The North Water – ecology, vulnerability and management options

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and

Greenland Institute of Natural Resources

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Introduction

This report[1] offers an overview of the North Water polynya, focusing on main biodiversity resources and ecosystems – with the aim of providing a basis for discussions between relevant authorities on the future management of the area.

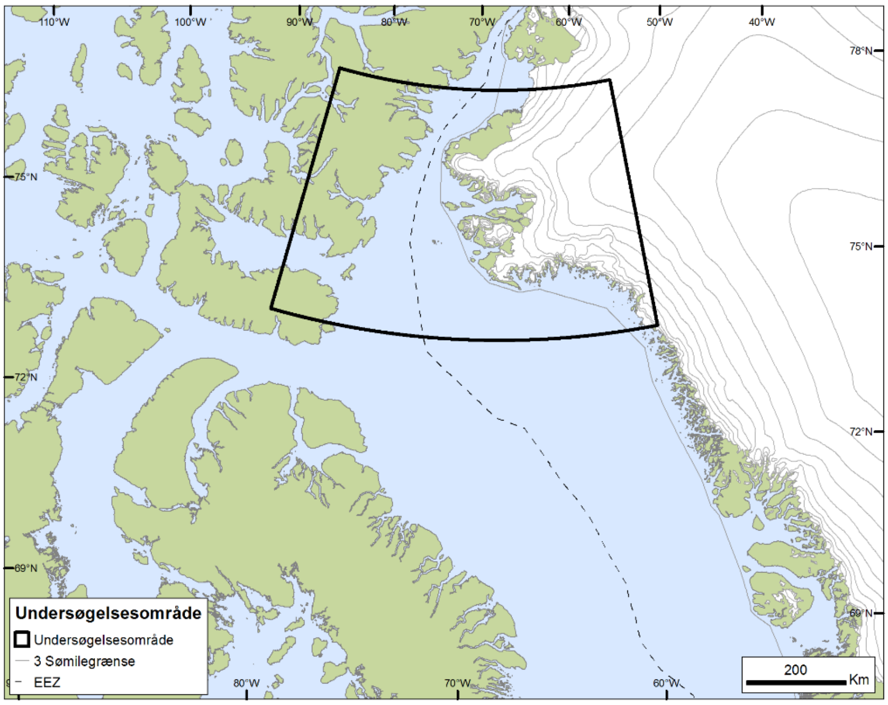


Figure 1. The study area covers both Canadian and Greenlandic parts (the dashed line between Greenland and Canada indicates international border), but with regard to sensitivity assessments and management aspects, this report emphasizes the Greenlandic part of the area.

The North Water polynya, and the study area defined for this report (Fig. 1), covers both Canadian and Greenlandic parts.

Based on the Terms of Reference and agreements with the Danish Ministry of Environment, this report includes:

- An overview of relevant national and international stakeholders
- An overview of current and completed projects regarding the North Water – to summarize a) relevant efforts in relation to the protection and management of the North Water and b) the importance for Greenland in case the North Water is designated according to an international agreement / convention.
- An overview and a description of the core biodiversity area – at species and seasonal level, including maps
- An assessment of particular sensitive areas
- Suggestions for management of the area.

[1] Funded by Danish Environmental Protection Agency, DANCEA, (MST. J. no. 112-00176)

1 The North Water – current stakeholders and management efforts

In recent years, the Arctic and its ecosystems have experienced increasing pressure and major changes, partly due to global warming. The warmer climate will lead to a reduction in the sea ice area, longer periods of ice-free sea areas during the summer periods and, thus, new opportunities for shipping, fishing, tourism, exploitation of mineral resources, etc. Increasing pressure on the Arctic marine ecosystems is also foreseen in Greenland's coastal and marine areas.

As summarized below, a number of international initiatives have focused on these issues and the North Water ecosystems and biodiversity have often been highlighted as being of particular importance.

1.1 International stakeholders

The Arctic Council working group on Protection of Arctic Marine Environment (PAME) published the Arctic Marine Shipping Assessment (AMSA 2009) offering a range of recommendations, including *identifying areas of great ecological and cultural importance* (*Recommendation IIC*). As a follow-up, PAME prepared a report that identified ecologically and culturally important and vulnerable marine areas (AMAP/CAFF/SDWG 2013) based on criteria developed by the International Maritime Organization (IMO) for identifying 'Particularly Sensitive Sea Areas' (PSSA). In Greenland, the report identified 12 areas, including the North Water.

The International Union for Conservation of Nature (IUCN) has highlighted the importance the North Water. In 2010, the IUCN organised an expert workshop, where particularly important areas in the Arctic were identified, based on the Biodiversity Convention's criteria for identification of Ecological and Biological Significant Areas (EBSA). In the process, the North Water was ranked very high and listed among the 13 Arctic Super EBSAs (Speer & Laughlin 2011). In 2016, the IUCN, in collaboration with the UN Organization for Education, Science, Culture and Communication (UNESCO), also held an expert workshop on the identification of Arctic marine areas that could be considered unique, and thus possible candidates for designation as World Heritage Sites (WHS) based on UNESCO's criteria. In 2017, the IUCN published a report where the North Water is listed among possible candidate for a marine WHS (Speer et al. 2017).

Several other organizations, have also realized the importance of, and shown interest, in the North Water. Inuit Circumpolar Council (ICC) has set up the Pikialasorsuaq Commission which released their report *People of the ice bridge: The future of The Pikialasorsuaq* in 2017, drawing upon Inuit people's knowledge of the area and providing recommendations for the future use and management of the area (Inuit Circumpolar Council 2017). In addition, the World Wildlife Fund (WWF) included the North Water in their 'Last Ice Area' and focuses on future protection of the North Water and has initiated a work with the aim of reducing disturbances and pollution in the area.

A range of other international organizations, conventions and processes may have relevance to the future management of the North Water, although it will not be possible to review all aspects. However, the objectives agreed by the Heads of State and Government under the auspices of the UN Convention on Biological Diversity (CBD – Aichi biodiversity targets) – should be mentioned; they stated that by 2020:

- *… 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved…*" (Target 11)
- *… the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained…* (Target 12), and
- *… all [marine resources] are managed … applying ecosystem based approaches, ecosystem-based management methods of marine species* (Target 6).

Finally, main relevant cooperation initiatives under the Arctic Council include the follow-up to the recommendations in the Arctic Biodiversity Assessment (Meltofte 2013), the follow-up work on establishing an Arctic network of marine protected areas under Protection of the Arctic Marine Environment (PAME 2015, 2017).

1.2 Main Greenlandic, Danish and Canadian efforts

In 2010, the respective Danish and Greenland Ministers of Environment hosted an *Arctic Environment Minister's meeting* - the outcome was a *Chairs Statement*, which encourages the parties identify areas of heightened ecological and cultural values that require protection against the effects of shipping.

As a consequence, the Danish Ministry of the Environment requested DCE and the Greenland Institute of Natural Resources to prepare a report on the identification of important and ecologically vulnerable marine areas in Greenland. Based on the PSSA criteria, twelve areas in Greenlandic waters and the North Water was ranked as highest priority (Christensen et al. 2012). Subsequently, it was decided to study three areas in more detail (the North Water, Store Hellefiskebanke/Disko Bay and the area around Scoresby Sound in East Greenland) in relation to possible effects of shipping (Anon. 2011). An analysis of a possible ecosystem-based approach to the management of shipping traffic in Disko Bay and Store Hellefiskebanke was prepared in 2015 by DCE and GN (Christensen 2015). The Government of Greenland (Naalakkersuisut) has also paying increased attention to important areas for species and habitats, in a strategic effort to enhance area-based protection of Greenlandic biodiversity. In this connection, an overview of areas of ecological and biological significance West and South-East Greenland has been prepared (Christensen et al. 2016). The basis for the identification is primarily the Biodiversity Convention's EBSA (Ecological and Biological Significant Marine Areas) criteria, the Ramsar Convention's criteria for identifying key wetlands, the International Nature Conservation Union (IUCN) criteria for Key Biodiversity Areas and the International Maritime Organization's (IMO) guidelines for identifying Particular Sensitive Sea Areas (PSSAs). Finally, national priorities/criteria are included to some extent. The report identifies 23 areas, including 3 within the scope of this report.

In 2011, the Canadian Government reviewed and approved in principle their *National Framework for Canada's Network of Marine Protected Areas* (Government of Canada 2011) with eligibility criteria for identifying areas as well as how best to ensure coherence and connectivity between the sites. In Canada, the

Department of Fisheries and Oceans Canada (DFO) has the overall responsibility for implementing the strategy, and in 2011 it identified 38 Ecologically and Biologically Significant Areas in Arctic Canada. The areas have been designated on the basis of a number of scientific workshops involving local knowledge (Pers. Comm. Francine Mercier 2016, Stephenson & Hartwig 2010). The purpose of the designation is to create a basis for ecosystem-based management and is also a component of the national development of a network of Marine Protected Areas (MPAs) (Cobb 2011).

According to Canadian authorities, Canada's marine protected areas will consist of 13 networks, equivalent to 13 marine bioregions – two of them includes parts of the North Water: #7 - The Arctic Archipelago and #8 – the Eastern Arctic. The Canadian Ministry of Environment and Climate Change reached the target of 5% of the total marine areas protected by 2017 and is now progressing towards the 10% by 2020 (see http://www.dfo-mpo.gc.ca/oceans/publications/mct-ocm/five-cinq-eng.html).

Four sub-areas within the Canadian part of the (North Water) study area of this report have been designated as Canadian EBSAs. More specifically, in August 2017 the Canadian federal authorities, in collaboration with the government of Nunavut and Qikiqtani Inuit Association, agreed to establish the 109,000 km² Lancaster Sound National Marine Conservation Area, which includes the Jones Sound and Coburg Island. Coburg Island is already listed as a "National Wildlife Area" mainly due to the area's huge seabird colonies.

The Arctic Protected Areas Indicator Report (CAFF & PAME 2017) provides an overview of the status and trends of protected areas in the Arctic.

1.3 Examples of research and monitoring activities

The ecosystems and biodiversity of the area is the focus of several research and monitoring projects. This includes the research by the Greenland Institute of Natural Resources (GINR) on seabird and marine mammal population dynamics to provide guidance on sustainable use of the wildlife resources.

In addition, a couple of major research projects in North Water will contribute to the pool of relevant knowledge over the coming years, including:

- The North Water Project (NOW) – 2014 to 2017 examined the long-term significance of climate change for the area's ecosystems and, thus, for the communities that depend on them. The project is based on multi-disciplinary collaboration between biologists (Aarhus University and GINR), anthropologists (University of Copenhagen) and archeologists (National Museum of Denmark and Greenland's National Museum, Nunatta Katersugaasvia)[2]. The project includes surveys of walruses, little auks and murres, and in collaboration with local hunters, current hunting patterns, hunting traditions and dietary habits are examined (Hastrup et al. 2016). Main findings of the project are summarized in a conference white paper (Kyhn & Mosbech 2019) and a range of scientific papers in Ambio Special Issue 2/2018: The North Water: Interdisciplinary studies of a High Arctic polynya under transformation.

[2] Funded by the Carlsberg Foundation and the Villum Foundation

- *ICE-ARC* is an EU-funded 4-year project with components throughout the Arctic with an interdisciplinary focus on the consequences of the reduced sea ice. In the North Water, Danish Meteorological Institute, Geological Survey of Denmark and Greenland, and GINR, in cooperation with local people in Qaanaaq, identify community vulnerability and resilience to Climate change and organise community-based observations and monitoring and oceanographic measurements.

Furthermore, Canada has a long track record of research focusing on the North Water; current focus is on ice and oceanography and ecology, partly by coupling remote sensing information with at-sea transects based on the research vessel 'Amundsen' (ArcticNEt, CEOS). Canada was also co-lead of the comprehensive international "International North Water Polynya Study" 1997-1999 (Deming et al. 2002).

Finally, several short-term projects have been carried out, including by GINR, in particular on the importance of the area for marine mammals and seabirds.

1.4 Current legislation relevant to this report

The responsibilities for Greenland's marine environment are shared between Greenland and Denmark. The area within the 3 nautical mile (nm) limit is under Greenland's jurisdiction (Inatsisartut [Gov. of Greenland] law no. 15 of 8 June 2017 on the protection of the marine environment), and Denmark takes responsibility from the 3 nm limit to the border of the exclusive economic zone (EEZ - the Marine Environment Act; No. 1035 of October 22 2004). It should be noted, however, that in relation with raw material resource activities outside the 3 nm limit, Greenland holds the authority on environmental issues.

Greenland's recent (2017 - above) law seeks to reduce the general pollution of the sea, to prevent any pollution from occurring, and to limit the harmful effects of pollution that already have happened. The legislation has become up-to-date and more in accordance with applicable international regulations such as the International Maritime Organization's (IMO) polar code mandatory for ships navigating Arctic waters.

