PAME I-2020 – MPA Expert Group Pre-meeting
Agenda item 4.1.2
Background Document

Bibliography for PAME Arctic Fact Sheet #1 - Marine Protected Areas

Note on Scope of Bibliography

The main drivers and changes described here will also be experienced in Arctic MPAs. However, there is currently a relative lack of information regarding the direct impacts of these changes in MPAs as an independent topic. Thus, rather than describe the impacts of climate change on Arctic MPAs, this bibliography is intended to gather and summarize the general information available with respect to the current and projected impacts of climate change on the Arctic on the whole. The information contained herein is derived from large, international reports and the trends described can be extrapolated to Arctic MPAs within the fact sheet.

"Of particular concern from a marine biodiversity perspective are the climate-related trends of diminishing sea ice resulting in habitat loss; melting permafrost and glaciers and reduced snow cover resulting in changes in ocean chemistry; releases of methane; increasing sea surface temperatures; and increased coastal erosion of some shorelines."[23] (could serve as an introduction)

Climate Drivers

Sea Surface Temperature

- Sea-surface temperatures are increasing over much of the Arctic Ocean.[1]
  - August sea-surface temperatures in the Chukchi Sea, between Siberia and Alaska, rose at a rate of 0.7°C per decade from 1982–2017.[1]
  - Mean August SSTs from 1982-2018 show warming trends over much of the Arctic Ocean -- linear warming trends of up to +1° C/decade have been observed.[2]
  - Prolonged exposure of the open sea surface to the atmosphere will lead to a substantial increase in the uptake of short-wave solar radiation and consequent warming of surface waters.[4]
    - Over large sectors of the seasonally ice-free Arctic, summer upper mixed layer temperatures increased at around 0.5°C per decade during 1982-2017, primarily associated with increased absorbed solar radiation accompanying sea ice loss and an increase in the the inflow of ocean heat from lower latitudes since the 2000s.[3]
- In the Barents Sea, the greatest temperature increase will occur in March, which differs from the rest of the Arctic Ocean.[4]
  - Northward shift in the ice edge in the Barents Sea will affect thermohaline properties in the upper mixed layer.[4]

- There is high confidence that marine heatwaves will increase in frequency, duration, spatial extent and intensity in all ocean basins in the future[3].
    - The largest increases in the probability of marine heatwaves will occur in the tropical and Arctic oceans.[3]
- In the Baffin Bay/Davis Straight region, sea surface temperature is expected to warm by 0.2$_o$C per decade over the next 50 years.[19,20]

Air Temperature

- The Arctic continued its long-term warming trend in 2018, warming at twice the rate relative to the rest of the globe with Arctic air temperatures from 2014-18 exceeding all previous records since 1900[3,5,6,7], with large increases in winter. [7]
    - From 1971–2017, Arctic annual surface air temperatures rose 2.4 times faster than the Northern Hemisphere average.[7]
        - The annual average Arctic surface air temperature rose by 2.7°C from 1971 to 2017, with a 3.1°C increase during the cold season and a 1.8°C increase during the warm season.[7]
    - Within this century, temperatures in the Arctic are projected to increase by several degrees above the 1980-2000 average.[6]
- Summer temperatures in the Arctic during recent decades have been warmer than at any time in the past 2000 years.[6]
- The increase in Arctic air temperature has included feedbacks from loss of sea ice and snow cover contributing to the amplified warming.[3]
- During the winters (January-March) of 2016 and 2018, surface temperatures in the central Arctic were 6°C above the 1981-2010 average, contributing to unprecedented regional sea ice absence.[3]
- Barents area is a 'hot-spot' even within the Arctic context.[4]
    - Temperatures in the Barents area increased by an average of 1-2°C over the period 1954-2003, with stronger warming in winter.[4]
    - Under a mid-range scenario for emissions growth (RCP4.5), average temperatures are forecasted to rise 3-10°C between 2010 and 2080.[4]
    - Warming under RCP8.5 in winter may be 8–15°C by mid-century and up to 20°C by the end of the century, while the corresponding values for summer are 3–4°C by mid-century and 6–8°C by the end of the century.[4,27]
- In the Baffin Bay/Davis Straight region, mean surface air temperature is projected to increase 1 (RCP 4.5) to 4$_o$C (RCP 8.5) by 2030 and 1.5 to 10$_o$C by 2080.[19,20]
- In the Bering, Chukchi, Beaufort region:
    - Annual mean air temperature has increased roughly 1.5°C over the last 50 years.[17,18]
    - Winter air temperatures are projected to increase a further 3-7°C by end of century under RCP 4.5.[17,18]
    - Permafrost has not yet begun to thaw.[17,18]

Sea Ice Change

- Observations of Arctic sea ice extent have shown decreasing trends in all months and virtually all regions.[8]

