable Development Goals (SDG) of the United Nations (UN), global treaties such as those on Persistent Organic Pollutants (POPs) and mercury, and Arctic treaties such as those on the Polar Code, Search and Rescue (SAR), oil, and research. This PAME workshop on MPAs is organized within the Arctic Council:s work for conservation and sustainable use of the Arctic marine and coastal environment. Similar work is going on within PAME on shipping, marine litter, Arctic offshore resources exploration and development, and the ecosystem approach.

A fact sheet on marine climate change impacts in the Arctic is proposed to be produced based on the workshop report, scientific literature, and indigenous and local knowledge.

Introduction to the workshop on behalf of the Swedish organizers

presented by **Jessica Nilsson**, Swedish Agency for Marine and Water Management

Figure 5: The Arctic MPA Toolbox project is working towards a representative and connected marine protected area network in the Arctic. Image: © Getty Images.

The Swedish Agency for Marine and Water Management (SwAM) is the Swedish government agency responsible for managing the use, and preventing the overuse, of Sweden's marine and freshwater environments. SwAM takes into consideration the requirements of the ecosystem, including people, both now and in the future, by gathering knowledge, planning, and making decisions about actions to improve the environment.

PAME released its framework for a pan-Arctic network of MPAs in 2015. This framework is not legally binding; each country is responsible for establishing its own MPA network based on its own authorities' priorities and timelines. However, the goal and hope is that these efforts are coordinated so that the whole is greater than its parts.

The framework sets out a common vision for international cooperation in MPA network development and management, based on best practices and previous Arctic Council initiatives. The purpose of a pan-Arctic MPA network, composed of individual Arctic state's MPA networks and other effective area-based measures, would be to protect, maintain, and restore marine biodiversity, ecosystem function and special natural features, and to preserve cultural heritage and subsistence resources for present and future generations.

SwAM participates in the PAME's MPA toolbox project, which aims to develop guidance to assist countries in advancing MPA networks in the Arctic. The project produces guidance in the form of a catalogue of examples of diverse existing area-based measures, including different types of MPAs and other effective area-based measures that contribute to the long-term conservation of important categories of Arctic marine biodiversity (e.g. important species and habitats). The toolbox is intended to be ready in 2019 and is a living document with a step-wise approach, with refinements over time.

This third PAME MPA workshop focuses on how Arctic MPAs, and networks of MPAs,may assist reduing negative effects of climate change and ocean acidification and thereby increase the resilience for the 18 large marine ecosystems of the Arctic.

Sweden is committed to also work towards increased marine area protection in the international waters of the Arctic.

Literature related Arctic MPAs

The Arctic Council, AMAP, CAFF and PAME publications can be downloaded from their web pages: www.arctic-council.org; www.amap.no; www.caff.is; www.pame.is

AMAP (2013) AMAP Assessment 2013: Arctic Ocean Acidification. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. viii + 99 pp.

AMAP (2015) AMAP Assessment 2015: Black carbon and ozone as Arctic climate forcers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. vii + 116 pp.

AMAP (2017) Snow, Water, Ice and Permafrost in the Arctic: Summary for Policy-makers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. 22 pp.

Arctic Council (2016). Arctic Resilience Report. Eds: Carson M, Peterson G. Stockholm Environment Institute and Stockholm Resilience Centre, Stockholm. 218 pp.

CAFF (2013) Arctic Biodiversity Assessment: Report for Policy Makers. Conservation of Arctic Flora and Fauna, Akureyri, Iceland. 23 pp.

CAFF (2013) Arctic Biodiversity Assessment. Status and trends in Arctic biodiversity. Conservation of Arctic Flora and Fauna, Akureyri, Iceland. 674 pp.

CAFF (2017) State of the Arctic Marine Biodiversity Report. Conservation of Arctic Flora and Fauna International Secretariat, Akureyri, Iceland. 198 pp.

CAFF and PAME (2017) Arctic Protected Areas: Indicator Report. Conservation of Arctic Flora and Fauna and Protection of the Arctic Marine Environment, Akureyri, Iceland. 20 pp.

Gross, John E., Woodley, Stephen, Welling, Leigh A., and Watson, James E.M. (eds.) (2016). Adapting to Climate Change: Guidance for protected area managers and planners. Best Practice Protected Area Guidelines Series No. 24, Gland, Switzerland: IUCN. xviii + 129 pp.

ICES (2016) First Interim Report of the ICES/PAME Working Group on Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA), 24-26 May 2016, ICES Headquarters, Copenhagen, Denmark. ICES CM 2016/SSGIEA:11. 222 pp.

OECD (2017), Marine Protected Areas: Economics, Management and Effective Policy Mixes, OECD Publishing, Paris. 179 pp.

PAME (2013) The Arctic Ocean Review Project, Final Report, (Phase II 2011-2013), Kiruna May 2013. Protection of the Arctic Marine Environment (PAME) Secretariat, Akureyri. 99 pp.

PAME (2013b) Large Marine Ecosystems (LMEs) of the Arctic area: Revision of the Arctic LME map 15th of May 2013. PAME International Secretariat, Akureyri, Iceland. 19 pp.

PAME (2015) Framework for a Pan-Arctic Network of Marine Protected Areas: A Network of Places and Natural Features Specially-managed for the Conservation and Protection of the Arctic Marine Environment. PAME International Secretariat, Akureyri, Iceland. 49 pp.

PAME (2017a) PAME MPA-network toolbox 2015-2017: Area-based conservation measures and ecological connectivity. PAME International Secretariat, Akureyri, Iceland. 95 pp.

PAME (2017b) Meaningful Engagement of Indigenous Peoples and Local Communities in Marine Activities (MEMA): Report Part I: Arctic Council and Indigenous Engagement – A Review. Arctic Council. 14 pp.

Speer L, Nelson R, Casier R, Gavrilo M, Cleary J, Halpin P, Hooper P (2017) Natural Marine World Heritage in the Arctic Ocean, Report of an expert workshop and review process. Gland, Switzerland: IUCN. 112 pp.

Summaries of plenary presentations

The presentations given at the workshop can be downloaded from the workshop website: http://pame.is/index.php/projects/marine-protected-areas may reduce negative effects of climate change and ocean acidification.

Figure 6: The Protection of Arctic Marine Environment (PAME) is one of six working groups within the Arctic Council. PAME, and its expert groups, meet twice a year.

Arctic climate change

***Michael Tjernström**, Department of Meteorology & Bolin Centre for Climate Research, Stockholm University, Sweden*

The average global air temperature has increased by ca. 1°C since the early 1900s. However, warming is not globally uniform; in the Arctic region the temperature has increased more than elsewhere; 2 to 4 time more than the global average, interval depending on time perspective. This 'Arctic amplification' is caused by feedback effects associated with temperature, water vapour and clouds as well as surface albedo (the increase in surface absorption of solar radiation when snow and ice retreat). Sea ice is disappearing in all seasons, most in summer, and ice volume goes away faster than ice area. The thicker and older sea ice cover disappears fast and there is a transition from multiyear ice to seasonal ice in most of the Arctic Ocean. Larger areas with multiyear ice will remain north of Greenland and the Canadian Arctic Archipelago.

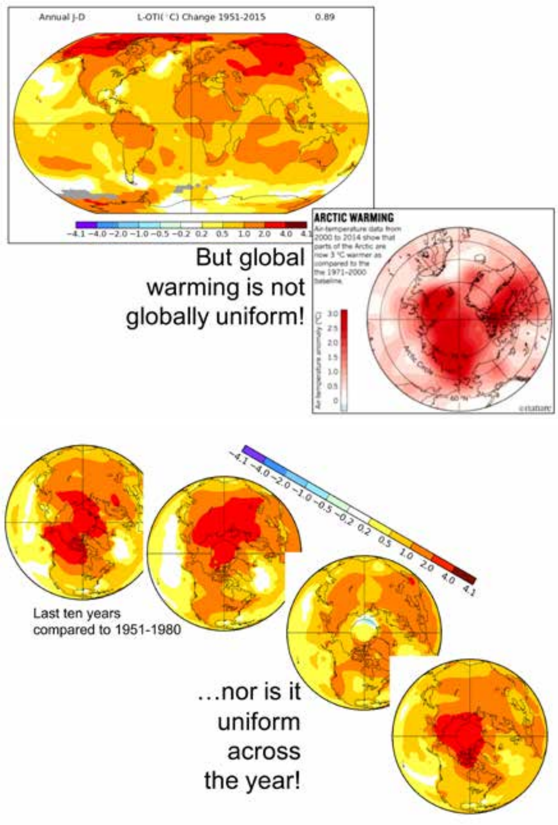


Figure 7: Distribution of global temperature change (top) spatially and (bottom) seasonally. The spatial distribution is displayed both as an absolute change in temperature over the 1951–2015 time period and in a polar display over the Arctic for the 1971 – 2000 time period (Tollefson 2017, Nature), while the seasonal distribution os shown in a polar context. Both the global distribution and the seasonal distributions are derived from NASA/GISS (https://data.giss.nasa.gov/gistemp/maps/).