This report does not include a description of international maritime law. However, in relation to shipping, it is important to note that the Greenlandic territorial waters – where Greenland's national laws apply – covers the waters from the coast to the baseline (inner territorial waters) and further to the 3 nm border (outer territorial waters). The inner territorial waters include all fjords, harbours, islands etc. According to the United Nations Convention on the Law of the Sea (UNCLOS), all navigation in the inner territorial waters (within the baseline), is fully governed by the jurisdiction of the coastal state (Stuer-Lauridsen & Overgaard 2012), i.e. all relevant national legislation must be complied with by all vessels. This includes regulations based on the Nature Conservation Act (including the Melville Bay Nature Reserve). However, between the baseline and the 3 nm limit, international shipping according to the UN is entitled to free passage (Christensen et al. 2015).

Nature conservation in Greenland is based the "Government of Greenland Act no. 29 of 18 December 2003 on nature conservation" (hereinafter the "Nature Conservation Act") which is a framework law that forms the basis for designating specific conservation areas via orders/decrees. Currently, 12 protection areas in Greenland designated by orders of which one, Melville Bay Nature Reserve, covers parts (southeast part) of the study area of this report. In addition, there are 40 areas in Greenland that are protected by the Birds Order (Gov. of Greenland Order no. 1 of 5 January 2017 on the protection and capture of birds) – seven of which areas are located the study area:

- Lion Islands
- Hakluyt Island
- Saunders Island
- Parker Snow Bay
- Appat Appai
- Carey Islands
- Sabine Islands.

In addition, the Nature Conservation Act stipulates some general conservation zones around certain habitats, either directly under the Act or through orders. Of relevance to the study area, this includes bird colonies and protection zones around them applicable from April 15 to September 15. Within this period, any unnecessary disturbance (including navigation) is prohibited within:

- 1000 m for colonies of thick-billed or common murre, little auk, black-legged kittiwake, fulmar or cormorant. Flying with fixed-wing aircraft or helicopters is prohibited within 3000 m vertical and horizontal distance.
- 200 m of islands or peninsulas with colonies of eider, black guillemot, puffin, Arctic tern or gulls other than kittiwake.

Figure 2 provides an overview of protected areas and management zones in the North Water based on the Greenland Nature Conservation Act. Figure 2 does not include "important areas for wildlife", which are designated according to the Mineral Resources Act and which regulate traffic in raw material surveys.

Mineral exploration and extraction activities, including associated shipping, is regulated under the Greenlandic Mineral Resources Act stipulating that activities must be carried out in accordance with recognized international 'good practice' (also see chapter 5.3), including due diligence in relation to environmental and safety aspects. Hence, exploration and extraction of non-living resources, including minerals, is not covered by the Nature Conservation Act and, thereby, by conservation orders issued pursuant to the Act. Instead, the Nature Conservation Act stipulates that such activities are regulated on the basis of the Mineral Resources Act.

The Environmental Agency for Mineral Resources Activities (EAMRA) in Greenland operates with a set of guidelines and manuals, including "Rules for field work and reporting regarding mineral resources in Greenland" that designate a number of "important areas for wildlife" including regulations for access (the Mineral Resources Directorate 2000). The regulations focus on species-specific core areas and periods when the species are considered sensitive (eg, breeding and moulting periods); the areas partly overlap with other conservation area designations. Mineral resource activities are also assessed on a case-to-case basis, applying the latest updated knowledge on the respective areas. Furthermore, for projects relating to resource extraction, an Environmental Impact Assessment (EIA) report must be prepared according to the

"Guidelines for preparing an Environmental Impact Assessment (EIA) report for mineral exploitation in Greenland" (Mineral Resources Authority 2015).

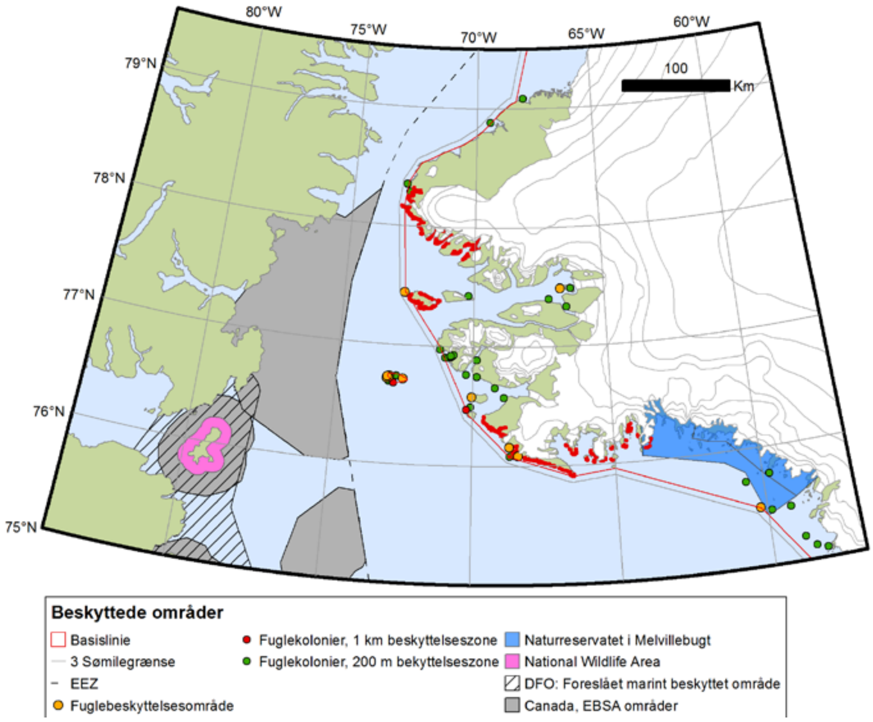


Figure 2. Overview of protected areas and management zones; see text for further guidance.

Legend

Red line: base line
Grey line: 3 nm limit
Orange circle: Bird conservation area
Red circle: Seabird cololny, 1 km protection zone
Green circle: Seabird cololny, 200 m protection zone
Blue area: Melvile Bay Nature Reserve
Purple zone: National Wildlife Area (Canada)
Grey zones: Candian EBSA areas
Hatched area: proposed MPA

2 The North Water ecosystem

2.1 General physical and biological factors

Polynyas are larger and recurring open water areas in an otherwise ice-covered sea and the North Water is one of the largest and most productive polynyas in the Arctic (Deming et al 2002). It is located in the northern part of the Baffin Bay and extends up into Smith Sound/Nares Strait (sometimes all the way to Robeson Channel) and into Jones Sound; the North Water is shared between Canada (Nunavut) and Greenland. The size and distribution vary considerably and can reach 80,000 km^2. In winter, large parts (up to 95%) are covered by dynamic drift ice which, however, always has open water bodies in the form of cracks and leads (Melling et al. 2001). The polynya is formed partly by the formation of an ice bridge in Smith Sound/Nares Strait which blocks the inflow of drift ice from the north; with a prevailing wind also from the north, the ice formed in the area south of the ice bridge is blown southwards, maintaining an open water. At the same time, there is up-welling of relatively warm water along the eastern, Greenlandic side of the polynya (Melling et al. 2001). Along the coasts, in the fjords, and at times also in the Smith Sound and Nares Strait, there is fast ice which forms a sharp ice edge to the drift ice and the open water. To the southeast, in the spring, a shear zone is formed along the fast ice in Melville Bay. In the southern part of the North Water, the adjacent coasts generally consist of bedrock, while low sediment coasts are more widespread to the north. To the far north of the Greenland side is the large Humboldt Glacier.

The polynya occurs in the winter period from October to June, but is very dynamic and varies in its distribution from year to year (Figure 3).

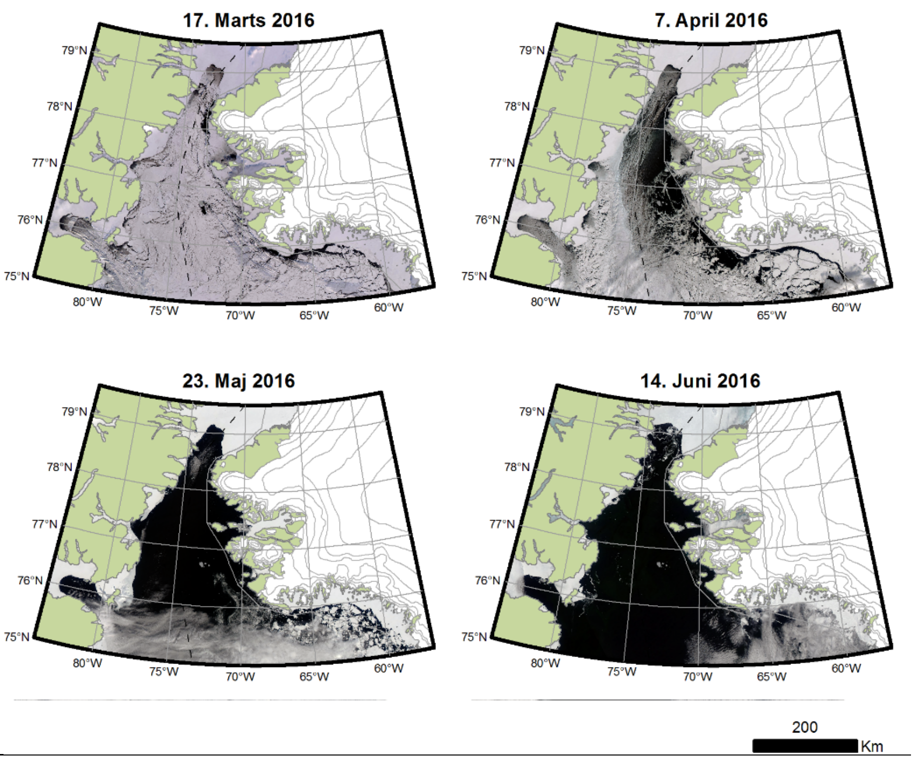


Figure 3. Ice cover in spring 2016. In March, drift ice with leads and areas of open water covers a large part of the polynya, which varies from year to year. In April and May, an ice-free area expands while leads and open areas emerge along the west coast of Greenland. In June, there are only remains of fast ice in the fjords and the polynya opens towards Baffin Bay.

In summer, large parts of the area are virtually ice-free and are not bounded by ice southwards, while there may be ice in Smith Sound and Nares Strait.

Primary production begins early – in April – due to the open water, and peaks in May-June. Production remains high throughout the ice-free period (Lovejoy et al. 2002, Tremblay et al. 2002, Tremblay et al. 2006a) and later in the summer takes place mainly at 0-20 m depth (Martin et al. 2010). Production appears to be significantly higher in the Greenlandic part of the North Water, in the parts of the polynya supported by upwelling, than in the Canadian part (Figure 4).

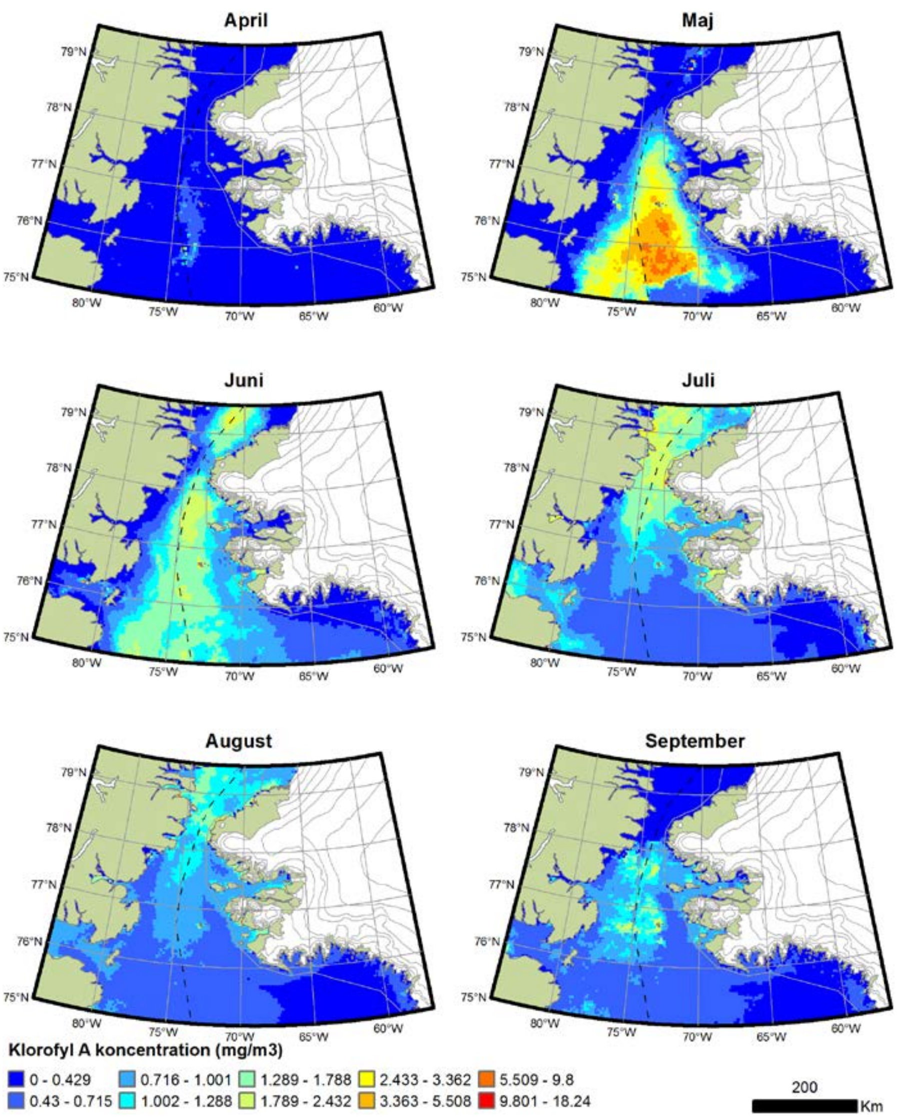


Figure 4. Primary production as indicated by the chlorophyll-a concentration as measured from satelite. Data is presented as monthly averages. The colors indicate different chlorophyll concentrations (red = highest concentration). Please note the bloom in May in the central part of the study area – in the polynya itself. The maps only show chlorophyll in the surface layer; knowledge of chlorophyll in the water column is extremely limited (Source: Oceancolor website, NASA).