  - Arctic winter sea ice maximums in years 2015-2018 were at record low levels, and the 12 lowest minimum extents in the satellite record have all occurred in the last 12 years.[1,8]
  - The past four years (2015-18) have the four lowest maximums in the satellite record.[8]
  - The 2018 sea ice cover winter maximum was 7.3% below the 1981-2010 average and was the second lowest maximum extent recorded.[8]
  - The 2018 sea ice cover minimum was 26% less than the 1981-2010 average minimum ice extent.[8]
- It is very likely that approximately half the observed sea ice loss is attributable to increased atmospheric greenhouse gas concentrations.[3]
  - It is very likely that Arctic sea ice extent continues to decline in all months of the year.[3]
  - It is very likely that projected Arctic warming will result in continued loss of sea ice and snow on land, and reductions in the mass of glaciers.[3]
- The volume of Arctic sea ice present in the month of September has declined by 75% since 1979.[1]
  - The strongest reductions in September (-12.8 ± 2.3% per decade; 1979-2018) are likely unprecedented in at least 1000 years.[3]
- Sea ice has gone through a transition from mostly thick multi-year sea ice to younger and thinner seasonal sea ice.[1]
  - The oldest ice (>4 years old) continues to make up a small fraction of the Arctic ice pack in March, when the sea ice extent has been at its maximum in most years of the satellite record.[8]
    - In 1985, the oldest ice comprised 16% of the ice pack, whereas in March of 2018 old ice only constituted 0.9% of the ice pack.[8]
      - Therefore, the oldest ice extent declined from 2.54 million km2 in March 1985 to 0.13 million km2 in March 2018, representing a 95% reduction.[8]
  - First-year ice now dominates the ice cover, comprising ~77% of the March 2018 ice pack compared to about 55% in the 1980s.[8]
  - It is virtually certain that Arctic sea ice has thinned, concurrent with a shift to younger ice: since 1979, the areal proportion of thick ice at least 5 years old has declined by approximately 90%.[3]
  - Arctic sea ice in 2018 remained younger, thinner, and covered less area than in the past.[8]
- Important differences in the trajectories of loss emerge from 2050 onwards, depending on mitigation measures taken.[3]
  - If global warming is stabilized at 1.5°C, the probability of an ice-free summer occurring in any given year would be roughly 2 percent; at 2°C, the probability would rise to 19–34 percent.[1]
  - For stabilised global warming of 1.5°C, an approximately 1% chance of a given September being sea ice free at the end of century is projected; for stabilised warming at a 2°C increase, this rises to 10-35%.[3]
  - Some models suggest the Arctic Ocean could be seasonally ice-free within the next few decades.[1]

- The sea ice thickness increase from October 2017 through April 2018 was less than normal, resulting in a relative decline in mean thicknesses over the winter.[8]
    - The total volume gain amounted to only 7.31 thousand km^3 compared to the 2010-18 average of 7.73 thousand km^3.[8]
- Losses of sea ice are causing individuals of many species have to travel further to feed, expending more energy, leading to concerns about individual and population health.[16]
- In the Bering Sea, winter sea ice extent reached a record low for virtually the entire 2017-2018 ice season. During two weeks in February, typically the height of winter, the Bering Sea lost significant ice cover, about ~215,000 km2, dropping from ~59% to only ~26% of normal (relative to the 1979-2016 median).[8]
- The Barents Sea region has experienced four times the average rate of change in terms of seasonal sea-ice coverage compared to the Arctic in general, with a reduction of 20+ weeks in just the last few decades.[4]
    - The Barents Sea is expected to become the first Arctic region free of sea ice all year round by mid-century.[4]
        - The projected decline in sea-ice extent ranges from 8% (RCP2.6) to 34% (RCP8.5) in February and 43% (RCP2.6) to 94% (RCP8.5) in September.[4]
    - Ice extent in the ‘cold’ 1965–1975 period reached on average 180,000 km2 in August, while in the ‘warm’ 2001–2012 period ice extent was considerably less at 46,000 km2.[4]
    - The observed sea ice decline in the Barents Sea has occurred at the same time as an observed increase in Atlantic heat transport due to both strengthening and warming of the inflow.[4]
        - Increased oceanic heat transport will be a major contributing factor to sea-ice decline in this area.[4]
    - During winter, the ice margin has shifted towards the north and east.[4]
- In the Baffin Bay/Davis Straight region
    - 15-20% reductions in sea ice by 2080 are expected during the fall related to later freeze-up.[19,20]
    - 10-15% reductions in sea ice by 2080 expected in spring due to earlier break-up.[19,20]
    - Winter ice thickness is projected to decrease by 20-30cm during this century with the largest decreases in more northerly regions.[19,20]
- In the Bering, Chukchi, Beaufort region:
    - Sea-ice extent has been declining, particularly in the summer.[17,18]
        - Region is now free of ice in the summer leading to greater wave heights and the amplification of coastal erosion.[17,18]