There are different scenarios for how fast climate change will proceed, based on how human society might manage the emissions of greenhouse gases (RCPs: Representative Concentration Pathways adopted by the IPCC), ranging from RCP2.6 to RCP8.5. With RCP2.6 an average global temperature increase of 1.5°C is possible but with RCP8.5 global average temperature will increase by 4°C. However, in the Arctic region the temperature increase will be higher, especially in winter. Arctic climate change will continue to be large and fast and warming can be as large as 8-12°C without substantial mitigation. At the current rate of warming, summer sea ice will likely be gone before mid-century but the inherent uncertainty is very large. With mitigation keeping global warming < 2°C, there is about an even likelihood that summer ice will be lost or not. However, the predictive skill for Arctic climate is quite poor, to a large part due to poor descriptions of processes in models but also due to a large inherent variability in Arctic climate. Models agree on the Arctic amplification and on the loss of summer sea ice in this century but disagree on both sensitivity (magnitude) of and location for change. Thus, only the broadest brush-strokes can be used with any certainty.

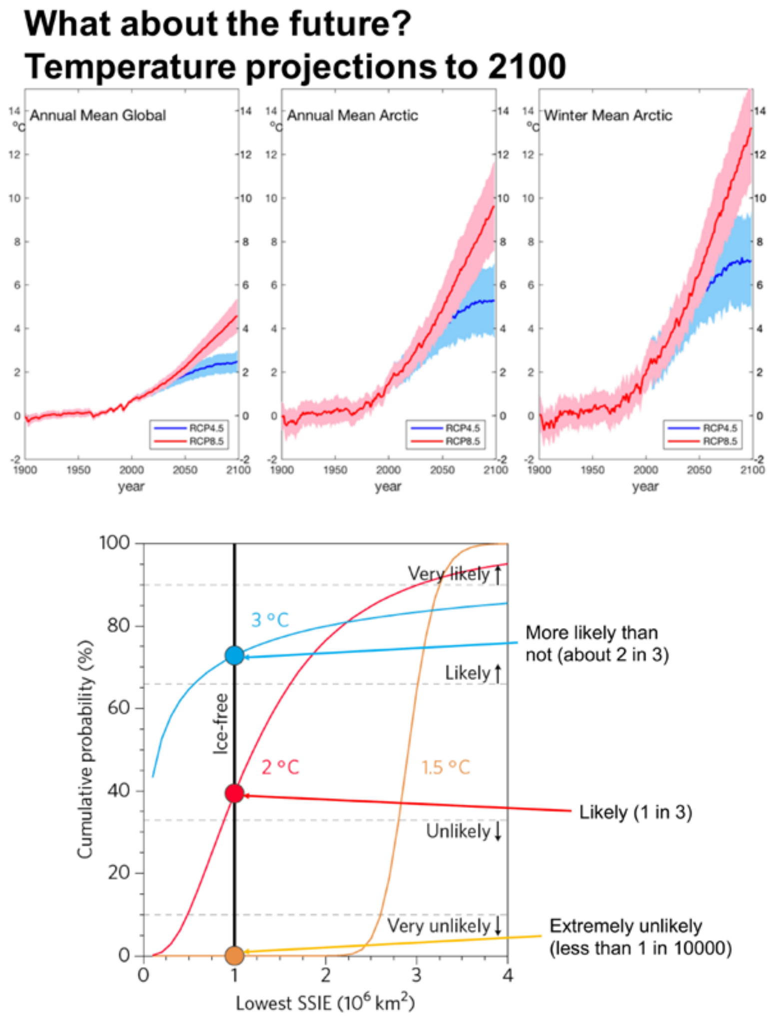


Figure 8: Projections of future (top) global, annual- and winter-Arctic temperature change under two emission scenarios (from AMAP) and (bottom) the likelihood of late summer sea-ice extent (area with >15% sea-ice concentration) under different global warming (Screen and Williamson, 2017, Nature Climate Change).**Figure 8:** Projections of future (top) global, annual- and winter-Arctic temperature change under two emission scenarios (from AMAP) and (bottom) the likelihood of late summer sea-ice extent (area with >15% sea-ice concentration) under different global warming (Screen and Williamson, 2017, Nature Climate Change).

Acidification of the Arctic Ocean, the basis for AMAP Arctic Ocean Acidification case studies

***Leif G. Anderson**, Department of Marine Sciences, University of Gothenburg, Sweden*

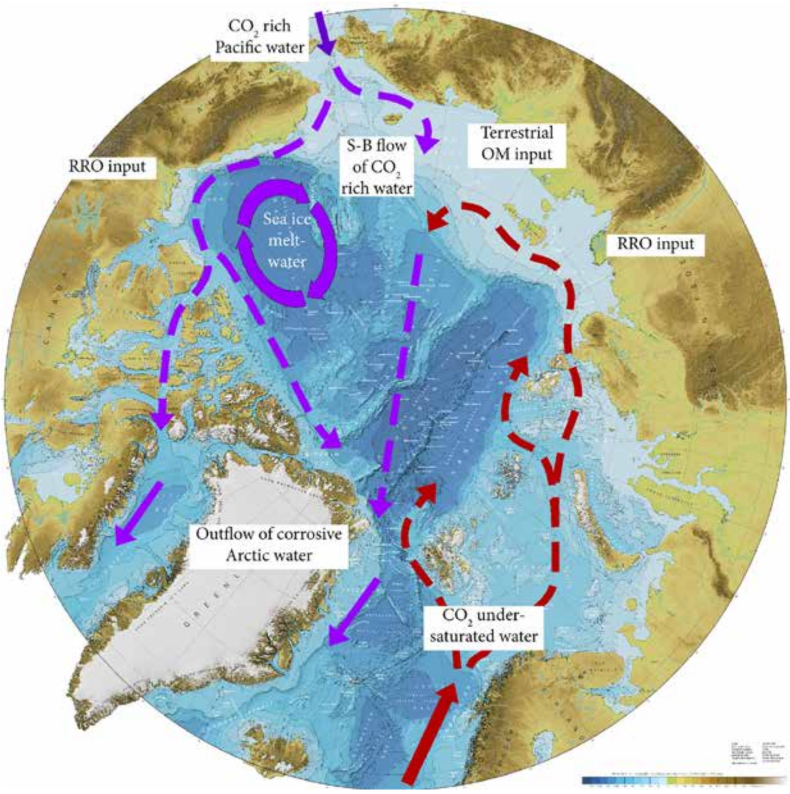


Figure 9: Map summarizing the conditions relevant to the acidification in the upper waters of the Arctic Ocean and its export to the Atlantic. The arrows indicate the general flow of the upper waters.

Ocean acidification is not uniform in the Arctic Ocean. Inflow from the Pacific: the bottom water entering through the Chukchi Sea is largely supersaturated with respect to CO2, a result of organic matter mineralization. One result is it being under-saturation with respect to calcium carbonate in the form of aragonite [an important metric of the ability of marine organisms to calcify]. Inflow from the Atlantic is mainly under-saturated in CO2 as it (1) has been in contact with the atmosphere for a long time, (2) cooled by the atmosphere and thus increased its solubility, and (3) exposed to primary production that consumes CO2.

In the Arctic Ocean large volumes of water with high pCO2 are formed on the Siberian shelves, caused by a decay of organic matter. This water is subsequently exported to the North Atlantic both to the west and east of Greenland. The pCO2 is substantially higher than the atmospheric values, even higher than values projected for the year 2100. There is a risk that with warmer climate the thawing of permafrost and increasing microbial activity will lead to more supply of organic matter and thus even higher pCO2 in these waters.

The resulting under-saturation of upper waters with respect to calcium carbonate is amplified by addition of freshwater from river runoff and sea ice melt, conditions that are also increasing with climate change. Since the shelf regions of the North Atlantic washed by Arctic Ocean outflows are both biologically active and support important commercial fisheries, continued monitoring of the changes in the ocean acidification states and investigations of biological responses to ocean acidification in this area are urgently needed.

CBMP/CAFF activities – update on work of relevance for PAME MPA work

***Tom Christensen** (Aarhus University, Kingdom of Denmark), **Cecilie von Quillfeldt** (Norwegian Polar Institute, Norway) and **Lis Lindal Jørgensen** (Institute of Marine Research, Norway)*

CAFF is the Conservation of Arctic Flora and Fauna biodiversity Working Group of the Arctic Council, with a mandate to address the conservation of Arctic biodiversity, and to communicate its findings to the governments and residents of the Arctic, helping to promote practices which ensure the sustainability of the Arctic's living resources. The first bigger CAFF biodiversity assessment was the Arctic Biodiversity Assessment (ABA, 2013) and in May 2017 the first Circumpolar Biodiversity Monitoring Programme (CBMP) published the first State of the Arctic Marine Biodiversity Report. The latter report tells us what existing biodiversity monitoring programs and other data are able to say about changes in Arctic biodiversity and ecosystems; it uses the ABA as platform where possible and provides key trends on biodiversity and advice for future monitoring, directed towards policy and decision makers.