The annual production of chlorophyll is among the highest recorded in Arctic ecosystems; on average over the entire area it amounts to 251 g C m^{-2} per year (Klein et al. 2002).

Available evidence suggests that the availability of nitrate is limiting to primary production (Tremblay et al. 2002). Only approx. 15-20% of production drops to the bottom, where it becomes available to benthic communities, while the rest is channelled through the food chains in the water column (Tremblay et al. 2006b)

Primary production also takes place in and on the underside of the sea ice. The magnitude of this production in the North Water is not known, but is presumably limited since it has been shown that ice algae accounted for less than 3% of the total algae biomass (Michel et al. 2002).

The high primary production provides the basis for a very diverse community of zooplankton grazing on the algae (Prokopowicz & Fortier 2002, Ringuette et al. 2002). Copepods are the dominant grazing zooplankters, in particular the genus *Calanus*; they are highly abundant and some, such as *C. Hyperboreus* are extremely nutritious, as they store lipids to be able to overwinter without feeding.

The benthic fauna is not very well studied in the polynya itself, but investigations further south in Baffin Bay indicate that it must be species-rich and with high densities of organisms (Sejr et al. 2011). The occurrences walruses and eiders in the polynya, species whose primary food is shellfish, also indicates a rich benthic fauna, at least at the depths they normally forage (eiders to about 25 m, walrus to 100 m).

The knowledge on fish populations in the polynya is limited. The most important species in the food chains is the polar cod, which appears very numerous and which is a key food item for birds, seals and larger fish (Boertmann & Mosbech 2017). In deeper parts, the Greenland halibut occurs; it has recently become an important resource for fishermen on the Greenlandic side of the North Water. Several rivers have stocks of Arctic char utilizing the marine environment during the summer months. Furthermore, limited populations of shrimps occur (Boertmann & Mosbech 2017).

2.2 Birds

The birds form a very important part of the ecosystem in the North Water. Thirteen seabird species breed along the coasts. Again, it is the Greenlandic side, with the highest marine primary production, that hold the most significant populations including large breeding colonies of little auk, thick-billed murres, and black-legged kittiwakes. The little auks (Figure 5) are extremely numerous and occur in dense breeding colonies on the Greenland side along the coastline from Cape Melville to Inglefield Land.

The little auk population is estimated at more than 30 million pairs (Egevang et al. 2003), which makes it the most abundant bird species in the area and also throughout the North Atlantic. It is estimated that approx. 80% of the world's population breeds along the coasts on the Greenlandic side of the North Water (Nettleship & Evans 1985). During the breeding season, the little auks rely almost exclusively on the large copepods *C. hyperboreus* (Pedersen & Falk 2001).

The North Water holds Greenland's largest colonies of thick-billed murres – five colonies (Figure 6.) with a total of approx. 308,000 birds, which make up approx. 68% of the total population in Greenland (Merkel et al. 2014). In contrast to other colonies in Greenland, these colonies in the North Water are not in decline, which makes the area extremely important for this species. On the Canadian side, there is another very large colony (160,000 pairs) on Coburg Island (Robards et al. 2000). The murres feed primarily on polar cod.

These abundant seabird populations are of great signifcance to the terrestrial environment in areas adjacent to the breeding colonies because the birds carry large amounts of nutrients from the sea to land. Around the colonies there is a particularly lush vegetation which is exploited by land mammals, such as hares and musk oxen (Gonzales-Bergonzoni et al. 2017).

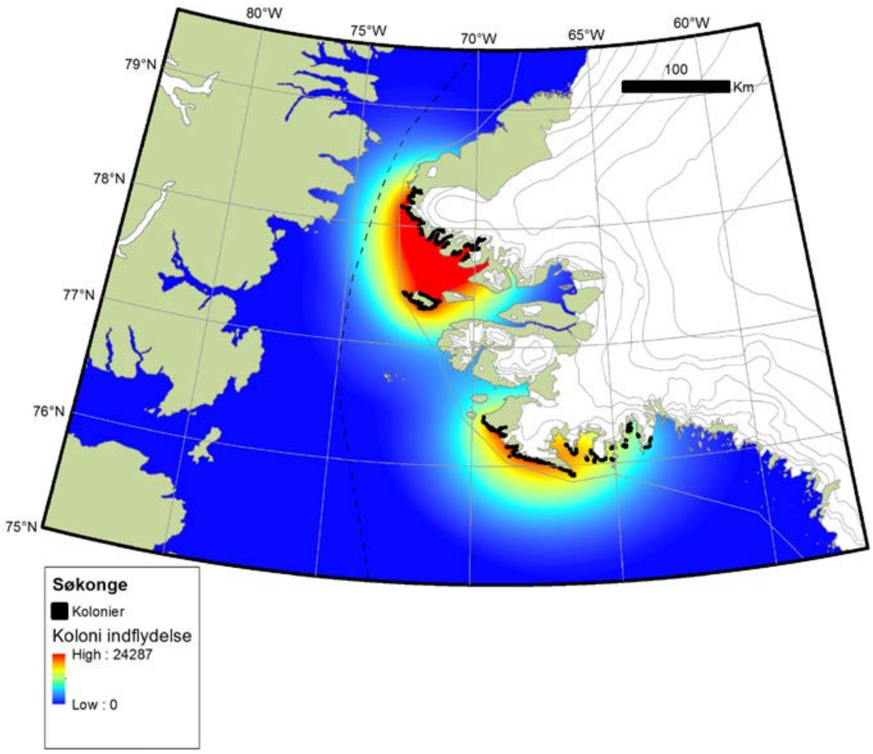


Figure 5. Little auk colonies (black dots) in the North Water. The colour gradients in the marine areas indicate a theoretical, relative density of birds on the sea, calculated by distributing the number of breeding birds from the individual colonies within a foraging radius of 105 km (as identified by GPS tracking of breeding birds from the North Water).

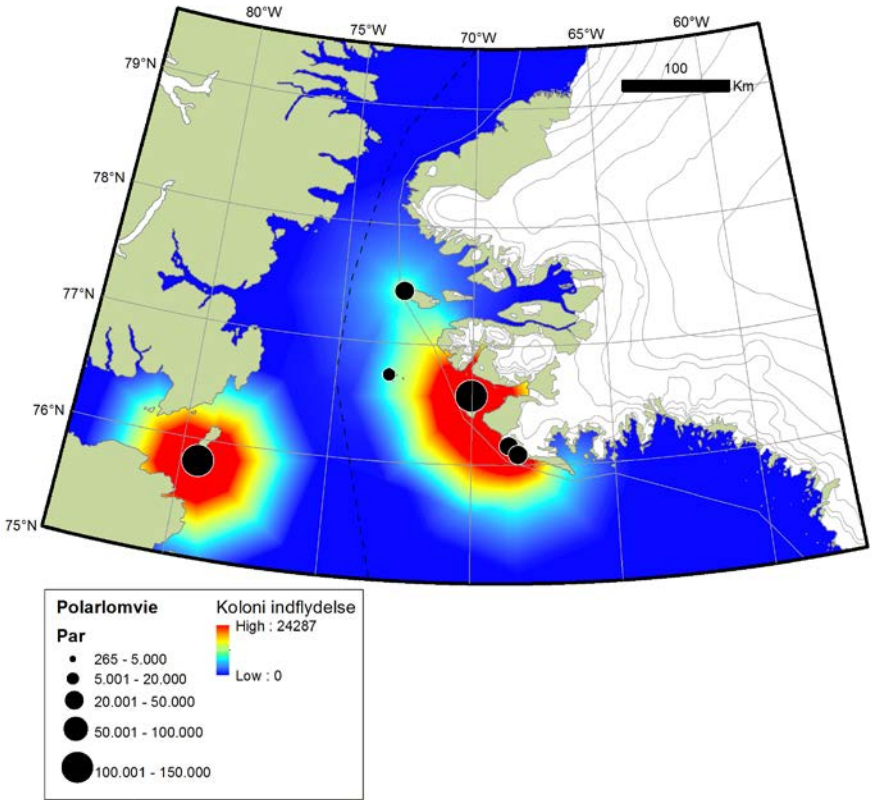


Figure 6. Thick-billed murre colonies (black dots) in the North Water. The colour gradients in the marine areas indicate a theoretical, relative density of birds on the sea, calculated by distributing the number of breeding birds from the individual colonies within a foraging radius of 114 km (as identified by GPS tracking of breeding birds from the North Water).

The common eider bird is a common breeding bird on islands along the coastline (at least on the Greenland side; there is no information from the Canadian side). Particularly in Wolstenholme Fjord there are several large colonies.

In addition to breeding birds, there are moulting common eiders as well as king eiders – the latter mainly coming from Canadian breeding grounds in inland freshwater ponds and lakes. These moulting birds gather in flocks along the coasts in late summer and early autumn. The eider species, unlike murres and little auks, are feeding on bottom-dwelling resources such as mussels, brittle stars and sea urchins. Important areas for eiders are shown in Figure 7.

The North Water is important for several other, less abundant bird species, including Sabine's gull, ivory gull and Atlantic puffin. For the gulls, these populations are of international importance since both species have very small populations in Greenland and Nunavut. The ivory gull, which is classified as 'near threatened' globally (Birdlife International 2018) apparently only breeds on the Canadian side of the polynya, although birds are also seen on the Greenland side in the summer.

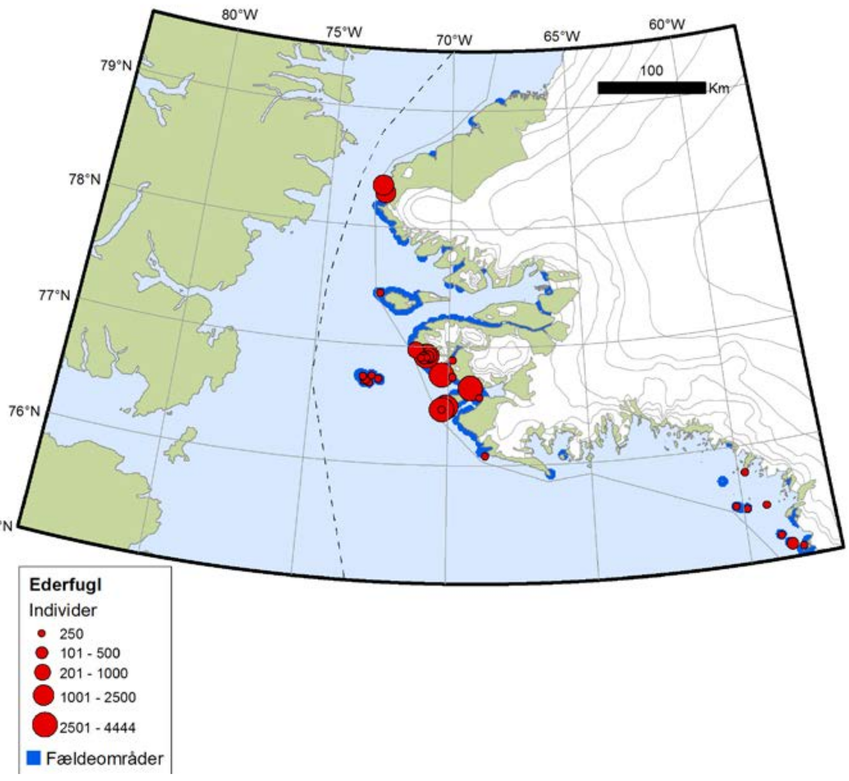


Figure 7. Breeding colonies (red dots) and moulting areas of common eider in the North Water.