Ocean Acidification

- Increased atmospheric carbon dioxide concentrations are leading to acidification of ocean waters worldwide, especially in colder Arctic waters that can absorb more carbon dioxide.[9]
    - Arctic marine waters are experiencing widespread and rapid ocean acidification.[10,11]
    - The Arctic Ocean is continuing to remove carbon dioxide from the atmosphere resulting in continued acidification.[3]

    - Some of the fastest rates of acidification are occurring in the Arctic, due mainly to the higher capacity of cold water to absorb CO_2, but also due to dilution by river runoff, ice melt, and the oxidation of methane from the melting of subsea permafrost[12,13]
        - Oxidation of methane from melting subsea permafrost has the potential to cause rapid and massive acidification, especially over local spatial scales.[12,13]
- The primary driver of ocean acidification is uptake of carbon dioxide emitted into the atmosphere by human activities.[10,11]
- The Arctic Ocean is especially vulnerable to ocean acidification.[10,11]
- Acidification is not uniform across the Arctic Ocean.[10-13]
- In the Baffin Bay/Davis Straight region, ocean water is expected to become more acidic as a result of increased precipitation and melt run-off.[19,20]
    - Expected to reduce convection depth in the winter and increase stability during ice-free months.[19,20]
- The continental shelves of the Beaufort and Chukchi Sea are especially vulnerable to ocean acidification because of the low pH water from the Pacific and dilution by high freshwater inflows.[17,18]
- Arctic marine ecosystems are highly likely to undergo significant change due to ocean acidification.[10-13]
    - The simplicity of arctic food webs make them susceptible to disruption due to ocean acidification and other climate change divers.[10,11]
    - Ocean acidification will have direct and indirect effects on Arctic marine life. It is likely that some marine organisms will respond positively to new conditions associated with ocean acidification, while others will be disadvantaged, possibly to the point of local extinction.[10-13]
    - In the Arctic Ocean, the area corrosive to organisms that form shells and skeletons using the mineral aragonite expanded between the 1990s and 2010, with instances of extreme aragonite undersaturation.[3]
        - The Arctic Ocean is among the first areas of the ocean to experience areas of surface and near-surface waters that are corrosive to aragonite.[10,11]
    - Ocean acidification, alongside other ecosystem stressors, is likely to affect the abundance and distribution of fish stocks and marine animals of commercial and cultural importance to Arctic communities.[10-13]
        - Acidification greatly increases the risk of fishery collapse in Northeast Atlantic cod, which are otherwise expected to benefit from warming waters.[12,13]
    - Ecosystem changes associated with ocean acidification may affect the livelihoods of Arctic peoples.[10,11]
    - Many organisms, including plankton, shellfish, deep-sea corals, fishes, and marine mammals are likely to be impacted by ocean acidification, altering the composition of the Arctic ecosystem[24]
- Ocean acidification must be assessed in the context of other changes happening in Arctic waters.[10,11]

- Ocean acidification from increased carbon dioxide levels largely affects shallow waters, with the ecosystems of the subarctic Pacific and western Arctic Ocean particularly affected.[24]
- The impacts of ocean acidification could have ecological and societal impacts.[28]

Ocean Circulation

- Melting land ice contributes to rising sea level and changes in ocean salinity that may drive changes in the global thermohaline circulation.[4]
    - Freshwater release from Greenland has the potential to modulate/inhibit the formation of water masses that represent the headwaters of the Atlantic Meridional Overturning Circulation (AMOC).[3]
        - There is medium confidence that the AMOC has weakened over the historical era but there is insufficient evidence to quantify a likely range of the magnitude of the change.[3]

Precipitation and Extreme Weather

- Annual precipitation appears to be increasing in the Arctic, by an estimated 1.5–2.0 percent per decade, with the strongest increase occurring during the October–May cold season.[7]
    - Total precipitation in the Arctic has increased by 8% through the 20th century and is projected to increase another 20% by 2100.[14]
- Some regions such as Scandinavia and the Baltic Sea basin are seeing less precipitation falling as snow and more as rain.[7]
- In the Barents area, the duration of snow cover is expected to be about 30-40% less in 2050 than in 2011.[4,27]
- Natural hazards in the Barents Area include synoptic storms, avalanches, and extreme wave heights, but current projections are unable to provide robust indications of change other than a poleward shift in storm tracks.[4]
    - At present, there is no clear signal for future changes in storm statistics.[4]
- The observed rise in precipitable water over recent decades has been greatest in summer and early autumn and over the northern North Atlantic, including the Norwegian and Barents seas.[4]
    - Indication that the maximum increase in marine precipitation may take place over the Barents and Kara seas.[4]
        - Recent projections suggest increases of the order of 50% in the Arctic region (2–10 mm per month) but substantially more for the Barents Sea (up to 50 mm per month) by mid-century, and the increase is expected to continue through the end of the century.[4]
            - Strongest in late autumn and winter and primarily attributed to increased evaporation from the local surface.[4]
- In the Baffin Bay/Davis Straight region, total precipitation is projected to increase with the largest increases during winter in the northwestern part of the region.[19,20]
    - Wind speed trends are difficult to predict but could be ±5% from 2016-2035 and ±10% for 2080-2099.[19,20]
- Higher temperatures will lead to later snowfall reducing the number of days of snow cover by 40-60 days by 2100.[19,20]
    - Reductions will be more pronounced in coastal areas.[19,20]