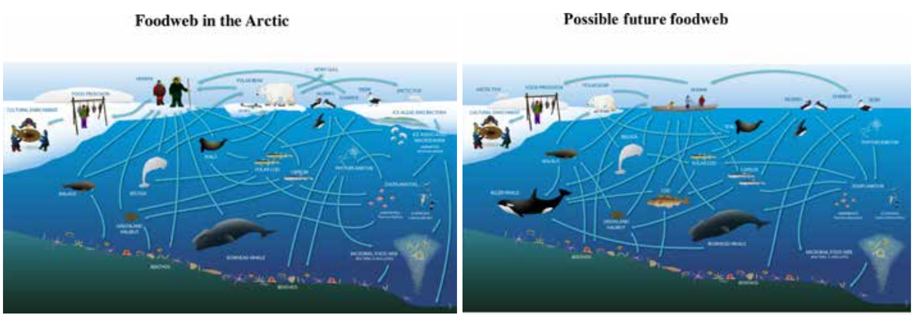


Figure 10: Foodwebs in the Arctic – now and in the future. Images © CAFF (2017) adapted from Darnis et al 2012 and Inuit Circumpolar Council – Alaska (2015).

Changes in biodiversity will change food webs. Food resources are being lost for many marine Arctic species. Some Arctic species are shifting their ranges northwards to seek more favourable conditions as the Arctic warms. Increasing numbers and diversity of southern species are moving into Arctic waters. Arctic marine species and ecosystems are undergoing pressure from cumulative changes in their physical, chemical and biological environment.

Increases in the frequency of contagious diseases are being observed. CBMP, and its network, has a potential to cooperate on the monitoring of changes in biodiversity and ecosystems within important and/or protected marine areas in the Arctic.

Sea ice is a species-rich habitat that is home to many species endemic to the Arctic Ocean. Sea ice algal community structure has possibly changed in the central Arctic between the 1980's and 2010's. Ice amphipod abundance and biomass have declined in the Svalbard area since the 1980's. Amphipods appear to have been more abundant in the late 1970's to mid-1990's than afterwards. Drivers include changes in sea ice (duration, thickness, structure, snow on the ice etc.), salinity and more. The functional and taxonomic diversity of microbes in the Arctic is vast and a scientifically underappreciated source of biodiversity. More than 2,000 phytoplankton species are reported from the Arctic marine environment. Some species are likely restricted to Arctic waters. Warming can have contradictory and surprising effects on plankton. Climate is the most important environmental driver (including changes in temperature, currents, changes in duration of open water versus sea ice, wind-driven mixing, increased freshwater etc.). More than 4,000 known Arctic macro- and mega-benthic species occur in the Arctic Ocean. Increasing numbers of species are moving into, or shifting their distributions in, Arctic waters. These species can outcompete, prey on, or offer less nutritious value as prey for Arctic species. Benthic species are important food sources for other species (marine mammals, seabirds). Major drivers of changes in benthic communities are: sea-ice dynamics, ocean mixing, bottom-water temperature change, commercial bottom trawling, ocean acidification, river/glacier freshwater discharge, and introduction of non-indigenous species. Several of the monitored seabird species have shown widespread declines in recent years, at least in parts of the Arctic.

Welcome to a second day of ocean governance in the Arctic

***Jakob Granit**, Swedish Agency for Marine and Water Management*

The main threats to marine ecosystems are habitat disturbance, pollution (eutrophication, hazardous substances, and marine litter), over-fishing, and climate change. Many pressures originate from land-based activities and end up in the sea. Therefore, water and marine governance policies need to be better coordinated from an upstream to a downstream perspective and linked to broader policy objectives in other sectors - source to sea.

Management and coordination efforts across national boundaries need to increase in several policy areas, such as environment, agriculture, fisheries, trade, business, and tourism, to achieve long-term sustainability.

At the Ocean Conference, organised by Sweden and Fiji at the UN headquarter in June, 2017, there were many examples of strong linkages between Sustainable Development Goal (SDG) 14 (Life Below Water) and other SDGs, especially SDG 6 (Clean Water and Sanitation). These linkages, naturally, call for a holistic, ecosystem-based and integrative management approach to the implementation of SDG 14 and its targets.

Sweden was very excited that this project, Arctic MPA networks in the context of climate change and ocean acidification, was one voluntary commitment submitted at the Ocean Conference. Another one related to the Arctic and PAME was the Arctic Marine Litter project.

Thanks to work taking place like here in Helsinki yesterday and today we bring hope for a more integrated governance approach of the Arctic. Thanks to you taking time from your everyday work and come here to share your knowledge, and gain some more, we can move the scientific and management frontiers forward.

Ten-step recipe for creating and managing effective marine protected areas

***Mark Carr**, Department of Ecology and Evolutionary Biology, University of California, Santa Cruz, USA*

Figure 11: Chronology of considerations and actions for creating and managing an MPA network to ameliorate the impacts of a changing climate in the Arctic.

Proposed design criteria:

Individual MPAs

- ensure sufficient level of protection (e.g., no-take)
- sufficient size to protect persistent populations
- extend from shallow to deep
- include multiple ecosystems
- design as an ecological network

- include and protect habitat for species and ecosystem to shift to
- locate in refuges (rise, temperature, ocean acidification, etc)
- locate to include stressed (adapted) populations

MPA network

- ecosystem representation
- within and among bioregions
- space to ensure larval connectivity
- if current shifts predictable, locate to accommodate species shifts
- if current shifts uncertain, distribute to maximize likelihood of maintaining network

Proposed evaluation criteria:

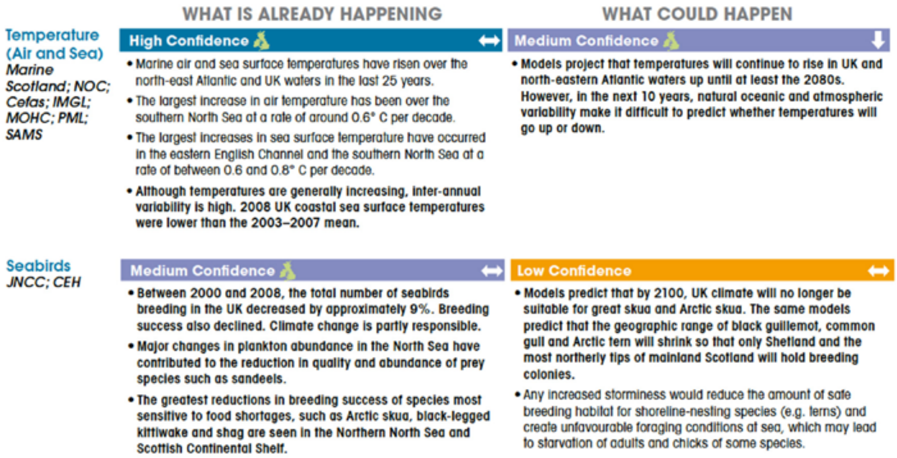
- Define evaluation criteria based on MPA goals and objectives
- Individual MPA and network criteria
- Develop appropriate criteria-based metrics
- Develop integrated empirical and analytical designs
- Link results to decisions made for adaptive management
- Develop financial model for evaluation program
- Institutional partnership model (e.g., GO's, NGO's, academia, communities)
- Develop data management model

Climate Change Report Cards: the marine climate change impacts partnership experience and Arctic possibilities

***John Baxter** (Scottish Natural Heritage, United Kingdom) and **Dan Laffoley** (International Union for Conservation of Nature, IUCN)*

A Report Card is an instrument that can be used to ensure politicians and their advisers take decisions in a timely fashion based on accurate, simple, timely information provided without bias. It does not provide advice on what to do.

Figure 12: Covers of three of the MCCIP Report Cards.