Figures 8 and 9 show bird colonies and foraging range for other bird species. Common to all the seabirds is that they migrate south in the winter.

Figure 8. Breeding colonies and foraging ranges for kittiwake (green), Arctic Tern (red), Sabine's gull (blue) and ivory gull (black) – foraging range for ivory gull is very large and not shown on map

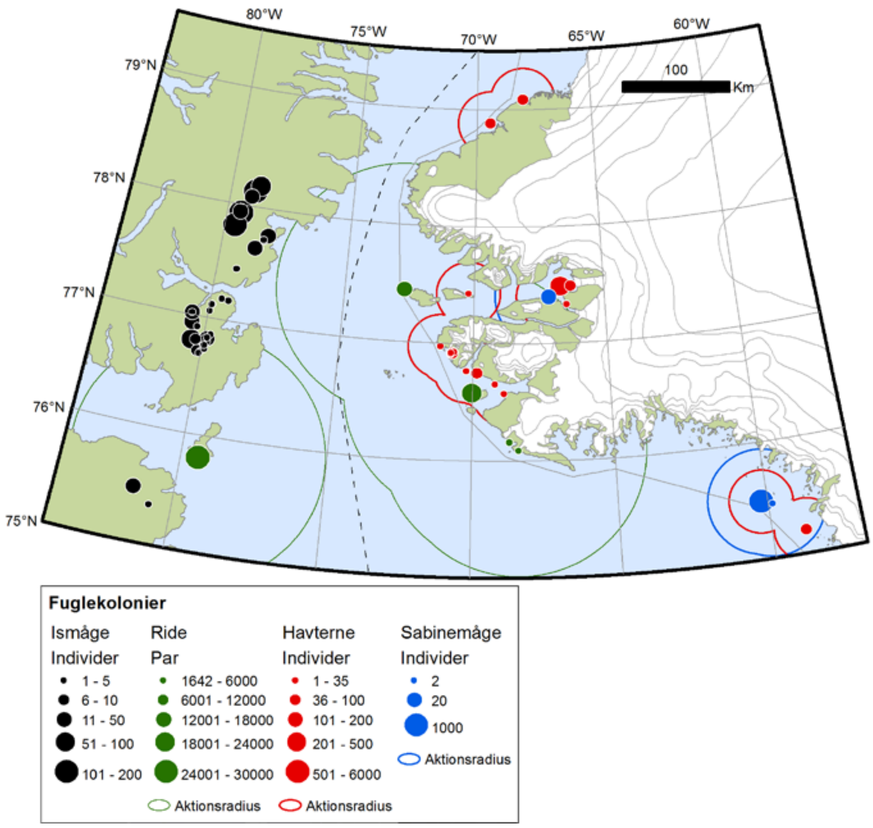
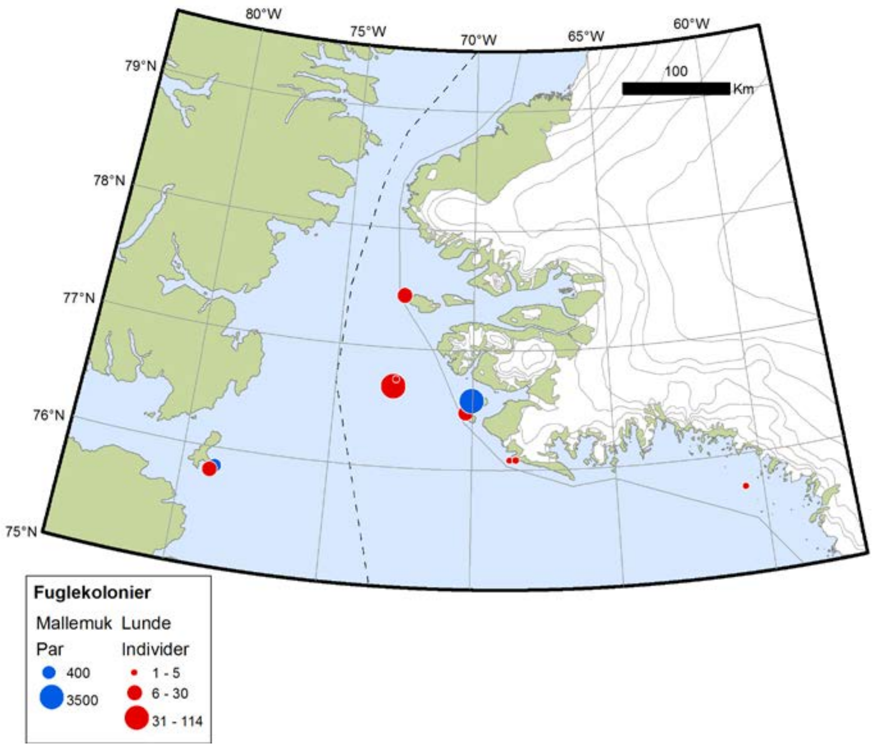


Figure 9. Breeding colonies of fulmar (blue) and Atlantic puffin (red)



2.3 Marine mammals

The North Water is very important for marine mammals (Heide-Jørgensen et al. 2013a 2016). Nine species occur regularly here; in addition, the minke whale has been observed or caught several times during summer in recent years. Among the seals two open-water species occur in summer, the hooded seal and the harp seal. Ringed seal, bearded seal and walrus occur year-round; the walrus, however, makes seasonal migrations between different areas within the polynya – in the summer they are primarily on the Canadian side and in winter on the Greenland side and in the mouth of Jones Sound (Born 2011, Stephenson & Hartwig 2010). The walrus distribution and key areas for the species are shown in Figure 10. The ringed seal and bearded seal are associated with to sea ice; the ringed seal in particular occur in high concentrations in fjords with stable and long-lasting fast ice. Spring surveys in May 2009 and 2010 covering the entire polynya (but not the whole distribution range within this study area), provided an estimate of approx. 9500 ringed seals and 6000 bearded seals (Heide-Jørgensen et al. 2013).

Among the whales three true Arctic species occur: Bowhead whale, beluga and narwhal. Narwhals occur year-round, while the other two mainly are migratory or winter visitors in the polynya. The Bowhead is scarce, while a larger population of belugas is wintering. In 2014, the beluga population in the Greenlandic part was estimated at approx. 2300 (Heide-Jørgensen et al. 2016).

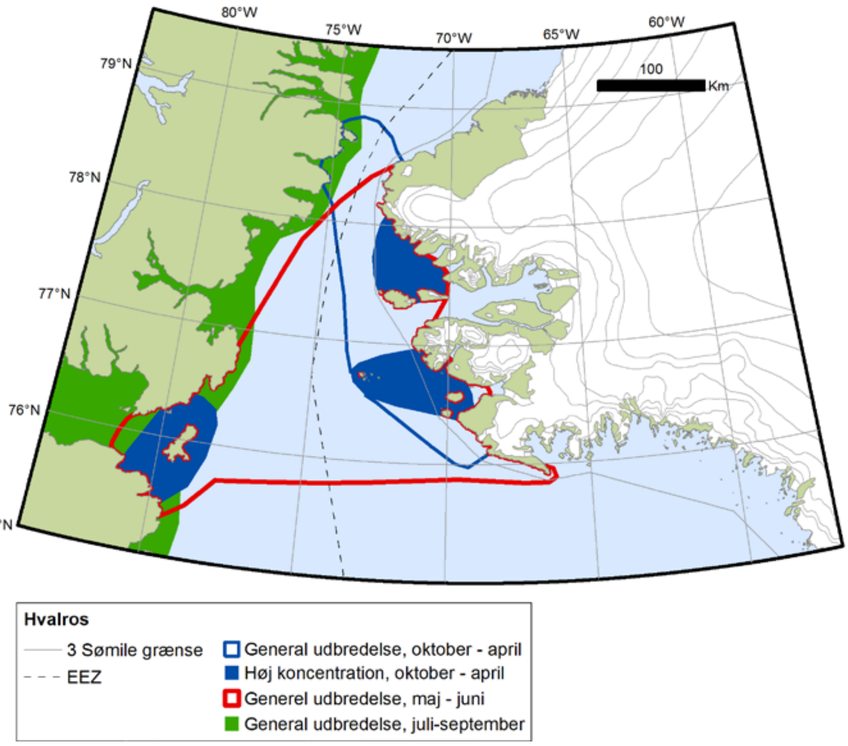
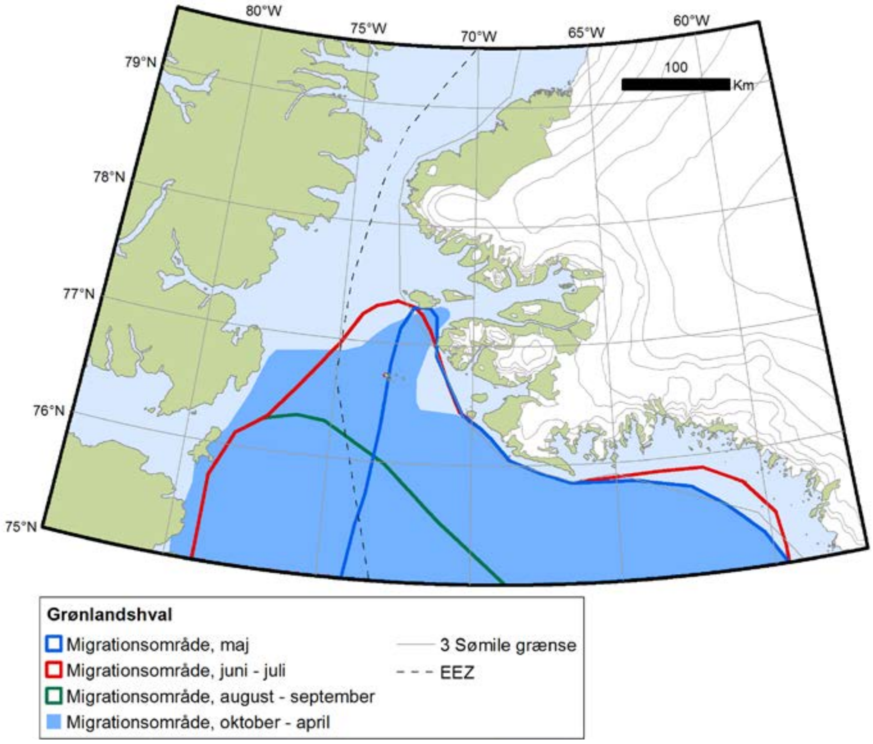


Figure 10. Distribution and key areas for walrus.

Legend
Blue line: general distribution, October – April
Blue areas: high density areas, October – April
Red line: general distribution, May - June
Green areas: general distribution, July - September

Figure 11.
Distribution and key areas for Bowhead whale.

Legend
Blue line: migration area, May
Red line: migration area, June - July
Green line: migration area, August – September
Light blue area: migration area, October - April



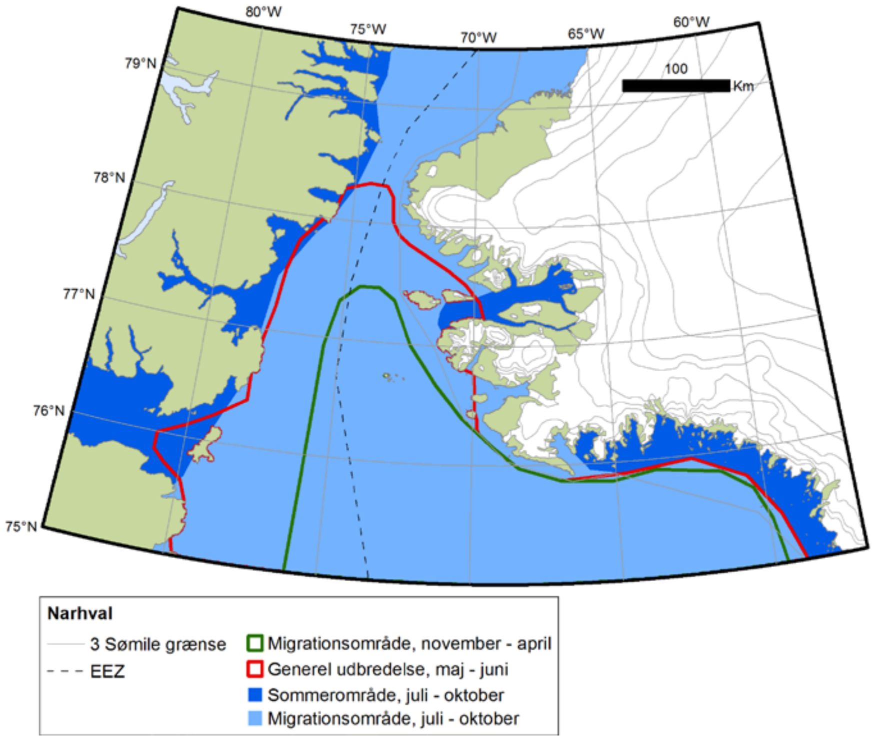
For the narwhal, coastal areas and fjords on both sides of the North Water are very important summering grounds (Figure 12). In the spring, these narwhals move through the polynya and surveys conducted in May 2009 and 2010 provided an estimate of up to 7700 narwhals (Heide-Jørgensen et al. 2013a). In Inglefield Fjord, the summer population was estimated at approx. 8300 animals in 2007 (Heide-Jørgensen et al. 2010). The population in Smith Sound, which mainly resides in the western part of the area, along Ellesmere Island, during summer, is estimated at approx. 16400 narwhals (NAMMCO / JCNB 2015).