Sea Level Rise

- Arctic glaciers, led by the Greenland Ice Sheet, are the largest land-ice contributors to global sea level rise.[7]
    - Even if the Paris Agreement is successful, they will continue to lose mass over the course of this century.[7]
- Contribution from the Greenland Ice Sheet to sea level rise over 2012–2016 (0.68 [0.64 to 0.72] mm yr^{-1}) was similar to the contribution over 2002–2011 (0.73 [0.67 to 0.79] mm yr^{-1}) and extremely likely greater than over 1992–2001 (0.02 [0.21 to 0.25] mm yr^{-1}).[3]
    - Summer melting of the Greenland Ice Sheet has increased since the 1990s to a level unprecedented over at least the last 350 years, and two-to-fivefold the pre-industrial level.[3]
    - The Greenland Ice Sheet is currently losing mass at roughly twice the pace of the Antarctic Ice Sheet. From 2005-2016 the Greenland Ice Sheet was the largest terrestrial contributor to global sea level rise.[3]
    - Mass loss from Arctic glaciers (-212 ± 29 Gt yr^{-1}) during 2006-2015 contributed to sea level rise at a similar rate (0.6 ± 0.1 mm yr^{-1}) to the Greenland Ice Sheet.[3]
- Most glaciers in the Barents region have been in retreat since the end of the Little Ice Age about 100 years ago.[4]
    - Despite differences between continental glaciers (decreasing) and oceanic glaciers (increasing), the overall trend is a major decline in glacier volume and area throughout the Barents area.[4]
- Sea-level rise in the Barents Area is expected to vary, depending on vertical uplift of land as ice sheets melt.[4]
    - Along the Norwegian coast sea-level projections vary by as much as 0.5m from place to place.[4]
- In the Baffin Bay/Davis Straight region, sea level is likely to fall with a range of +10 to -90 cm (RCP 4.5) this century.[19,20]
    - Due to a combination of decreased gravitational pull of the shrunken ice sheet and crustal uplift.[19,20]
- Relative sea level is rising along the Beaufort coast of Canada, the north coast of Alaska, and the Chukchi coast but falling around the Arctic Archipelago Islands in the eastern portion of the region.[17,18]
    - In many areas of the Canadian Arctic, relative sea level rise is falling due to rebound from the last ice age and recent loss of ice on the Greenland ice shelf.[17,18]

Biodiversity

- For purposes of biodiversity and ecosystems, the definition of the Arctic is:
    - the land north of the tree line, which generally has a mean temperature below 10-12 ^{o}C for the warmest month (July)
        - land comprising 7.1 million km^2 (4.8% of Earth's land surface)
    - Arctic waters covering 10 million km^2.[15]
- Many Arctic regions have seen little or no locally-driven, human-induced habitat change compared with other parts of the world.[15]
- Arctic marine species and ecosystems are experiencing multiple pressures due to cumulative changes in the physical, chemical, and biological environment[16]