	WHAT IS ALREADY HAPPENING	WHAT COULD HAPPEN
Temperature (Air and Sea) *Marine Scotland; NOC; Cefas; IMGL; MOHC; PML; SAMS*	**High Confidence** • Marine air and sea surface temperatures have risen over the north-east Atlantic and UK waters in the last 25 years. • The largest increase in air temperature has been over the southern North Sea at a rate of around 0.6° C per decade. • The largest increases in sea surface temperature have occurred in the eastern English Channel and the southern North Sea at a rate of between 0.6 and 0.8° C per decade. • **Although temperatures are generally increasing, inter-annual variability is high. 2008 UK coastal sea surface temperatures were lower than the 2003–2007 mean.**	**Medium Confidence** • **Models project that temperatures will continue to rise in UK and north-eastern Atlantic waters up until at least the 2080s. However, in the next 10 years, natural oceanic and atmospheric variability make it difficult to predict whether temperatures will go up or down.**
Seabirds *JNCC; CEH*	**Medium Confidence** • **Between 2000 and 2008, the total number of seabirds breeding in the UK decreased by approximately 9%. Breeding success also declined. Climate change is partly responsible.** • **Major changes in plankton abundance in the North Sea have contributed to the reduction in quality and abundance of prey species such as sandeels.** • **The greatest reductions in breeding success of species most sensitive to food shortages, such as Arctic skua, black-legged kittiwake and shag are seen in the Northern North Sea and Scottish Continental Shelf.**	**Low Confidence** • **Models predict that by 2100, UK climate will no longer be suitable for great skua and Arctic skua. The same models predict that the geographic range of black guillemot, common gull and Arctic tern will shrink so that only Shetland and the most northerly tips of mainland Scotland will hold breeding colonies.** • Any increased storminess would reduce the amount of safe breeding habitat for shoreline-nesting species (e.g. terns) and create unfavourable foraging conditions at sea, which may lead to starvation of adults and chicks of some species.

Figure 13: Example extracts from an MCCIP Report Card summarising what is already happening and what could happen in the future as a result of climate change together with an indication of the confidence of these assessments.

The process of producing a Report Card should include: commission topic experts to provide up-to-date briefing; address specific questions and provide confidence assessments; peer-review the briefing; revise the briefing in light of peer review comments; summarize and simplify key messages from briefing documents; check with experts that simplified key messages are accurate; publish report card and full briefing documents.

Feedback studies have shown that the report cards are used by a wide range of people including advisers and politicians to inform thinking and policy decisions. The full briefing papers and cards are well cited in peer review literature and the process is well respected. Experts are fully engaged and willing to continue to contribute, and special topic reports are sometimes requested by advisers and politicians.

Protecting marine areas beneath Antarctic ice shelves – Special Areas for Scientific Study (SASS)

Susie Grant, British Antarctic Survey, United Kingdom

In 2016, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) agreed to a UK proposal to implement precautionary protection for marine areas exposed following the collapse or retreat or ice shelves in the Antarctic Peninsula region.

Ice shelf collapse and retreat is one of the most evident signals of climate change on the Antarctic Peninsula; loss of ice shelves and retreat of coastal glaciers around the peninsula in the last 50 years have exposed at least 2.4 × 104 km2 of new open water. Such changes result in phytoplankton blooms, increased productivity, rapid change from low-nutrient conditions, colonisation by species from adjacent areas, changes in community structure and species turnover.

This agreement allows for the automatic designation of Special Areas for Scientific Study (SASS) in newly-exposed marine areas. These locations are protected for an initial two years immediately following a retreat or collapse, and can be extended to a further 10 years after consideration of available data. CCAMLR Members are encouraged to undertake research in SASSs, particularly in order to understand ecosystem processes in relation to climate change. Research fishing activities are only permitted under certain conditions, with the agreement of the CCAMLR Scientific Committee.

A SASS is a short-term measure to facilitate research – not an MPA. However, SASSs are an important addition to the suite of area-based conservation and management measures for the Southern Ocean. Research will inform decisions on future protection or management by improving scientific understanding of possible ecosystem responses to impacts of climate change, and helping develop measures to improve ecological resilience.

CCAMLR's first Special Area for Scientific Study (5,818 km2) was established on 9th Sept 2017, in the area left exposed when a massive iceberg (A68) calved from the Larsen C Ice Shelf, resulting in the loss of 12% of the previous ice shelf area. The Larsen C iceberg calving may be part of natural growth/decay cycles rather than a direct impact of climate change, but it nevertheless provides a unique opportunity to study ecological responses to such events.

CCAMLR is also developing a Climate Change Response Work Programme, which sets out actions and research required to address impacts, and to integrate information on climate change into management decision-making.

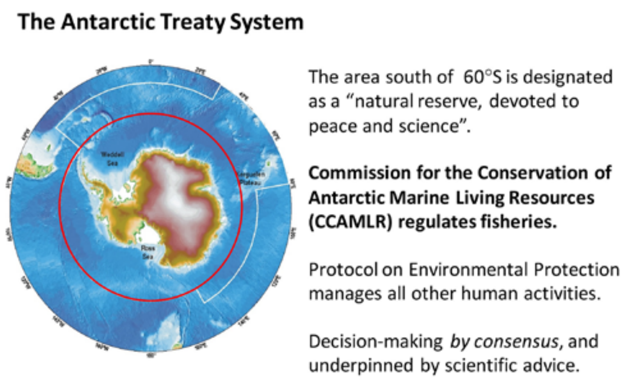


Figure 14: CCAMLR has the mandate to implement marine protected areas in the Southern Ocean.

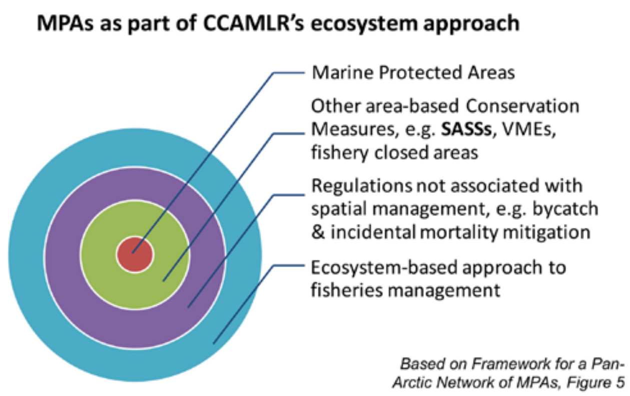


Figure 15: MPAs is one tool CCAMLR uses practising ecosystem-based fisheries management.

The journey towards a Weddell Sea Marine Protected Area (WSMPA)

Thomas Brey, Alfred Wegener Institute (AWI), Helmholtz Centre for Polar and Marine Research and Helmholtz Institute for Functional Marine Biodiversity, Germany

The general objective of the WSMPA project is to establish an MPA in the Weddell Sea. The tasks of the AWI are to: (1) produce the scientific foundation; (2) support the implementation process; and (3) coordinate future research and management.

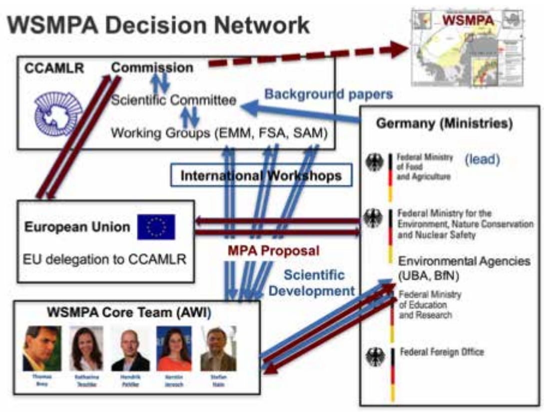


Figure 16: The decision-making process creating an MPA in the Southern Ocean involves a lot of stake holders – both nationally and internationally.

Scientific foundation: Altogether, the Weddell Sea geo-referenced ecological information system has produced over 75,000 raw data files. Twenty-five documents on the Weddell Sea ecosystem have been published, mostly in the grey literature, e.g. as reports of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). There are also a number of exciting 'spin-off' projects that have resulted in international scientific publications, e.g. Deininger et al. (2016): Towards mapping and assessing Antarctic marine ecosystem services – The Weddell Sea case study. Ecosystem Services 22(A): 174-192.

Tool: The MARXAN software, designed to aid systematic reserve design on conservation planning, is used in the project.

Challenges: Diverging opinions on the extent and the mode of conservation/protection constitute the major challenge of the WSMPA process at the levels of national and EU coordination, while diverging interests (exploitation vs conservation) play a major role at the level of CCAMLR.

Current Status: The first submission of the WSMPA project was submitted to CCAMLR in October 2016 but this proposal was not adopted by the European Commission. The work at the AWI is continuing.

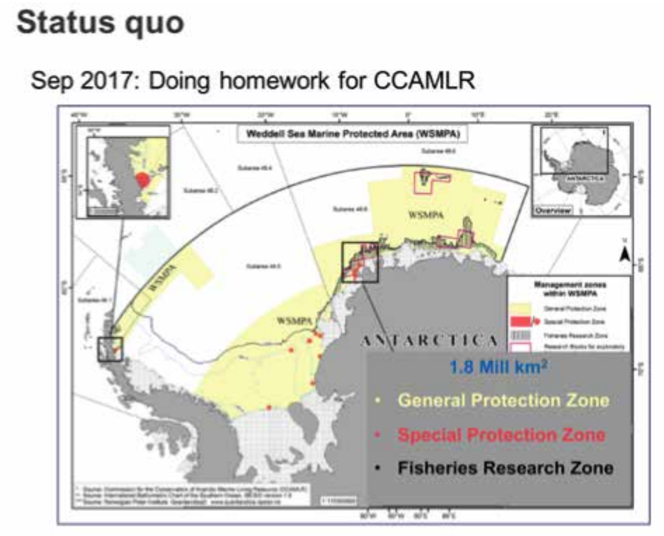


Figure 17: The Weddell Sea Marine Protected Area (WSMPA) proposal consist of 1.8 million km2.