Narwhals that have been tagged with satellite transmitters in Arctic Canada and the Melville Bay, leave the polynya area to overwinter in the central part of Baffin Bay (Heide-Jørgensen et al. 2013b). Wintering grounds for the narwhals that use Inglefield Fjord and Smith Sound in the summer, are unknown, but some do occur in the North Water in the winter, as a survey in April 2014 on the Greenland side provided an estimate of approx. 3000 narwhals (Heide-Jørgensen et al. 2016).

The polar bear occurs in the area all year round. There are two different management subpopulations: one to the south on the Baffin Bay, and one to the north on the Kane Bassin. In 2016, the Baffin Bay subpopulation was estimated at approx. 2826, and the Kane Bassin subpopulation at 357 individuals (SWG 2016).

Figure 12.
Distribution and key areas for narwhals.

Legend
Green line: migration area, November - April
Red line: general distribution, May – June
Dark blue area: summering range, July – October
Light blue area: migration area, July – October



The polar bears of the Baffin Bay subpopulation undertake long, seasonal migrations: in the winter and early spring they are mainly on the Greenland side, where there are leads and break-up zones in the sea ice, and they follow the ice's retreat towards the Canadian side during late spring and summer. However, a group of polar bears remain in Melville Bay over the summer (SWG 2016). In the Kane Basin, where there is still sea ice all year round, the polar bears roam both the Canadian and Greenland sides year-round (SWG 2016).

The marine mammals are important hunting animals for the human inhabitants in the area, and they have been the basis of the various human settlements around the North Water during the past 4000 years.

2.4 International significance

As pointed out in Chapter 1, the biodiversity and environmental conditions of the North Water have been identified as particularly important at international level in several regards:

An IUCN expert workshop identified the North Water study area as one of 13 particularly important Arctic marine areas ("Super EBSA") based on the EBSA criteria of the Biodiversity Convention (Speer & Laughlin 2011).

In another expert workshop, the IUCN recently included the North Water among Arctic marine areas that meet UNESCO's criteria for World Heritage Sites (Speer et al. 2017).

The area has been listed as particularly valuable in an identification of ecologically valuable and vulnerable marine areas in the Arctic (AMSA IIC – CAFF/ AMAP / SDWG 2013).

In a national assessment of important and vulnerable marine areas in Greenland, the North Water achieved the highest score and highest priority on the basis of IMO's criteria for identifying 'Particularly Sensitive Sea Areas' (PSSA) (Christensen et al. 2015).

The reasons for those high rankings include: The North Water is critical for internationally shared populations of migratory birds and marine mammals. It is the most productive polynya in the Arctic and a number of animal species are depend on its resources: Eighty percent of the world's population of little auk rely on the area; especially in the eastern part of polynya - the Greenland side - the upwelling of nutrient-rich water provides the basis for high biological production and diversity, not least Arctic endemic species of marine mammals and seabirds. Through millennia, the natural resources of the North Water have also served as the basis for the immigration of people into Greenland from the west (on several occasions), and therefore also have great historical/cultural significance (Hastrup 2015). Today, the resources of the North Water still form the basis of a unique hunting culture.

The socioeconomically important marine mammals include ring seal, narwhal, beluga, bowhead whale, walrus and polar bear. For some of these species, parts of the study area are critical to their survival through certain periods of the year. In addition, it should be noted that some seabirds, including little auk, thick-billed murre and kittiwake, have their most important Greenlandic breeding sites in the polynya. Finally, a number of the species in the study area are included in the Greenland List of Endangered Species of 2018 (Table 1).

Tabel 1. Red listed species occurring in the North Water (Boertmann & Bay 2018).

Species	National Red List	International red list	Occurrence in North Water (NOW)	NOW importance for population
Polar Bear	Vulnerable (VU)	Vulnerable (VU)	All year	International
Walrus	Vulnerable (VU)	Vulnerable (VU)	All year	International
Hooded seal	Vulnerable (VU)	Vulnerable (VU)	Summer	Local
Bowhead	Near threatened (NT)	Least concern (LC)	Spring and summer	Regional
Beluga	Vulnerable (VU)	Vulnerable (VU)	Autumn, winter, spring	International
Narwhal	Near threatened (NT)	Least Concern (LC)	All year	International
Brent Goose	Vulnerable (VU)	Least Concern (LC)	Summer	Local
Long-tailed duck	Least concern (LC)	Vulnerable (VU)	Summer	Local
Sabine's gull	Near threatened (NT)	Least concern (LC)	Spring and summer	National
Black-legged kittiwake	Vulnerable (VU)	Vulnerable (VU)	Spring, summer and autumn	National
Ivory gull	Vulnerable (VU)	Near threatened (NT)	Spring, summer and autumn	International
Arctic tern	Near threatened (NT)	Least concern (LC)	Spring and summer	Regional
Thick-billed murre	Vulnerable (VU)	Least concern (LC)	Spring, summer and autumn	International
Atlantic Puffin	Vulnerable (VU)	Vulnerable (VU)	Spring, summer and autumn	Regional

3 Identification of important areas and assessment of management options

3.1 Identification of important areas for biodiversity and ecosystems

The purpose of this report is to identify the core biodiversity areas and particularly sensitive areas within the study area and assess the variation and changes of key areas in time and space.

While the most important examples are summarized in Chapter 2 above, this Chapter provides further analyses of spatial data on the distribution of a variety of species and ecosystem components. The starting point is the project *Identification of biological core areas* initiated by Government of Greenland (see Christensen et al. 2016) where spatial data for a wide range of species, habitat types and ecosystem components in Greenland have been mapped and described. For this report, the data have been supplemented with updated information with higher spatial resolution. In addition, seasonal variations are included for the distribution of all species/ecosystem components.

The data base mainly derives from the research and analyses carried out in connection with the strategic environmental assessments prior to oil exploration activities in Greenland (Boertmann & Mosbech 2017), supplemented by recent literature where relevant and available.

Complementing data from the Canadian side of the North Water are included; the data are primarily derived from the Canadian efforts in relation to Ecologically and Biologically Significant Areas Identification (Pers. Comm. Francine Mercier 2016, Fisheries and Oceans Canada 2015, Stephenson & Hartwig 2010, Kenchington et al. 2011, Cobb 2011). In addition, for the Canadian parts, data from CAFF´s *Circumpolar Seabird Data Portal* (http://axiom.seabirds.net/maps/js/seabirds.php?app=circumpolar#z=2&ll=NaN,0.00000) are included as are, to some extent, data from Canadian ship-based bird surveys (Gjerdrum et al. 2012).

The analyses were conducted as a so-called "overlay analysis" in GIS (Geographical Information System), where thematic maps are layered on top of each other to highlight areas where many and/or important occurrences overlap. In this analysis, 57 mapping layers with seasonal distributions were used for a total of 24 different species/ecosystem components. Thus, far more maps could be made available than those included in Chapter 2. The basic method of analysis was previously used by DCE in connection with the above-mentioned project on *Identification of biological core areas* (Christensen et al. 2016), and in a project on *Analysis of possible ecosystem-based approach to ship traffic management in Disko Bay and Store Hellefiskebanke* (Christensen et al. 2015). In this report, however, analyses are expanded, mainly by including seasonal variation. (Detailed descriptions of the methods, the data base and various ranking procedures are described in the annexes to the original Danish version of this report.)

The results are presented as maps for different periods across the year (Figures 14 - 17). The maps are colour-shaded in 5% percentiles (i.e. 20 colour shades) on a scale from dark blue (low values), over yellow, to dark red (high values). The darkest red shading identifies the 5% of the area with the highest scoring within the period, i.e. shows the areas that are biologically most important based on the criteria used. Consequently, the darkest red zones combined with the lighter-red coloured zones covers the 10% of the area that has the highest scoring at the given time of year, etc. In principle, maps could be prepared for each day throughout the year but here four sets of maps, representing different seasons in the annual cycle, are presented (see below). The mapping based on percentiles reveals which areas are the most important at any given season. However, the maps are relative and cannot be directly compares across seasons (i.e. dark red areas in *summer* means higher abundance and diversity than dark red areas in *winter*). The absolute values/rankings of biological importance across the year are shown in Figure 13.

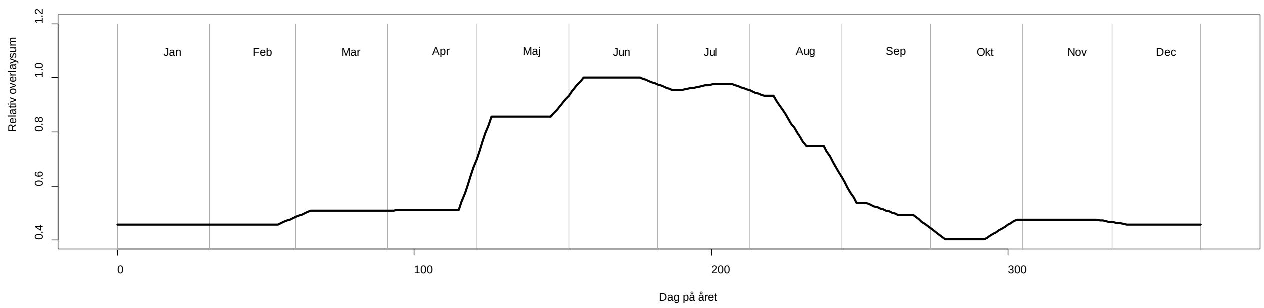


Figure 13. This figure shows how the overall summed scores in the overlay analysis (the basis for the maps in Figures 14 – 18) varies throughout the year. Note that the summed scores increase in the spring as most the migratory species arrive in the North Water, and gradually declines during the fall as these species depart from the area again. Thus, the curve reflects that the biological significance / importance of the polynya, based on the given criteria, is highest in May - August. As the sum of scores is not constant throughout the year, the important areas cannot be directly compared between the maps - a red area in the winter typically does not have as high rankings as a red area in summer, where a significant number of species are present. Thus, the maps in Figures 15-18 show only the relative biological importance of the areas at the given time.

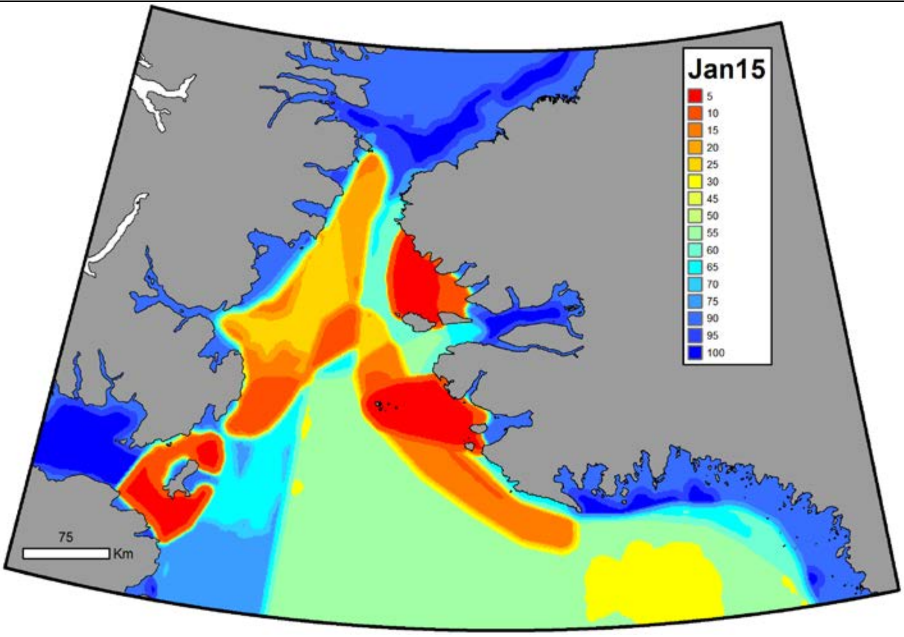


Figure 14. Winter. Map of biologically important areas in a typical winter situation (here, mid-January). During this period, the most important areas are the walrus's three main wintering areas in Murchison Sound, west of Wolstenholme Fjord and around Coburg Island, respectively (see Chapter 2). The dark-orange area along the Greenland continental slope is primarily due to overlapping distribution areas for narwhal, walrus, beluga and bearded seal. The orange-red areas in the north-western Canadian parts of the polynya is mainly due to beluga wintering areas. This mid-January map is characteristic of much of the winter period, from the early December to early March. During this period, it is primarily the propagation of the land-based ice that affects the spatial distribution of the species, thus causing minor changes in the delimitation of the important areas.