- Introduction of non-indigenous species through increased vessel traffic may pose a serious threat to the ecosystem. Ocean acidification may impact group of organisms including plankton, shellfish, deep sea corals, fish (including larval stages), and marine mammals, therefore altering the composition of the Arctic ecosystem.[23]
- The Arctic Species Trend Index (ASTI):[15]
    - The temporal trends vary for different species, with some declining populations and some stable and increasing from the 1950s to the 2000s. However, of the 366 locations monitored in the Arctic, there is a continual decline in the percentage of stable or increasing populations.[15]
- Northward (or upslope) range shifts are the most prominent climate related changes to biodiversity in the Arctic.[15]
    - Have been documented in mammals, birds, amphibians, fish, terrestrial and marine invertebrates, parasites, plants, and marine plankton.[15]
- Food resources are being lost for many species in Arctic marine environments.[16]
    - Individuals of many species have to travel further to feed, expending more energy, leading to concerns about individual and population health.[16]
    - Many of these cases are due to reduction of sea ice.[16]
- Some species are shifting northward as the Arctic warms with unknown consequences for Arctic species and ecosystems.[16,29]
    - Increasing numbers of southern species are moving into Arctic waters, e.g. presence of Pacific zooplankton now as far north as the Beaufort Sea.[16,17]
- Current trends indicate that species reliant on sea ice will experience range reductions as sea ice retreat occurs earlier and the open water season is prolonged.[16]
- There have been observed increases in the frequency of contagious diseases.[16]
- Most Arctic species are highly seasonal and specialized in feeding, reproduction, and migration patterns so the timing and duration of sea ice retreat and ice-free ocean determine when, where, and for how long species can accomplish vital activities.[16]
    - Changes to sea ice could have large and direct impacts on specialized species.[16]
- In the Barents area:
    - There have been northward shifts of marine and terrestrial species, and increased penetration of invasive species, pests and diseases.[4]
    - Food webs will be altered, while species relying on sea ice will be negatively affected.[4]
        - The replacement of Arctic species of zooplankton and fish by less energy-rich southern species may not allow sufficient accumulation of body reserves for capital breeding animals like seals.[4]
    - Higher phytoplankton productivity in previously ice-covered waters as well as northward shifts in boreal zooplankton, fish, benthos, seabirds and marine mammals at the expense of Arctic species.[4]
        - Less ice algae as well as reduced occurrence of other ice biota represents a major qualitative change in the ecosystem in the northern Barents Sea.[4]
        - An expansion of boreal zooplankton (e.g. *C. finmarchicus*) and a reduction in Arctic zooplankton (e.g. *C. glacialis*).[4]
        - Krill are expected to expand their distribution and increase in the Barents Sea.[4]

    - Amphipods have shown declining trends over recent decades due to the reduction in Arctic Water within the region.[4]
    - Over the last two decades, jellyfish have showed a northern shift in distribution, partially explained by an increase in water temperature and increased areas of Atlantic and mixed waters.[4]
    - The impacts of continued warming on capelin, herring, and polar cod is a key issue due to their importance in the ecosystem.[4]
        - The complex biological interactions involved make it difficult to develop predictions.[4]
    - Projected warming may lead to a permanently reduced polar cod stock in the Barents Sea with consequences for the ecology of the northern and southeastern Barents Sea.[4]
        - Since 2007, the size of the polar cod stock has decreased, apparently driven by poor recruitment related to warming and associated reductions in sea ice and the area of Arctic Water.[4]
        - Expansion of Atlantic cod into the northern Barents Sea has also played a role, leading to increased spatial overlap between the two species and increased predation pressure from Atlantic cod on polar cod.[4]
    - Climate change is expected to affect all marine mammals in the Barents Sea through impacts on the productivity of plankton, benthos and fish. Ice-associated species (e.g. ringed seal, hooded seal, harp seal, bearded seal) are very likely to be negatively affected by the loss of sea ice, while open water species (e.g. baleen whales) are very likely to benefit from the warming trend.[4]
        - Continued retraction of the sea ice will almost certainly lead to large reductions in the abundance of all ice breeding seals and thereby to a reduction in the prey base for polar bears.[4]
        - Seasonal, migrant whales (e.g. minke, blue and fin whales) will have an increasing/northward distribution shift.[4]
        - Boreal-temperate species (e.g. harbour seals, harbour porpoises, sei whales) are already benefiting from climate change in northern areas of the Barents Sea.[4]
        - Ringed seals in Svalbard have experienced major reductions in available breeding habitat since 2006, when sea ice suddenly and unexpectedly declined markedly. In addition, they must now travel further to reach summer foraging areas in the pack-ice and once there must spend more time travelling and diving and less time resting at the surface or on the ice.[4]
- Biodiversity is declining faster than at any time in human history.[24.28]
- The compounding effects of drivers such as climate change, land-/sea-use change, overexploitation of resources, pollution and invasive alien species are likely to exacerbate the negative impacts on nature, as seen in different ecosystems including coral reefs, the Arctic systems and savannas.[24]
- Nature managed by indigenous peoples and local communities is under increasing pressure.[24]

    - Nature is generally declining less rapidly in indigenous peoples' land than in other lands, but is nevertheless declining, as is the knowledge of how to manage it.[24]
- Ecosystems such as tundra and taiga and regions such as Greenland, previously little affected by people directly, are increasingly experiencing the impacts of climate change.[24]
- Arctic marine species and ecosystems are experiencing multiple pressures due to cumulative changes in the physical, chemical, and biological environment[28]