Networks, platforms and the wind of change – MPAs and climate change in the Baltic Sea

Jannica Haldin, Baltic Marine Environment Protection Commission (HELCOM), Finland

Nine different nations, together with the EU, make up the Contracting Parties of HELCOM and thus constitute a common platform for nations to tackle challenges and coordinate their marine work regionally.

Background: The first 62 coastal and marine Baltic Sea protected areas (HELCOM MPAs) were established in 1994, following the adoption of the 1992 Helsinki Convention. At a later stage, the Baltic Sea Action Plan (HELCOM 2007) and the HELCOM 2010 and 2013 Ministerial Meetings agreed upon objectives for the network of protected areas, encouraging the Contracting Parties to nominate new areas. The HELCOM MPA network overlaps with sites established under other frameworks, foremost the Natura 2000 network established under EU legislation.

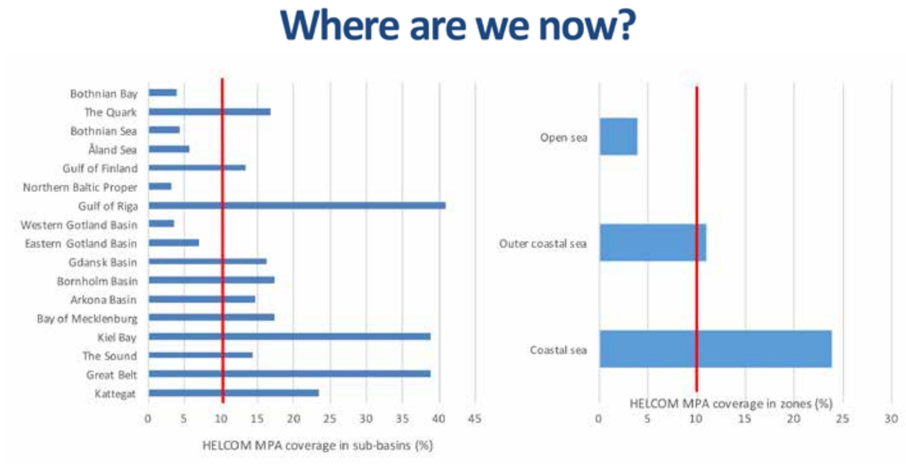


Figure 18: Coverage of HELCOM MPAs in each sub-basin of the Baltic Sea. The HELCOM MPAs cover 13,7% of the entire Baltic Sea (January 2018). The values in the figure were calculated as the area covered by HELCOM MPAs of the total area of the sub-basin, based on shapefiles of the MPAs provided by the HELCOM countries in 2016. The target (red line) is 10% coverage in each sub-basin.

Figure 19: Coverage of HELCOM MPAs in the Baltic Sea zones. The zones are 1) coastal sea: from the coastline to 1 nm beyond the baseline, 2) outer coastal sea: 1-12 nm beyond the baseline, and 3) open sea: >12 nm beyond the baseline (see Figure 5). The values were calculated as the area covered by HELCOM MPAs of the total area of the zone, based on shapefiles of MPAs provided by the HELCOM countries in 2016. The target (red line) is 10% coverage in each zone.

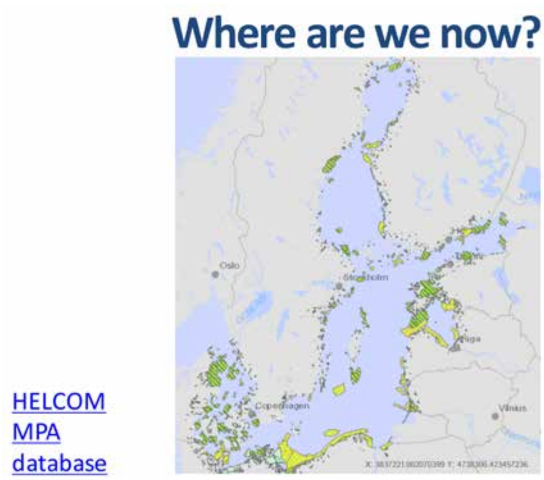


Figure 20: Spatial extent of the MPA network in the Baltic Sea, as reported by the HELCOM countries (status in September 2017), including both marine Natura 2000 sites and the HELCOM MPAs.

Today there are 176 HELCOM MPAs. They cover a total area of 53,642 km², which includes both coastal and marine areas. The marine fraction of this area is 90 % (48,392 km², excluding coast and islands). The marine area covered by HELCOM MPAs has risen from 3-9 % in 2004 to 11.7 % in 2013. The HELCOM Recommendation 35/1 also emphasizes the development and implementation of management plans for MPAs, as well as assessing the effectiveness of management plans, or other measures, to ensure protection.

Current challenges are management effectiveness, MPA management plans and their implementation and adjacent transnational MPA management, how to combine Marine Spatial Planning with MPAs, network coherence, representativeness, replication, adequacy, and connectivity.

Conclusions: it is necessary to better understand and take regional measures to increase resilience, the potential role of MPAs under climate change and the changing/increasing pressures on MPAs, and plan for early mitigating measures.

Russian research in the Barents Sea

Gennady Matishov*, Murmansk Marine Biological Institute (MMBI KSC RAS), Russian Federation*

Factors impacting the marine ecosystem and bioresources in the Barents Sea are fisheries and hunting, the production of wastes and aquaculture, tankers with oil products, oil development, ballast water, introduced species, chemical contamination, oil spills, regulation of rivers and navy activities. Zoobenthos is a good indicator of marine ecosystem pollution and climate change.

The 'Russian Arctic' National Reserve covers the northern part of the Severnyi Island of the Novaya Zemlya Islands, the Large and Small Oransky Islands, Loshkin Island, Heemskerk Island, the Franz Josef Land, and a series of other islands. It was established on 15 June 2009 and has a total area of 1,426,000 ha, including land areas 632,090 ha, and sea areas 793,910 ha.

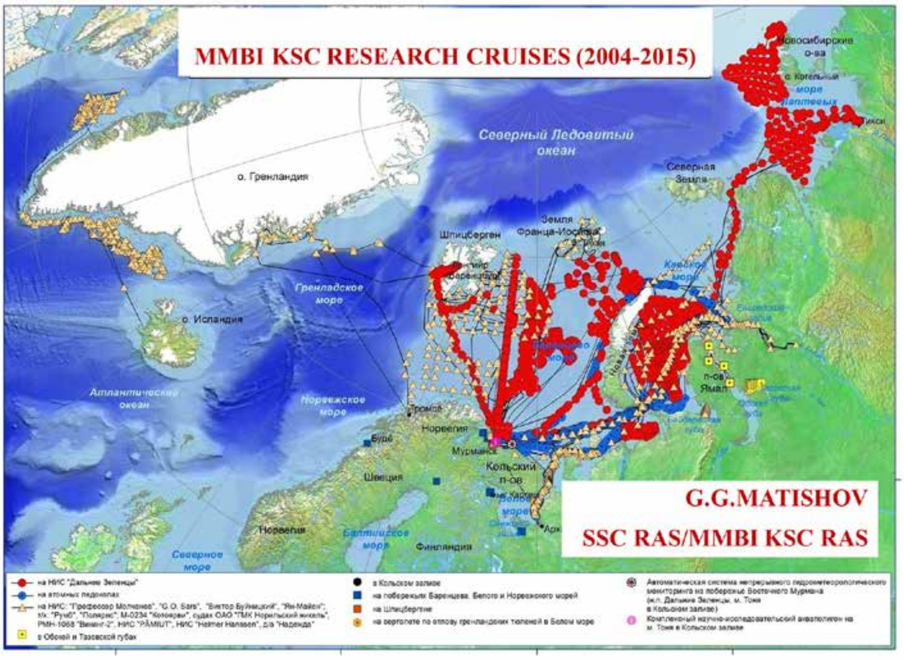


Figure 21: There are many anthropogenic factors impacting the marine ecosystem and bioresources in the Barents Sea.

Figure 22: The 'Russian Arctic' National Reserve was established on 15 June 2009 and has a total area of 1,426,000 ha, including land areas 632,090 ha, and sea areas 793,910 ha.