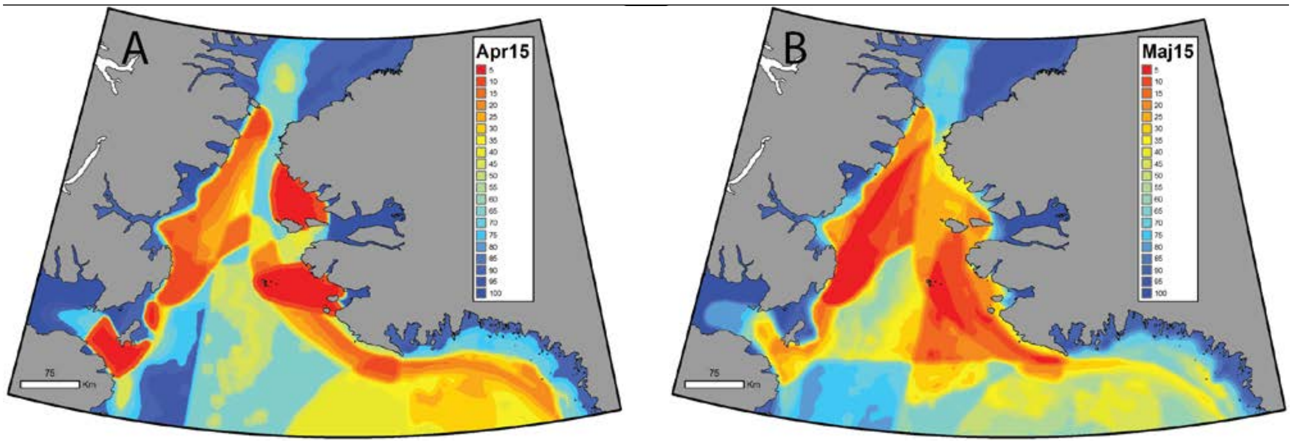


Figure 15. Spring. Two maps illustrating the change in biologically important areas during spring: A) mid April; B) mid May.

A. From March 1 to mid-April the main walrus distribution areas dominate the scoring, partly like in the winter (Figure 14). However, in April, polar bears start arriving to the eastern Baffin Bay and the outer reaches of Melville Bay, highlighted as orange along the Greenland side of the area. In the centre of the polynya, the emerging algae bloom shows as light yellow shades while the productivity along the ice edge also remains visible.

B. Later in the spring, the summed scores of importance increases rapidly (cf. Figure 13), mainly due to the fact that seabirds and marine mammals find their way into the polynya as the ice disappears, and the primary production gradual increases. Unfortunately, there are no spatial data available on seabird distribution and specific concentrations before the breeding season in June. Consequently, seabirds do not contribute much to the spatial distribution of important areas in this analysis, although it is known that in May they often gather in huge flocks. The distribution patterns of several marine mammals change around 1 May (cf. Chapter 2). The winter concentrations of the walrus are now abandoned and the animals disperse; in the Greenlandic part of the North Water, a triangular area appears as important (red / dark orange) mainly due to the spring distribution of walrus, narwhal, beluga and bowhead whale. Similarly, the elongated important area off the Canadian coast is mainly due to the distribution of beluga, walrus, narwhal and polar bear. The colour shades in the central parts of the polynya are mainly due to the algae spring bloom. Throughout May great shifts occur in the important areas. Therefore, it should be emphasized that the map (B) is not representative of the whole of May, but should be seen as a snapshot in the middle of a dynamic transitional period.

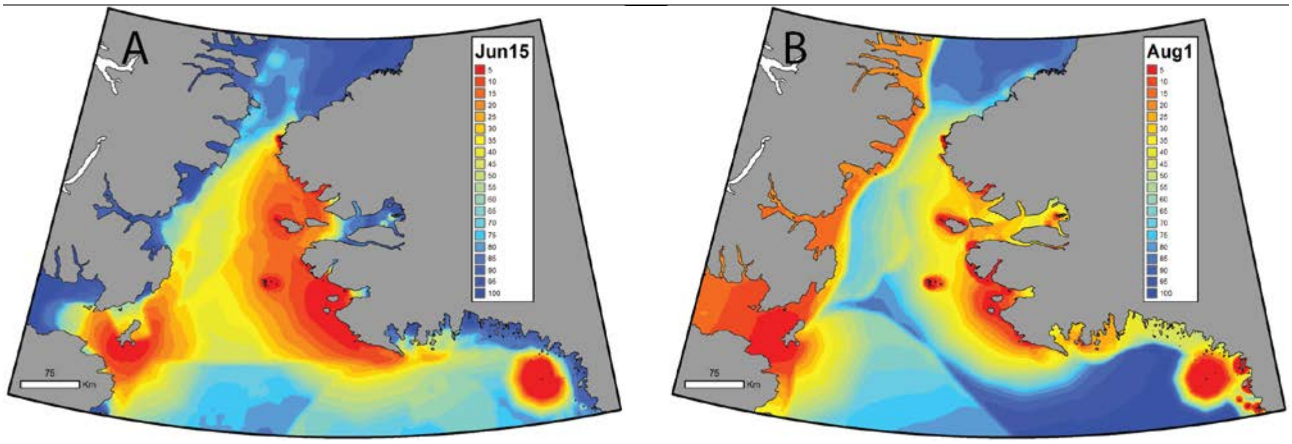


Figure 16. Summer. Two maps illustrating the change in biologically important areas during summer: A) mid June; and B) early August.

A. From June the summer pattern begins to settle, mainly due to the fact that seabirds are now initiating the breeding season. The areas around the large bird colonies (compare with Fig. 5-9) will appear as the most important ones since, during this period, many individuals are concentrated on a relatively small area close to the colonies. Therefore, there is also a much greater variation in the biological importance of the area compared to the spring situation, where no similarly concentrated and well-defined occurrences are found. The large thick-billed murre colonies, which also hold other species, as well as Sabine Island (red dot in Melville Bay) with large colonies of Sabine’s gull and Arctic Tern dominate the analysis and show up as distinct red/orange zones. In addition, the large eider colonies along the Greenland coastline contribute to define the local important areas. The distribution of the marine mammals continues to influence the colour nuances, but they now contribute with a background tone rather than define distinct areas.

B. Over the summer, the seabird colonies continue to dominate the picture, but by early August they are less dominant and the areas more contracted. Much of the relative weight is shifted to the Canadian coast. This is because walrus and polar bears concentrate here during the summer months, where they have overlapping areas of distribution with each other and with the narwhal. Melville Bay and Inglefield Fjord appear to be relatively more important than previously due to the narwhal's summering areas; in addition, the polar bear has a summer range in Melville Bay. The eider and king eider moulting areas along the coast of Greenland are gradually beginning to emerge as important areas.

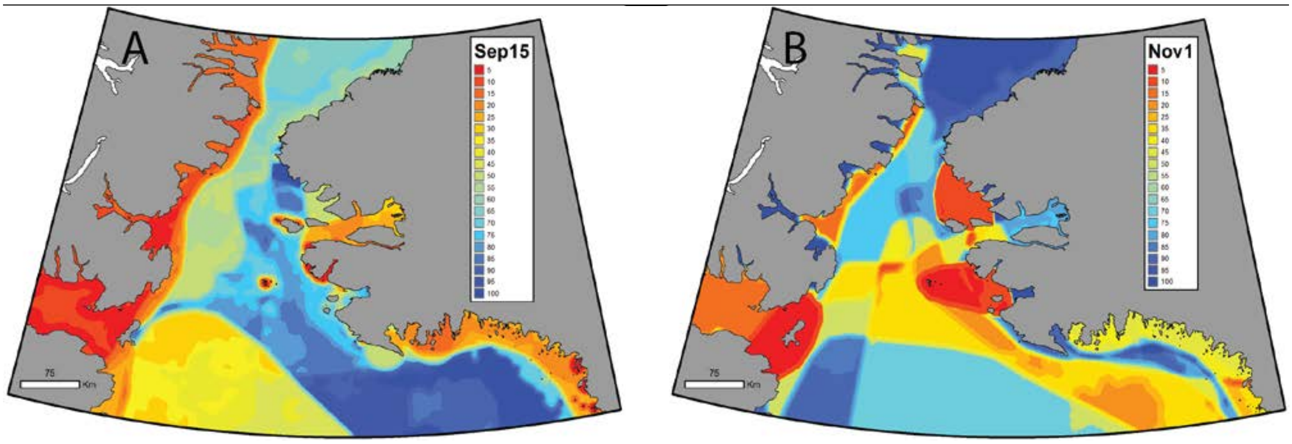


Figure 17. Autumn. Two maps illustrating the change in biologically important areas during the autumn: A) mid September; and B) early November.

A. By September the seabird breeding season is over and their colonies are no longer clearly reflected on the map. The summed scores has also dropped significantly (cf. Fig. 13), reflecting that many of the seabirds leave the North Water around this time. As the seabird colonies are abandoned, the spatial variation in the relative importance of the areas has also shifted significantly, and the winter situation is gradually returning. The Canadian coastal areas continue to be very important due to overlapping distribution areas of walrus, polar bear and narwhal. Inglefield Fjord and Melville Bay also have relatively high values due to the narwhal population, and Melville Bay also because of polar bears. Along the coast of Greenland, the eider and king eider moulting areas are still clearly visible, but they will be abandoned during September.

B. From mid-October, the walrus begins to concentrate in its three main wintering areas – areas that dominates the picture for the remainder of the autumn. The Canadian coastal areas, as well as Inglefield Fjord and Melville Bay on the Greenland side, also have relatively high values, due to the distribution of narwhal. At the beginning of November, the narwhal gradually moves from coastal "summer range" (along the Canadian coast, in Inglefield Fjord and Melville Bay) to a "winter range" in the central parts of the North Water. Around the same time, the polar bear population shifts from being concentrated along the Canadian coast and in Melville Bay to being generally widespread throughout the area along with the expansion of sea ice. Another important event is the beluga autumn migration, which also takes place in early November. Therefore, the areas of importance are quite dynamic in early November. Along the Canadian coast an important area is seen (in orange) which is due to an overlap between the summer areas – not yet completely deserted – of narwhal and polar bear, as well as the beluga's autumn migration areas. The Melville Bay also appears to be a relatively important area due to overlap between the summer distribution of narwhal and polar bear. The dark yellow / orange band, cutting west-to-east across the study area, is primarily due to overlap between the beluga migration area and the northern part of the narwhal's upcoming wintering area. Later in November, the narwhal's summer areas will be completely deserted, and after the cessation of the beluga's autumn migration around December 1, the winter situation as depicted in Figure 14 returns.

3.2 Human impacts, sensitive areas and management options

The most significant impacts on the North Water ecosystem so far undoubtedly stem from climate change. In addition, the area is affected by long-range pollution; the area around the polynya and the Avanersuaq area is characterized by having the highest mercury loads in the Arctic, in both the hunted animals as well as the local hunters – at levels that raises health concerns (Dietz et al. 2018). Among the more direct human impacts on the North Water ecosystems, hunting is a major factor. Tourism, mineral resource exploration and fishing also take place, but on a small scale. However, these activities are growing and have the potential to cause more significant impacts in the future. For example, fishing for Greenland halibut has been increasing in recent years and in 2016 amounted to approx. 130 tonnes purchased halibut in Qaanaaq, and 250 tonnes in 2018 (Greenland Statistics 2019). Both the reduced sea ice and the development of the above sectors are likely to result in increased shipping traffic in the area, including cruise ships (AMAP 2018) – see further below.

Climate change will lead to additional warming of air and sea, less ice, more extreme weather and greater variation in weather conditions within and between years (Langen et al. 2018). One of the mechanisms that help ensure open water in the polynya in winter is the ice bridge that forms across Smith's Sound / Kane Basin (see Chapter 2) and blocks the ice drift into the polynya: the sea current and strong northern winds keep the sea south of the ice bridge free of ice. The effects are summarized by Langen et al. (2018): "The presence of an ice bridge is necessary for the formation of the polynya (Melling et al., 2001). With the observed and projected changes (e.g., warming, freshening, thinning of sea ice; more mobile sea ice), the duration of ice bridges in Nares Strait/Smith Sound – and thus the duration of the North Water Polynya – will likely decrease. The existence of the North Water Polynya could be at risk in the future, with significant consequences for primary production (Michel et al., 2015). An important reduction in primary production in the polynya was indeed observed in the last decade and was attributed to freshening and increased stratification resulting from fresher Arctic water flowing through Nares Strait and from increased Greenland glacier melt (Bergeron and Tremblay, 2014). The changes in the ice bridge (i.e., its shorter duration) have also led to an increased advection of multi-year ice through Nares Strait and along the western side of Baffin Bay in recent years (Barber and Massom, 2007; Michel et al., 2015)."