Expanding Ocean Uses

- Increasing industrial activity is leading to disturbance, especially through construction of new roads.[15]
    - Overall trend is towards a greater human footprint in the Arctic.[15]
- Modern construction, extraction and transportation techniques offer the potential for developments to have lower impacts than past techniques.[15]
- The impacts can be physical (e.g. construction, dredging), chemical (e.g. direct waste discharges, oil spills) or biological (e.g. invasions of nonindigenous species, reef effect around platforms and pipelines).[4]
- In the Bering, Chukchi, Beaufort region:
    - Most of the commercial fishery of Alaska and Chukotka is located south of the Bering, Chukchi, Beaufort region, so it is not clear whether commercial fisheries are or will be a significant driver of change within the Bering, Chukchi, Beaufort region.[17]
    - Under scenarios of climate change, maximum potential catch and economic benefits from fisheries in the Canadian Arctic region are projected to increase, while ocean acidification may reduce expected catches and values.[17]
        - The projected increase in catches is driven by poleward shifts in the distribution of subarctic and temperate fish species, a decrease in sea ice extent, and an increase in net primary production.[17]
    - Oil and gas development has the potential to be one of the most important drivers of change. Oil prices, technological developments (related to both accessibility and the transport of oil/gas to market), sovereignty, and energy security all play a role in setting the pace and magnitude of future development.[17]
- The greatest human impact on the Barents Sea fish stocks, and thus on the functioning of the ecosystem as a whole is from commercial fisheries, which covers most of the Barents Sea except the far north.[4]
    - Ice is opening new grounds for trawling and for transport routes, with potential for impacts.[4]
    - Discard of the main commercial species in the Barents Sea can represent 10–30% of catches.[4]
        - Discards may lead to local organic pollution and can affect the natural balance of the marine food web.[4]
        - Bycatch endangers non-commercial and protected species with vulnerable life histories and low population levels.[4]
    - Destructive impact of bottom trawling operations on benthic habitats and communities.[4]

        - In areas of traditional trawl fishing, including the Barents Sea, such operations can cover up to half the sea area and can result in the death of 20–40% of benthic organisms.[4]
        - Trawling impacts are greatest on hard bottom habitat dominated by large sessile fauna.[4]
        - The most vulnerable species include corals, sponges and other components of benthic communities. Such species can take tens to hundreds of years to recover from trawling pressure.[4]
- Longer navigation seasons (as sea ice declines) could have several consequences for the marine environment, including increased risk of introducing non-indigenous species through ballast waters, noise pollution, more ship strikes of marine mammals, disruption of migratory patterns, and potential displacement from preferred habitat.[4]
- It is likely that Arctic tourism will continue to grow and expand.[4]
    - Some of the main impacts – for marine and terrestrial ecosystems – are environmental degradation, damage to ground cover through trampling, disturbance of wildlife, introduction of non-indigenous species, and pollution.[4]
- Oil spills are the most significant threat associated with Arctic marine shipping.[21]
- Table A.2 of ref. 21 details the ecological sensitivity of various animals and animal populations to primary threats[21]
    - Fish species tend to have high sensitivity to oil spills and low sensitivity to disturbance.[21]
    - Bird and mammal species have generally high sensitivity to both oil spills and disturbance.[21]
- The number of unique vessels entering the region increased by 25% between 2013 and 2019, and in 2019 fishing vessels accounted for the largest portion (41%) of all unique vessels in the region, as defined by the International Maritime Organization's Polar Code[30]
- Oil prices, technological developments, sovereignty, and energy security all play a role in setting the pace and magnitude of future development in the region.[30]

Marine Protected Areas

- Terrestrial protected areas are a major contributor to Arctic conservation, but marine protected areas are nearly nonexistent.[15]
    - Good map of Arctic MPAs can be found in ref 22 (pasted below)
- Oil spills are considered to represent the main threat to the marine environment, both from oil and gas activities and marine shipping. Tourism and transport represent additional threats.[6,11]
- Protective measures for species are increasing.[15]
    - May indicate greater commitment to this conservation method but could also indicate that more species are in need of protection.[15]
- The design and implementation of mechanisms to ensure the maintenance of ecosystem structure, functions and processes and the representativeness of marine habitats and refugia with low human impact should be considered.[15]
    - "A circumpolar Marine Protected Area (MPA) network could be an important part of such an effort. As many important areas cross jurisdictional boundaries,

    cooperation is essential. Such a network could include the establishment of an effective management system of deep-sea areas and large estuaries, which contain a relatively high proportion of endemic invertebrate species as well as several members of the species-rich fish families."[15]