Radioactive contamination issues in the Arctic

***Nadezhda Kasatkina**, Murmansk Marine Biological Institute (MMBI KSC RAS), Russian Federation*

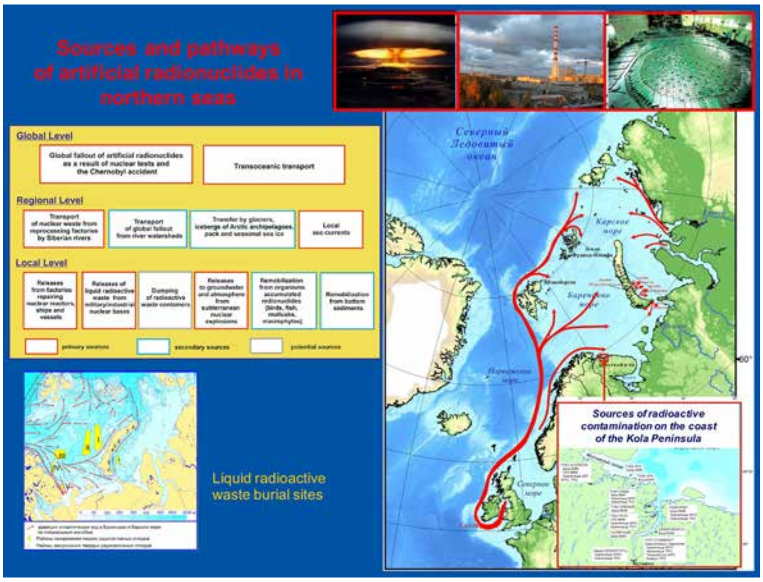


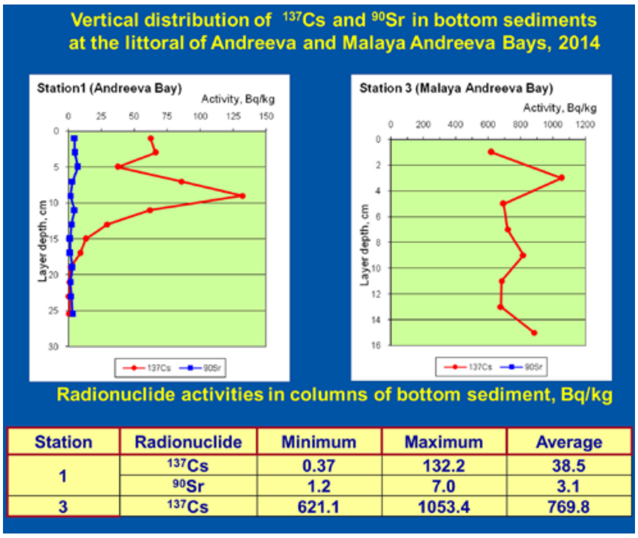
Figure 23: There are many anthropogenic factors impacting the marine ecosystem and bioresources in the Barents Sea.

Ongoing international projects on radioactive substances in the Arctic are:

- CEEPRA: Collaboration Network on EuroArctic Environmental Radiation Protection and Research.
- CETIA: Coastal Environment, Technology and Innovation in the Arctic
- Evaluation of the Present Radio-Ecological Situation in Andreeva Bay and adjacent offshore zones.

- MEMO-PRO: Development of methods for ecosystem-based monitoring of the coastal zone and continental shelf of the Barents Sea and the High Arctic, methods for scenario modelling of emergency situations related to transport of petroleum products and radioactive waste, accompanied with and innovative technologies for marine environment protection under conditions of the marine periglacial.

Results were presented of the levels of ^{137}Cs and ^{90}Sr in 2014 in the of bottom sediments of the Andreeva and Malaya Andreeva Bays and of a simulated accident at the planned Finnish nuclear power plant at the Bothnian Bay coast



Station	Radionuclide	Minimum	Maximum	Average
1	^{137}Cs	0.37	132.2	38.5
	^{90}Sr	1.2	7.0	3.1
3	^{137}Cs	621.1	1053.4	769.8

Figure 24: Vertical distribution of 137Cs and 90Sr in bottom sediments from the littoral zone near the Site for Temporary Storage (STS) for spent nuclear fuel and radioactive waste at Andreeva Bay (Barents Sea).

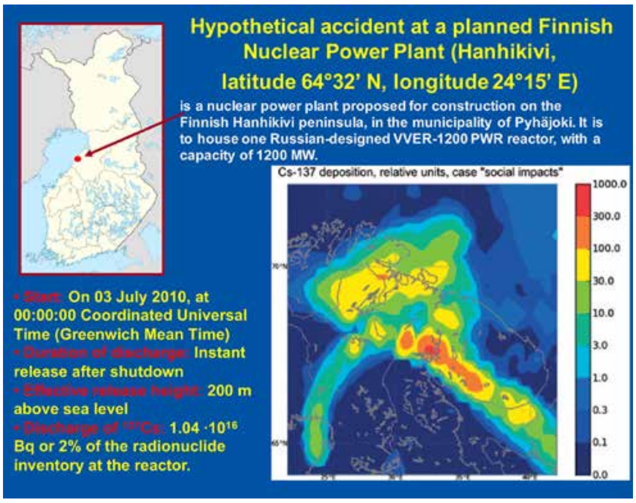


Figure 25: 137Cs deposition after the hypothetical accident in the planned Finnish Nuclear Power Plant (mathematical modeling results). It was calculated that in case of the accident radioactive substances could reach the Euro-Arctic region. The most important residential and tourism centres as well as the reindeer herding areas in the Euro-Arctic region would be exposed to radioactive fallout. The effects of the accidents on the image of the area would be much greater than the real physical effects. The recovery of the changed image would take much longer time than the physical recovery of the environment.

The Ross Sea Region MPA (RSRMPA)

***George M. Watters**, Southwest Fisheries Science Center, NOAA Fisheries, United States of America*

On 28 October, 2016, after several years of negotiation, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) adopted Conservation Measure 91-05 and thereby established the Ross Sea Region MPA (RSRMPA) in Antarctica, the world's largest MPA (1.5 million km2). Experiences from the planning and management of this MPA can be used as examples for Arctic MPAs.

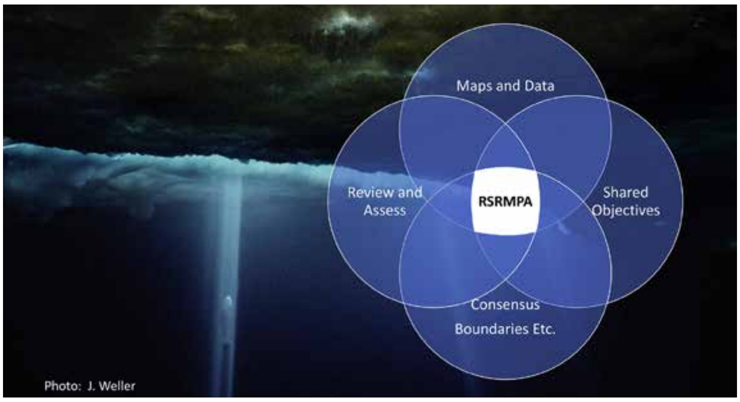


Figure 26: In 2016, CCAMLR established the world's largest MPA (1.55 million km2) in the Ross Sea, Antarctica. The proposal was presented by the USA and New Zealand.

Key elements of CCAMLR MPA process are: (1) Collate data and map everything; (2) Define national priorities and policy aims – link these to the maps; (3) Consider alternative boundaries etc. to achieve policy aims; (4) Negotiate collective set of objectives, boundaries, etc.

In the planning phase special priorities for protection should be mapped (what MPA boundaries would you draw if you could only protect 10 % of the area? What if you could protect another 10 %?, and so on). Overlay this map with e.g. important areas for air-breathing predators, fisheries, etc. followed by negotiations. At present the RSRMPA has specific objectives and 3 management zones for a period of 35 years beginning 1 Dec 2017 with a review at least every 10 yrs. A Research and Monitoring Plan has been submitted to deliver knowledge to assess the degree to which objectives being achieved, the degree to which objectives still relevant in given location, and actions to improve achievement of objectives.

The protection objectives are: (1) 'representative' benthic and pelagic bioregions; (2) large-scale 'ecosystem-process areas'; (3) core distributions of key prey species; (4) core foraging areas of land-based predators or those possibly in direct competition with fisheries; (5) coastal locations of ecological importance; (6) toothfish habitats; and (7) rare or vulnerable benthic habitats.

The science objectives are: (1) Spatial comparisons to learn about ecosystem effects of fishing and climate change; (2) Tagging to underpin toothfish stock assessment and learn about their distribution and movement; and (3) Studies to understand ecosystem role of krill.

Synthesis of group discussions

Set-up of the group discussions

On each of the two days of the workshop three hours were spent on group work during which six pre-defined themes (Themes A-F) were discussed. Each of the six discussion groups consisted of 7-11 experts, selected to create a diverse combination of knowledge in the respective groups. Themes A-C were discussed on Day 1 and each theme was discussed by two groups. Themes D-F were discussed on Day 2 and each theme was discussed by all six groups. For each theme 1-3 questions were prepared to get the discussions going, but discussions were not restricted to these questions. The groups were asked to produce two slides that were presented during a ca. 1 hour plenary summary session at the end of each day: one slide with key conclusions ('what is known and can already be applied') and one slide with key challenges ('what is not known and needs more scientific research'). These slides formed the basis of Chapter 3 (Synthesis of group discussions) in this report.