Other changes have also been reported: The open water period (defined as the time with less than 50% ice cover) in the Kane Basin (i.e. north of the North Water) and Baffin Bay (south of the polynya) was 12.4 and 12.7 days longer per decade, respectively, over the period 1979–2014 (Stern & Laidre 2016).

The impacts of climate change will reduce the habitat available to the species associated with the sea ice, including the polar bear. In contrast, increasing temperatures and extended duration of summer conditions will offer opportunities for southern species which may expand northwards. It is a relatively recent phenomenon that capelin can be caught all the way north Qaanaaq, where also minke whales have been caught several times in recent years. There is evidence that the pattern of primary production in the polynya is changing, but it is unknown how overall primary production will develop (Tremblay et al. 2006, Merkel & Tremblay 2018). Therefore, major changes may be induced in the food web as the pattern of primary production changes and new species immigrate from the south, including capelin and the less nutritious species of *Calanus* copepods which, as mentioned earlier, are key organisms in the ecosystem. The magnitude of future climate impacts depends largely on global efforts to limit further global warming, while adaptation actions to limit the impacts of climate change may take place at a local and regional scale. In order to alleviate the effects of climate change on biodiversity and ecosystem services, there is a need to focus on the state of the ecosystem and address and manage other (non-climatic) human impacts on the ecosystem. There is a need for closer linkages between monitoring of both the ecosystem and the impacts/"stressors", and a management regime that considers the entire North Water ecosystem.

Table 2 provides an overview of existing and possible future non-climatic impact factors in the area.

Table 2. Overview of possible non-climatic impact factors and effects on the North Water ecosystem.

	Population effects*	Habitat effects	Disturbance
Commercial fisheries, incl. trawling	X	X	X
Subsistence hunting and fishing	X		X
Traffic/transport			
Dinghy traffic			X
Ice-based transport: dog sled, skidoo			X
Aviation: Helicopter, fix-wing aircrafts			X
Tourism		X	X
Mineral resource activities			
Drilling		X	X
Discharges to water (oil, chemicals)	X	X	
Discharges to air		X	
Seismic exploration			X
Sand dredging / marine mining activities	X**	X**	X**
Shipping			
Emissions to air		X	
Discharges to water – oil	X	X	
Discharges to water – organic		X	
Noise			X
Collisions with marine mammals		X	X
Invasive species (ballast water)	X	X	

* direct mortality potentially affecting a population

** Sand dredging typically have very local effects, while extraction of minerals from the seabed (placer mining) can affect populations of mussels and benthic animals in a larger area, as well as the predators of benthic animals (e.g. eider and walrus).

Currently, the most significant local impact on wildlife populations is the hunting that takes place in the area. The impact is partly through the direct mortality, and partly through the disturbances caused by the shooting and the traffic, especially with motorized dinghies. The hunt is regulated in order to promote sustainable harvest, but in some years the allotted quotas for narwhal in Melville Bay are higher than the recommended catch levels (GINR 2018). For the important hunted species, there are continuing assessments of the stock sizes and a discussion of the regulations and whether the catch is sustainable. The regulations apply a combination of quotas, temporal and spatial restrictions in hunting and traffic as well as stipulation for types of vessels and weapons allowed in the hunt.

It is recommended that these types of management and regulations be maintained and that, based on further scientific assessments, it be considered to supplement them with no-hunting zones, i.e. areas that are completely exempt from hunting. On the other hand, there is a unique hunting and fishing culture associated with the North Water polynya, and just as there is a need to protect the area's natural assets, there is also a need to maintain and protect some of the hunting fishing areas that are of great importance to local communities. Therefore, future management should be planned in dialogue with the stakeholders. Nevertheless, it is to be expected that some species will decline due to ecosystem changes while some species will increase or colonize the area – and it is recommended that the hunting regulations and practise be adapted accordingly.

The main environmental impacts of shipping are air pollution, underwater noise, disturbances above the water, as well as discharges of sewage, oily water and waste (AMSA 2009).

Invasive species transported by ships (typically in ballast water) are a likely future threat which is expected to rise with increasing ship traffic and higher water temperatures (Ware et al. 2014). A potential major threat is oil spills associated with shipping (AMAP 2018).

Currently, there is relatively limited shipping in the North Water, mainly with supplies to the dispersed communities, and although shipping is generally expected to increase, it is still expected to be relatively limited in the coming decade or so compared to southern areas (AMAP 2018). Immediately southwest of the study area, increasing transit traffic is expected through the Northwest Passage with entry through Lancaster Sound, while no significant increase in transit traffic is expected through Smith Sound in the coming decades (AMAP 2018).

For the Northwest Passage, projections suggest that it is likely to take decades before it may become a major transit route. There is increasing activity in the region from cruise ships and private pleasure boats (AMAP 2018), a trend that is expected to continue in the coming decades. Since such vessels are targeting spectacular sites and events such as bird cliffs and main whale habitats, it is important from a management perspective to be aware of the potentially disruptive effects of the traffic. In the future there is a need to adjust the regulations and guidelines for the tourism vessels and activities and there may be a need for further monitoring and on-site supervision (AMAP 2018, Naalakkersuisut, 2014).

Mineral resource extraction can have a significant environmental impact depending on the activity, where/when it takes place and how it is regulated. In the North Water region, there is currently resource exploration in several areas on land, and mining is to be expected in the future. In one area there is also ongoing exploration in a coastal marine area, Wolstenholme Fjord in Greenland, where subsequent mining, if initiated, can potentially affect foraging areas for walruses and eiders as well as the subsistence hunting for these species.

In 2010, oil exploration and extraction licenses were awarded in five 'blocks' in the northern part of Baffin Bay, the northernmost of which overlaps with the study area of this report. Intensive seismic surveys and a so-called 'shallow core drilling programme' were carried out in 2010-2012. However, the results were not promising and now all the blocks licenses are being returned. In 2017, a new bidding round was held, where the blocks in Baffin Bay were offered again. Oil exploration activities involve underwater noise, discharges of potentially harmful substances and the risk of oil spills. Models indicate that ocean currents can transport the oil from southern areas directly north to the North Water area (Boertman & Mosbech 2017).

All types of mineral resource extraction will lead to shipping and for larger projects it must be expected to occur year-round. Seismic surveys and icebreaker traffic cause underwater noise that can have a significant impact on marine mammals, especially narwhal. Currently, there are regulations of seismic activities (see seismic guidelines, EAMRA 2015), but there is still considerable uncertainty about the effects of noise and what regulation is needed to protect the marine mammals (Heide-Jørgensen et al. 2015, Heide-Jørgensen et al. 2013c) so further knowledge is needed, and research is ongoing. In the future, there will be a need for linking the noise level and narwhal monitoring with the regulation of the activities.

Long-range pollution, especially with mercury, is a major problem throughout the Arctic, including the North Water. Mercury levels have risen almost by a factor of 20 since 1850 (Dietz et al. 2009), and the harvested species as well as the human population in Avanersuaq have the highest mercury levels in the Arctic (Dietz et al. 2018). It is recommended that these background levels be taken into account when regulating potentially polluting activities in the area, including mineral resource exploration and extraction.

3.3 Management and zoning options – examples

According to the Terms of Reference for this report, it should describe potential international instruments that may provide the basis for protecting the North Water and its assets so the polynya, or the most important parts of it, obtains some form of protection that meets international standards for a Marine Protected Area (MPA).

There is no exact definition for an MPA. However, various international organisations have developed different standards for the use of the term. Likewise, there are different standards for how such areas can and should be designated and managed to achieve the best possible coherence between the (neighbouring) areas and, thus, ensure optimal conservation and management of the biodiversity and ecosystems.

Under the Arctic Council, the PAME working group has developed a common framework for principles and objectives for MPAs in the Arctic (PAME, 2015). PAME adheres to the IUCN/WCPA definition – "*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*." To meets PAME's definition of an MPA it should:

1) Conform to the IUCN definition of a 'protected area' (Dudley 2008, Day et al. 2012).

2) Meet at least one of PAME's stated ‘MPA Network goals’ – strengthening ecological resilience, promote the long-term protection of marine biodiversity, ecosystem function and special natural and cultural features, support integrated stewardship, conservation and management of living Arctic marine resources, enhance public awareness, and foster coordination and collaboration among Arctic states to achieve more effective MPA planning and management in the Arctic.

3) Have a corresponding management plan, or relevant legislation on the management of the area, and the plan is being implemented.

In addition, PAME has organised ‘MPA workshop series’ to develop principles and tools to aid the Arctic countries in their identification, designation and implementation of a representative Arctic MPA network. In 2017, PAME released its “MPA-network toolbox” (PAME 2017), which intends to guide the Arctic Council member countries in designating a representative and coherent MPA network

Among the currently designated conservation areas within the North Water, the Melville Bay Nature Reserve in Greenland may be considered meeting all the of PAME criteria for an MPA.

As far as the seven bird protection areas (see Chapter 1.4) are concerned, they are clearly geographically delineated, have well-defined conservation objectives – protection from noise and disturbance during the breeding season of the birds. Based on those criteria, the seven areas can be characterized as IUCN category IV areas (Habitat/Species Management Area). The areas may also be considered to meet the PAME goal of ‘strengthening ecological resilience’ and be subject to specific ‘relevant legislation’. On this basis, the bird protection areas can also be interpreted to meet the PAME criteria for MPAs.

Regarding the general disturbance buffer zones around bird colonies, there is no clear record of their demarcation and, hence, it is unclear whether this general protection can fall within the IUCN protection categories.

The Melville Bay Nature Reserve, the seven bird protection areas, and the general protection zones around bird colonies combined add up to 5.3% of the Greenlandic part of the marine sections of the study area. The areas are not designated on the basis of an MPA network approach, as described by the PAME tools for designating a representative and coherent network. In that line of thinking, an ecosystem-based approach may be considered in order to protect the various ecosystem components and key areas during different species' life stages, including breeding sites, nursery and staging grounds as well as migration corridors. It should be noted, however, that Melville Bay Nature Reserve can be considered as a protection of a coherent ecosystem, which is an important ingredient in PAME’s MPA network approach.

This report, with the description of the seasonal, spatial distribution of key areas for a range of species dependant on the polynya, provides a basis for a systematic approach to the future management of the North Water in cooperation between relevant authorities and stakeholders.

Since most of the important areas in the polynya include Greenlandic as well as Canadian territorial waters, it would also be relevant to cooperate with the Canadian authorities. The Canadian EBSA areas within the study area cannot currently be characterized as MPAs, whereas the new Lancaster Sound National Marine Conservation Area would meet the criteria (IUCN 2017). As stated earlier, the Canadian authorities are progressing towards designating at least 10% of Canadian maritime areas as MPA by 2020, based on the identified EBSA areas. In this context, the Canadian authorities are striving to set protection objectives based on an MPA networking approach. (Pers. comm. Bethany Schroeder DFO, 2016).

For future management of the North Water, national regulations and designations may be sufficient for managing a range of the relevant disturbance factors. As noted above, the responsibility is shared between Greenlandic and Danish authorities (Chapter 1.4). According to UNCLOS, all inner territorial waters are under the jurisdiction of the coastal state. However, as far as conditions at sea are concerned (outside the baseline, but within the EEZ), any regulation will, for the most part, be rooted in international conventions, including UNCLOS. Thus, a number of issues at sea cannot be regulated by national regulations.

Regardless of whether any future regulations are based on Greenlandic, Danish or international authority it can be argued that the North Water meets international criteria for identifying particularly important areas for biodiversity and ecosystems (see Chapter 2.4). Depending on possible protection objectives for the area, several of the international frameworks may provide a basis for designation and subsequent management, including:

- IMO´s *Particular Sensitive Sea Areas* (PSSA)
- UNESCO´s Biosphere reserves - Man and Biosphere (MAB)
- UNESCO´s World Heritage Sites (WHS)
- Ramsar Convention – internationnally important wetlands.

The criteria for designation – and the obligations – differs between those international designation options, they have different protection and management objectives and focus on different types of threats.

Regardless of which framework is chosen for the further management of the area, it may be considered to include an ecosystem-based approach in the management planning. The relevant anthropogenic impact factors, their interactions and combined effects on the area's ecosystems should be considered for the entire international polynya area. A prerequisite for an ecosystem-based approach to management is the development of a cross-sectoral monitoring of key elements such as: ice, primary production and wildlife populations, as well as the various impact factors such as hunting, fishing, shipping, underwater noise, etc. Such a monitoring programme should also support the monitoring and reporting required in relation to the international designation.