- Habitats of particular significance for conservation, such as breeding grounds and biodiversity hotspots, should be identified in time and space and protected accordingly[15]
- It is important to establish and continue observation sites for long-term monitoring of marine ecosystems in different parts of the Arctic proper to obtain a more holistic view of the changing Arctic.[15]
    - The existing biological stations together with marine protected areas could serve as a base for such long-term observations.[15]
- "For the regulation of a fishery, an ecosystem-based approach entails restrictions set on a fishery that are configured to take the effects of environmental factors e.g. changes in water temperatures into account. At the same time, the impacts of the fishery on the ecosystem have to be minimized, for example by placing restrictions on the type of gear that can be employed in a given area. In Norway, demersal fishing gear is not permitted in marine protected areas in efforts to protect cold water corals."[15]
- Ten areas of heightened ecological significance and sensitivity were defined in the Barents Sea. These areas comprised a total of 43 subareas.[4]
    - They include areas where large numbers of individuals from one or several species aggregate during migrations or during certain times of the year for purposes such as breeding, spawning, feeding, staging, molting and are thus vulnerable to the impacts of shipping and traffic (oil spills, noise, physical disturbance).[4]
    - Use of such areas by animals is characterized by a strong seasonality. Sensitivity and increased ecological importance often occur during only one to two months of the year.[4]
    - The physical boundaries for some areas vary from year-to-year depending on weather and ice conditions.[4]
- 98 areas of heightened ecological significance have been identified within the Arctic large marine ecosystem, primarily on the basis of their ecological importance to fish, birds, and/or mammals.[21,22]
    - These areas comprise a total area of about 14 million km^2, 76% of the Arctic marine area[21,22]
    - Approximately 5% of these areas of heightened ecological importance lie within protected areas[22]
- in 2014, 13 Arctic areas of ecological and biological significance (EBSAs) were identified in a CBD regional workshop[22]
    - Cover 4.2 million km^2, 22.7% of the Arctic marine area[22]
    - Less than 1% of the ESBAs are within protected areas[22]
- The Arctic council recognized that the Arctic environment needs to be protected as a basis for sustainable development, prosperity, lifestyles, and human well-being.[22]
- The extent of protected areas, marine and terrestrial, within the Arctic (CAFF boundary) has almost doubled since 1980.[22]
    - The extent of MPAs in the Arctic has nearly quadrupled over this timeframe
- As of 2016, 4.7% of the Arctic's marine area was in MPAs[22]

  - There are important gaps in the representativeness and connectivity of Arctic MPAs[22]
- “A well-designed MPA network can also improve regulatory predictability and inform sound and sustainable business plans by allowing resource users to better plan development to mitigate adverse effects, avoid ecologically and culturally sensitive areas, avoid undesirable costs, and reduce conflicts with other interests.”[23]
- Benefits of MPAs and MPA networks include:
  - Ecological resilience, i.e. strengthened capacity of Arctic ecosystems to respond to perturbations or disturbances, by protecting and connecting key habitats and marine community structure[23]
  - Direct economic, cultural and heritage, societal, educational, and scientific values through protection of marine biodiversity and ecosystem processes to maintain associated ecosystem goods and services[23]
- The eight Arctic States follow a variety of approaches in the design and management of their MPAs and MPA networks.[23]
  - Canada: 40 areas (+2 in progress) that protect part of its Arctic marine environment, with 3 federal departments that are legislatively enabled to create, manage, and monitor marine spaces[23];
  - Greenland/Denmark: 5 areas recognized as MPAs, with other area-based conservation measures to protect fauna, flora, and specific ecosystems in Greenland[23];
  - Iceland: 30 marine areas protected on the basis of the Law on Nature Conservation and Law on Fishery within its EEZ, 14 of which have been submitted to the OSPAR MPAs network[23];
  - Norway: Marine portions of 7 national parks and 4 nature reserves in Svalbard submitted as OSPAR MPAs, with ecosystem-based management plans for all Norwegian Sea areas[23];
  - Russia: 1 national protected area network, as well as 7 regional networks, in the Arctic zone of the Russian Federation, with 5 new federal MPAs in the process of being established[23];
  - United States: 15 multiple-use MPAs in the Arctic, 8 of which are managed by NOAA Fisheries to protect marine mammals specifically and not biodiversity or marine ecosystems generally, with ongoing effors to expand the National System of MPAs[23]
- Some major challenges for establishing a pan-Arctic Network of MPAs include: limitations in the availability of scientific information, diverse and widely-dispersed stakeholder communities, variability in governance regimes and national priorities, sustainable funding, and a shifting environmental baseline[23].
- The 10% goal for marine protection is insufficient to sustain a healthy ocean and the ecosystem services it provides.[25]
  - Call for broader protection goals of 30% or more.[25]
- There is a growing need for dynamic place-based measures that can manage species in rapidly changing conditions.[26]
- MPAs can:[26]