Theme A: Theme A: Current status, projected changes and knowledge gaps of spatial and temporal environmental variation

Discussion questions Theme A

- What is known, and what are the uncertainties, about the likely extent of climate change and ocean acidification in the Arctic in 2050 and 2100?
- How can the understanding of spatial and temporal heterogeneity in the magnitude, rate, and direction of change in the Arctic be improved? I.e. to what extent might small-scale (< 100 km) shifts in protected areas change the marine climate regime?
- What modelling / monitoring / observing / TLK information is needed to be able to plan MPAs (or other spatial tools) in the Arctic effectively?

Key conclusions Theme A (combined group slides)

(1) *Time plan:* There are already enough data available to plan for an Arctic MPA network that will support resilience to CC.

(2) *Climate change:* An MPA network cannot stop climate change, nor can it stop its effects. However, it is possible to identify those areas that will remain less affected by climate change for a longer time than other areas. Such less affected areas could be prioritized as MPAs because here there is a larger chance to preserve habitats (refugia) while the global emissions of greenhouse gases will hopefully decrease. Other areas that may need MPAs are those at risk for over-exploitation, sensitive areas with respect to water circulation in the Arctic Ocean (transporting e.g. pollutants),

or areas with a high degree of uniqueness and/or vulnerability (e.g. the Central Arctic Ocean and areas that hold important carbon stores).

(3) *Ice habitat:* there is a general ice cover decrease, especially of multi-year ice. Spatial variability: multi-year ice is mainly accumulated and preserved north of Greenland and hardly found in the Siberian shelf seas. Temporal variability: warming will induce larger ice-habitat variation with a shifting marginal ice zone and a very large inter-annual variability. Water habitat: general effect of climate change is stronger stratification. Central Arctic Ocean: less saline upper layer (20 m) from ice melt. Shelf seas: sea ice melt, permafrost melt, glacier melt, higher precipitation, higher river runoff.

(4) *Ocean acidification:* Freshwater and organic matter discharges from land will increase with climate change. There are large differences in ocean acidification between the shelf seas largely depending on the input of organic material. The Laptev Sea is a sensitive area for climate change and ocean acidification because of permafrost melting with freshwater and organic matter input to the sea as a result.

(5) *Productivity:* coastal areas are expected to become more productive when more nutrients become available through increased runoff; the Central Arctic Ocean is expected to remain nutrient-poor since no new nutrients (N and P) are projected to reach this remote area with climate change or ocean acidification.

(6) *Water circulation:* there are some areas from which discharges of hazardous substances would be more catastrophic than elsewhere because the pollutants would circulate all over the Arctic Ocean for a long time with the ocean currents. Examples of such areas are the northern Barents Sea (north of Svalbard) and the Laptev Sea.

Key challenges Theme A (combined group slides)

(1) There is a general lack of data, poor time series, poor accessibility of certain data, integration of existing and new data is necessary, better use of satellites (re-analysis)

(2) There is a need for consistent monitoring programs using harmonized methodology at pan-Arctic scales.

(3) Monitoring efforts should be intensified in time and space in order to develop planning and adaptive management.

(4) Improve cooperation: Endorse measurements/sampling by using ships of opportunity, indigenous mapping to identify ecologically and culturally important areas, citizen science.

(5) Not only scientific cooperation between countries but also truly integrate research between counties to decrease research fragmentation and promote international interdisciplinary cooperation in research projects funded by a joint research council for Arctic environmental research. This could be organised by the Arctic Council.

(6) Improve regional Arctic models: global models do not work well for the Arctic.

(7) Increase knowledge on physical mechanisms (Arctic circulation, decadal variation), e.g. by field experiments on mixing processes (very few have been made for the Arctic Ocean)

(8) Climate models must be better connected to biologically relevant monitoring.

(9) There is a need for a dedicated group to compile relevant geophysical and biological data for the purpose of MPA network planning in the changing environment.

(10) Finer scale (both in time and space) data of the marine environment would improve the effectiveness of an MPA network.

(11) There is a need to investigate how an MPA network can contribute to the mitigation of climate change effects.

(12) Understand the 'moving target issue' (moving physico-chemical fronts create moving ice habitats).

Theme B: Climate change effects on marine biodiversity and the environment

Discussion questions Theme B

- What is known, and what are the uncertainties, about key species, process and ecosystem vulnerabilities?
- To what extent can known responses of species and processes be generalized? What existing information is relevant for the Arctic? (other polar information? Is it possible to generalize from non-polar regions?). How broad generalizations can be made? How can this be known?
- How will projected changes shift ecologically important features (e.g. how will marginal ice zones move in space and time)? How big is the biological challenge to protect them? What will be the impacts on Arctic food webs?

Key conclusions Theme B (combined group slides)

(1) There is sufficient information to initiate the design and implementation of an Arctic MPA network.

(2) It is necessary to start to act now on what is already known.

(3) Generally ecological theory is valid in the Arctic, too.

(4) Generally valid ecophysiological animal models can be applied to Arctic animals.

(5) The projected ecological changes depend on climate scenario.

(6) The CAFF and AMAP Reports are a good start for current conditions; they document biodiversity, identify trends, summarize features higher trophic levels are better understood.

(7) There is high natural spatio-temporal variability in the system and uncertainty in effects of GCM model projections. Species distributions, interactions and ecosystem functions are changing. MPA network designs must

adapt to this. Well-designed MPA networks can be research tools (Ross Sea, Beaufort Sea). Best guess for change is based on established ecological principles.

(8) Basic environmental drivers are well understood (temperature increase, ocean acidiication, sea ice, freshwater) and environmental scenarios can be developed.

(9) There will be a general biogeographical shift towards the north.

(10) Ecological knowledge is abundant, albeit unevenly distributed: trophic hierarchy (top > down), spatially (coast > Central Arctic Ocean), seasonally (summer > winter).

Key challenges Theme B (combined group slides)

(1) Projected ecological change depends on climate scenario. Which climate scenario should be planned for?

(2) How will variability/uncertainty be affected by climate change and ocean acidification? How will this change species distributions and interactions? How will this change system connectivity within and outside the Arctic?

(3) What is the acceptable level of uncertainty?

(4) Additive, multiplicative, and cumulative effects of climate change and ocean acidification at all ecosystem levels (especially plankton).

(5) Connectivity data to create/design an MPA network.

(6) Implication of sea ice loss to the Central Arctic Ocean (from the surface to the deep sea), which is a unique environmental setting. How will this ecosystem function? At which levels of production and biodiversity/stability?

(7) Interaction of effects unique to the Arctic: sea ice loss + freshwater input + permafrost erosion -> stratification, sediment load, carbon load, etc.

(8) Achieving a pan-Arctic ecological knowledge base with joint use of diverse data sources and including long-term observations (LTO) and suitable reference areas.

(9) Developing Arctic-specific MPA approaches, conservation targets, conservation measures, stakeholders, including TLK, to identify MPA look at e.g., species - functions, vulnerability, cumulative impacts, consider review and adaption, mobility, etc.

Theme C: Climate change effects on ecosystem services

Discussion questions Theme C

- What are the most important ecosystem services (ES) that will likely be impacted? What provisioning services? What cultural services? What regulating services?
- What additional stressors might have substantial modifying effects (either positive or negative)? What options are there for adaptation/remediation?

- How will changing food webs, changing food quantities and qualities affect human activities in the Arctic?

Key conclusions Theme C

(1) Knowledge of ES is a vital component in MPA designation, but also important in Ecosystem-Based Management (EBM) and other spatial management measures such as Marine Spatial Planning (MSP).

(2) ES make us think beyond threats, to functionality, connectivity, values, and this reflects what the indigenous people think as well.

(3) Ice is an important regulating factor for human activities in the Arctic: decrease in ice cover may lead to increased accessibility for open-sea-related ES (by ship) and decreased accessibility for coastal-related ES (e.g. ice-fishing).

(4) An important existing provisioning ES is fishing (commercial, subsistence, recreational); Fishing and hunting (traditional, recreational) are also important cultural services (traditional, recreational); Climate changes may lead to changes in regulatory services (coastal defence/erosion control).

(5) Climate change is expected to lead to a shift from benthic-associated to open-water-associated ES. For example: small-scale coastal fisheries will probably be more negatively affected by CC than large-scale open-water fisheries.

(6) ES-related data for the Arctic exist, and the spatial location and extent of ES are mapped in some areas (e.g. in Russia and Norway).

(7) Specific ES that will be impacted by climate change can be identified, but details on the extent of impacts and the rate of change are lacking.

(8) It is known that many of the ES changes will impact indigenous and coastal local people and their culture.

Key challenges Theme C

(1) Uncertainty: although it is known what is likely to change, uncertainty in the link from climate change to changes in the ecosystem lead to uncertainty changes in where, how much and when ES will change.

(2) Changes in accessibility (ice cover)

(3) Changes in productivity patterns

(4) Changes in the distribution of species

(5) Changes in technology – the capacity to exploit and protect

(6) Spatial (location): ES in many areas are not mapped and the available data are scattered and often only broad-scale. Some ES are difficult to define spatially, especially at higher resolutions.

(7) The rate of ES change in different areas of the Arctic is unknown (but it is known that there will be differences).

(8) There is a communication problem: knowledge of ES in the Arctic exists but this knowledge is poorly shared.

(9) There is no shared view of an AC ES framework.

Actions that could be taken quickly Theme C

Some of the challenges are relatively easy to address, e.g. the communication problem between the AC, the WGs, and the AC and others:

(1) A review of currently available ES information, identification of data and knowledge gaps
(2) A common shared AC ES framework, including beneficiaries of specific ES (local/regional/global)
(3) Map of existing broad ES (using existing information)
(4) Spatial definition of ES (where feasible) can help understanding of connectivity between the ES hot-spots
(5) Once ES are mapped, then links between ES and locations important to indigenous people and local communities can be identified and acknowledged, e.g. in MSP
(6) Sharing of ES frameworks between the two polar regions could be beneficial

Themes D-F: Arctic MPA networks

Discussion questions Themes D-F

Theme D: Mitigation, adaptation or remediation – what is the aim of MPAs? How can relevant mitigation, adaptation and/or remediation strategies be incorporated into the design of MPA networks (including other area-based measures)?

Theme E: Optimal design of MPA networks – specific issues caused by acidification vis á vis warming and other stresses. What specific issues does acidification bring to the design of MPA networks? How do these issues differ from those of warming, freshening, and other stressors?

Theme F: Other area-based measures – what information is required in order to achieve success? How can other (non-MPA) area-based measures identified in the MPA Toolbox be used to reduce negative impacts of ocean acidification? How can implementation/ performance to maximize successful outcomes be measured? How can traditional and local knowledge (TLK) be integrated?

Key conclusions Themes D-F

(1) Climate change and ocean acidification are the primary problems and MPAs are no tangible solution for these global problems. Consequently, other stressors that can be controlled by MPAs need to be targeted, i.e. other human activities.
(2) The aim of using MPAs is to preserve uniqueness, representativeness, rare habitats/species, biodiversity, productivity and to achieve connectivity and resilience.

(3) MPAs minimize cumulative stressors (tourism, resource extraction, etc.) on ecosystems, maintain buffer capacity of the Arctic LMEs.

(4) Diversity (redundancy) of a functional role increases the resilience a system.

(5) Major impacts of ocean acidification are changes to productivity and impacts to fisheries and aquaculture.

(6) Other effective area-based measures can protect sources of blue carbon (e.g. sequestering marine primary production in sediment, extraction of e.g. kelp). In Norway there are plans for large-scale kelp-farming to sequester carbon and reduce ocean acidification.

(7) Dynamic MPAs may assist with adaptation to systemic threats (climate change and ocean acidification) and connectivity.

(8) An MPA network supports ecosystem adaptation to change but also human communities and society to adapt. Socio-economic analyses need to be performed.

(9) Regional agreements on MPAs could help ensure some continuity across a region.

(10) Knowledge-sharing mechanisms across the Arctic will facilitate better MPA monitoring and support 'effectiveness'.

(11) There are enough data to start planning an MPA network for the Arctic that will support resilience to climate change and ocean acidification.

(12) The overall strategy should be precautionary.

(13) It is urgent to act now in the Arctic due to the fast changing climate – as the additional stressors are not yet entrenched.

(14) Identify clear objectives and operational goals for an MPA network, including stakeholder engagement and monitoring, identify milestones, review and revision timelines, continued evaluation and update monitoring processes.

(15) Need to design effective networks that not only account for current features but also for future change (climate tracking, emerging ES).

(16) Networks need to be iterative / dynamic in response to shifts, monitoring needs to provide data and knowledge to assess whether MPA objectives are achieved, still relevant and can be improved.

(17) There is a need for a dedicated group to compile relevant geophysical and biological data for the purpose of MPA network planning in the changing environment, e.g. on 'spatial adaptation planning', biochemical gradients, identification of low impact areas of acidification.

(18) There is a need for participation in global evaluation and monitoring efforts using sentinel MPA sites to track climate change and ocean acidification.

(19) Early involvement of stakeholders is important for design and implementation of MPA networks, political will to implement will follow.

(20) There is a need for early dialog and engagement of TLK. There is eagerness to include TLK in the MPA network process, provision of resources

needed (personnel and other resources), ensure all different competencies (interdisciplinary), and different geographies are included in discussion and management

(21) MPA strategies should be identified: protect resistant communities, species and populations, protect refugia, manage additional stressors.

(22) Manage additional stressors so that they do not erode the ability to adapt (erode genetic variation).

(23) Ocean acidification is not uniform across the Arctic, therefore do not plan for the average: plan for the extremes. Representation of regional differences in aragonite saturation state, account for differential sensitivity of different life-stages and populations/species. Reduce negative impacts of human activities on ocean acidificationsensitive species/processes.

(24) Manage land-based stressors to reduce extremes e.g. from acidification and hypoxia.

Key challenges Themes D-F

(1) Lack of local, regional and international political commitment.

(2) Aligning common language and common conservation goal across the Arctic.

(3) Establish pan-Arctic regional agreements on marine conservation that would assist regional MPA network design, implementation and monitoring.

(4) Build on existing cooperation agreements (including fishing moratorium in the Central Arctic Ocean).

(5) A focus of the Task Force on Arctic Marine Cooperation (TFAMC) of the Arctic Council should be the development of an Arctic MPA network.

(6) To produce a pan-Arctic vulnerability analysis for climate change and ocean acidification – this will help prioritizing the actions needed.

(7) The current system to measure the 'success' of MPAs needs evaluation. It is important to identify specific aims for success – for components of ecosystem, and efforts directed towards aims not being met, need to revise aims as necessary.

(8) To be precautionary.

(9) To think outside the 'marine box', e.g. in the case of black carbon.

(10) To include cultural criteria.

(11) To design and maintain consistent monitoring programs using harmonized methodology at pan-Arctic scales to gauge effectiveness of protection.

(12) To create scientific study areas within and outside MPAs.

(13) To achieve better prediction/projection of future ecosystem features and ES by modelling future connectivity.

(14) To involve more social science and Permanent Participants in the Arctic Council to understand how human communities will respond to future changes in the Arctic.

(15) Early stakeholder involvement is important for the design and implementation, monitoring of MPA networks. How best to involve all possible stakeholders? Build a strategy for MPAs acceptable to stakeholders to ensure political backing – the Polar Code is a successful example to follow.

(16) How to deal with the Areas Beyond National Jurisdiction (ABNJ)? – The Arctic Council, regional organisations, indigenous and local communities, individual countries coming together?

(17) To identify those areas that will change the least.

(18) To identify refugia, also considering biochemical variables.

(19) The identify the location of resistant communities/species/populations.

(20) To assess the patterns of dispersal, genetic diversity and functional roles/traits that need to be protected.

(21) How to manage human activities to minimize the erosion of genetic diversity (adaptability).

(22) To develop and establish tools for dynamic protection regimes, 'mobile reserves'.

(23) To collect and compile finer-scale data (both in time and space) on the marine environment to improve the effectiveness of MPA networks.

(24) To put TLK into formats usable by managers (Canada is an example of indigenous participation in monitoring).

(25) To assess the efficiency of carbon sequestration and storage in a range of habitats – what are ecosystem effects of carbon sequestration measures?

(26) To assess freshwater runoff impacts in marine ecosystems (climate change and ocean acidification impacts).

(27) To assess what are the ocean acidification sensitive species in Arctic and what is their role? How can they be protected? (refugia? pH variable areas? low pH areas?)

(28) To assess connectivity between individual MPA regions (for key species/processes).

(29) To achieve better prediction/projection of future ecosystem features and services modelling future connectivity.

Actions that could be taken quickly Themes D-F

(1) Design a strategy for linking MSP and MPAs.

(3) Consider the IUCN Green List that looks at how to better define 'success' when including traditional Ecological Knowledge (TEK) and Local Ecological knowledge (LEK).

(4) Expand human networks: e.g. the Canadian Ecologically and Biologically Significant Areas (EBSA) process for integrating TEK/LEK in MPA processes.

(5) Set up a similar process as Network of Marine Protected Areas managers in the Mediterranean (MEDPAN) for the Arctic to support MPA managers.

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Scientific considerations of how Arctic Marine Protected Area (MPA) networks may reduce negative effects of climate change and ocean acidification

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