    - Protect marine ecosystems by reducing harmful impacts from non-climate stressors, such as new or expanded ocean uses, so healthy resources can better withstand climate impacts and sustain livelihoods.[26]
    - Support food security, livelihoods and ways of life for indigenous peoples.[26]
    - Protect carbon-storing habitats, such as salt marshes and seagrasses, as well as the carbon stored in other marine life.[26]
    - Protect coastlines and coastal communities from storm impacts.[26]
    - As networks, protect species on the move due to climate impacts and provide “insurance” if some MPA resources are harmed due to climate-driven warming, storms, or disease, by protecting them in other areas.[21]
    - Protect climate refugia -- areas that are less affected by climate impacts, where species may have more time to adapt to climate change.[26]
- Almost the entire territorial waters of the Svalbard archipelago are covered by three MPAs (Svalbard West, Svalbard East and Bjørnøya) with a total area of 78,411 km² and varying levels of protection[31]

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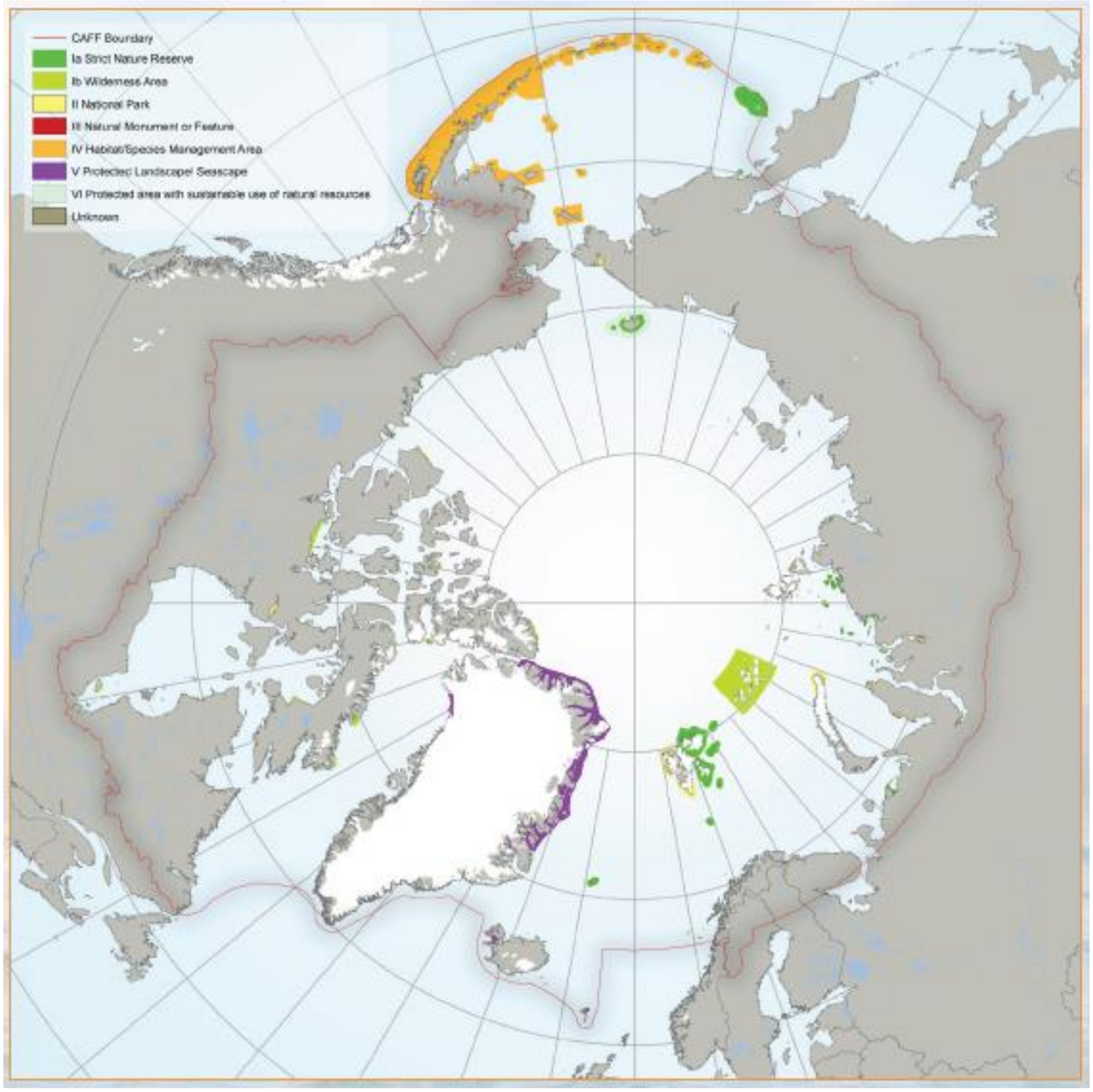
Map of Arctic MPAs (Ref 22)


CAFF Boundary
Ia Strict Nature Reserve
Ib Wilderness Area
II National Park
III Natural Monument or Feature
IV Habitat/Species Management Area
V Protected Landscape/ Seascape
VI Protected area with sustainable use of natural resources
Unknown