Applying an ecosystem-based approach to ship traffic management has been suggested for Disko Bay and Store Hellefiskebanke – based on similar efforts in Canada, Norway and the work of the Arctic Council – please refer to Christensen et al. (2015) for elaborate examples from the countries mentioned. In the Arctic Council, ecosystem-based management (EBM) is regarded as an important tool in the future management of a rapidly changing Arctic.

4 Conclusions and recommendations

The North Water is a unique ecological system with a unique high-arctic fauna and an associated hunting and fishing culture. It is the most productive polynya in the Arctic and a number of species depend on its resources – the polynya is critical for many marine mammals and migratory bird populations of international importance.

Eighty percent of the world's population of little auks is dependent on the area, and especially in the eastern part of polynya – the Greenland side – the upwelling of nutrient-rich water stimulates high biological production and diversity, including endemic Arctic species. The spatial analyses used in this report illustrate where the relatively most important biological areas occur throughout the year, pointing out where there may be a need for increased attention to possible disturbance factors. In addition, the analyses show that the biological value and critical areas of the polynya, as determined on the basis of national and international criteria, varies over the year.

The North Water is changing, mainly due to climate change but shifting hunting patterns and increasing mineral resource exploration and utilization, tourism and shipping may also cause a significant impact on the area over the coming decades. Approximately 5% of the Greenlandic part of the study area is currently designated as protected areas that would meet the Arctic Council's criteria for a Marine Protected Area, but several of the most important areas are not protected. Due to the unique features of the area – which, for instance, is the basis for IUCN’s assessment of the North Water as a possible candidate for a UNESCO World Heritage Site designation – there may be a basis for considering additional protection and management initiatives.

In order to preserve the unique qualities of the North Water, there is a need for a management regime that is based on monitoring of the ecosystems and wildlife populations as well as of how the impacts of human activities such as hunting, (underwater) noise, fishing and other impacts may change over time. It is also important that the practical management actions are developed in close dialogue with the users of the area, so that local knowledge on, e.g. changing distribution of the hunted species and the main hunting grounds can be duly considered in the planning. In this regard, the protection of subsistence hunting areas is of great importance to the local population.

Identification of particularly important and vulnerable sub-areas in need of special protection could be a relevant option in future management planning. The analyses presented in this report suggest that the study area, or parts of it, could meet the criteria for inclusion in the IMO's list of Particularly Sensitive Sea Areas (PSSA), UNESCO's list of World Heritage Sites and Biosphere Reserves, as well as the Ramsar Convention's list of internationally significant wetlands. In relation to ship traffic, the regulatory tools available under the PSSA, including the Associated Protective Measures specifically to be defined for a designated PSSA, appear the most relevant among possible supplementary management measures.

However, protection by designating regulation zones cannot stand alone – the protected areas should be dynamic to be able to accommodate the likely shifts in the distribution of core habitats in the coming decades. It may be useful to draw inspiration from experiences from other Arctic countries, including Norway, where a holistic management approach has been adopted. In addition, principles on ecosystem-based management (EBM), as well as on 'connectivity' in relation to Marine Protected Areas – as emphasized by Arctic Council's focus on "area-based conservation measures and ecological connectivity" (PAME 2017) – would be a useful starting point for further thoughts on the management of the North Water.

The maps presented in this report can be considered in the development of zoning and management regulations with regard to:

- Shipping corridors for larger vessels in relation to
    a) Minimizing impacts of underwater noise
    b) (b) special focus on oil spills that may affect the most important and sensitive areas
    c) Planning of oil spill preparedness
- Special regulations for hunting and fishing/trawling
- Special regulations for tourism/cruise ships
- Special regulations for mineral resource activities
- Special limitations or no-go zones around core habitats in relation to other types of disturbances

To protect the area's unique qualities, it is recommended that the ecosystem-based management approach be adopted – based on dialogue and involvement of the local residents and other stakeholders. As the ecosystem, and the human activities, are dynamic, one of the tasks could be to develop a joint cross-sectoral monitoring programme for key elements such as: ice, primary production and wildlife populations, as well as the various impact factors such as shipping, underwater noise, and hunting and fishing etc. Obviously, a monitoring programme should be based on a collaborative effort involving scientists as well as traditional and local knowledge holders – both in the planning phase and the practical implementation. Key partners to involve in all steps of the planning may include the Pikialasorsuaq Commission, the local branches of the Association of Fishermen and Hunters in Greenland (KNAPK); in addition, close cooperation with the Canadian authorities would offer clear benefits.

5 References

AMAP/CAFF/SDWG 2013 Identification of Arctic marine areas of heightened ecological and cultural significance: Arctic Marine Shipping Assessment (AMSA IIc). Arctic Monitoring and Assessment Programme (AMAP), Oslo. 114 pp. ISBN-978-82-7971-081-3 http://www.amap.no/documents/download/1548

AMAP 2018. Adaptation Actions for a Changing Arctic: Perspectives from the Baffin Bay/Davis Strait Region. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. xvi + 354pp AMSA 2009. Arctic Marine Shipping Assessment 2009 Report. Arctic Council, April 2009, second printing.
https://www.pmel.noaa.gov/arctic-zone/detect/documents/AMSA_2009_Report_2nd_print.pdf

Anon 2011. Kongeriget Danmarks Strategi for Arktis 2011– 2020. ISBN: 978-87-7087-559-2.

Arctic Council 2013. Ecosystem-Based Management in the Arctic. Arctic Council, May 2013, Printed by: Lundblad, Tromsø, Norway https://oaarchive.arctic-council.org/bitstream/handle/11374/122/MM08_EBM_report%20%281%29.pdf?sequence=1&isAllowed=y

Barber DG, Massom RA 2007. The role of sea ice in Arctic and Antarctic polynyas. In: Smith WO and Barber DG (Eds.). Polynyas: Windows to the World, pp. 1-54. Volume 74, Elsevier Oceanography Series, doi:10.1016/S0422-9894(06)74001-6.

Bergeron M, Tremblay J-E 2014. Shifts in biological productivity inferred from nutrient drawdown in the southern Beaufort Sea (2003-2011) and northern Baffin Bay (1997-2011), Canadian Arctic. Geophysical Research Letters, 41:3979-3987.BirdLife International 2018. *Pagophila eburnea*. The IUCN Red List of Threatened Species 2018: e.T22694473A132555020. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T22694473A132555020.en. Downloaded on 09 July 2019

Boertmann D, Bay C 2018. Grønlands Rødliste 2018 - Fortegnelse over grønlandske dyr og planters trusselstatus. – Aarhus Universitet, Nationalt Center for Energi og Miljø (DCE) og Grønlands Naturinstitut.

Boertmann D, Mosbech A (eds) 2017. Baffin Bay. An updated strategic environmental impact assessment of petroleum activities in the Greenland part of the Baffin Bay. – Scientific Report from DCE – Danish Centre for Environment and Energy No. 215, 319 pp.

Born EW 2011. Walrus *Odobenus rosmarus*. Pp.102-113 in Boertmann D, Mosbech A (eds). Eastern Baffin Bay. A strategic environmental impact assessment of hydrocarbon activities. – DCE Scientific Report No. 9, Danish Centre for Environment and Energy, Aarhus University, Roskilde. 270 pp.

CAFF and PAME 2017. Arctic Protected Areas: Indicator Report, 2017:

Conservation of Arctic Flora and Fauna and Protection of the Arctic Marine Environment, Akureyri, Iceland. ISBN 978-9935-431-64-6 https://www.caff.is/assessment-series/414-arctic-protected-areas-indicator-report-2017

Christensen T, Falk K, Boye T, Ugarte F, Boertmann D, Mosbech A 2012. Identifikation af sårbare marine områder i den grønlandske/danske del af Arktis. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi. 72 pp. http://www2.dmu.dk/pub/sr43.pdf

Christensen T, Mosbech A, Geertz-Hansen O, Johansen KL, Wegeberg S, Boertmann D, Clausen DS, Zinglersen KB, Linnebjerg JF. 2015. Analyse af mulig økosystembaseret tilgang til forvaltning af skibstrafik i Disko Bugt og Store Hellefiskebanke. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 103 s. - Teknisk rapport fra DCE - Nationalt Center for Miljø og Energi nr. 61. http://dce2.au.dk/pub/TR61.pdf

Christensen, T., Aastrup, P., Boye, T., Boertmann, D., Hedeholm, R., Johansen, K.L., Merkel, F., Rosing-Asvid, A., Bay, C., Blicher, M., Clausen, D.S., Ugarte, F., Arendt, K., Burmeister, A., Topp-Jørgensen, E., Retzel, A, Hammeken, N., Falk, K., Frederiksen, M., Bjerrum, M. & Mosbech, A. 2016. Biologiske interesseområder i Vest- og Sydøstgrønland. Kortlægning af vigtige biologiske områder. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 210 s. - Teknisk rapport fra DCE – Nationalt Center for Miljø og Energi nr. 89. https://dce2.au.dk/pub/TR89.pdf

Cobb, D.G. 2011. Identification of Ecologically and Biologically Significant Areas (EBSAs) in the Canadian Arctic. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/070. vi + 38 p

Day J., Dudley N., Hockings M., Holmes G., Laffoley D., Stolton S. & S. Wells, 2012. Guidelines for applying the IUCN Protected Area Management Categories to Marine Protected Areas. Gland, Switzerland: IUCN. 36pp. https://portals.iucn.org/library/sites/library/files/documents/PAG-019.pdf

Dietz R, Mosbech A, Flora J, Eulaers I 2018. Interactions of climate, socio-economics, and global mercury pollution in the North Water. Ambio (2018) 47(Suppl 2): 281. https://doi.org/10.1007/s13280-018-1033-z

Deming JW, Fortier L, Fukuchi M 2002. Editorial. The International North Water Polynya Study (NOW): a brief overview. – Deep Sea Reeseach II 49:4887-4892.

Dudley N (ed) 2008. Guidelines for Applying Protected Area Management Categories. Gland, Switzerland: IUCN. x + 86pp. https://cmsdata.iucn.org/downloads/guidelines_for_applying_protected_area_management_categories.pdf

EAMRA 2015. Offshore Seismic Surveys in Greenland. Guidelines to Best Environmental Practices, Environmental Impact Assessments and Environmental Mitigation Assessments. DCE – Danish Centre for Environment and Energy; Greenland Institute of Natural Resources GINR; Environmental Agency for the Mineral Resource Activities, Greenland. https://www.govmin.gl/images/Documents/Terms_guidelines_hydrocarbons/Environmental_Impact_Assessment_Guidelines.pdf

Egevang C, Boertmann D, Mosbech A, Tamstorf MP 2003. Estimating colony area and population size of little auks *Alle alle*, at Northumberland Island using aerial images. – Polar Biology 26: 8-13.

Fisheries and Oceans Canada 2015. Ecologically and Biologically Significant Areas in Canada's Eastern Arctic biogeographic region, 2015 (http://www.dfo-mpo.gc.ca/csas-sccs/publications/sar-as/2015/2015_049-eng.pdf)

GINR 2018. CITES non detriment findings for havpattedyr i Grønland 2018. Greenland Institute of Natural Resources. CITES Scientific Authority in Greenland. http://www.natur.gl/biologisk-raadgivning/cites/

Gjerdrum C, Fifield DA, Wilhelm SI, 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms, Canadian Wildlife Service Technical Report Series Number 515.

Gonzales-Bergonzoni I, Johansen KL, Mosbech A, Jeppesen E, Davidson TA 2017. Small birds, big effects: the little auk (Alle alle) transforms high Arctic ecosystems. Proceedings Royal Society B 294, 20162572. http://dx.doi.org/10.1098/rspb.2016.2572

Government of Canada 2011. National Framework for Canada´s Network of Marine Protected Areas, Fisheries and Oceans Canada, Ottawa 31pp.

Greenland Statistics 2019. Statbank Greenland (http://bank.stat.gl) accessed 1 August 2019.

Hastrup K 2015. The North Water. Life in the Ice Edge in the High Arctic. In Hastrup K, Hastrup F (eds.) Waterworlds: Anthropology in Fluid Envidonments. Oxford and New Yourk 2016: Berghahn, pp. 279-299

Hastrup K, Grønnow B, Mosbech A 2016. The NOW project – living resources and human societies around the North Water in the Thule area, NW Greenland, Annual report. (http://now.ku.dk/documents/NOW2014AnnualReportFinal.pdf/NOWreport2015endelig.pdf)

Heide-Jørgensen MP, Laidre KL, Burt ML, Borchers DL, Marques TA, Hansen RG, Rasmussen M and Fossette S 2010. Abundance of narwhals (Monodon monoceros L.) on the hunting grounds in Greenland. Journal of Mammalogy 91(5):1135–1151

Heide-Jørgensen MP, Hansen RG, Nielsen NH, Rasmussen M 2013a. The significance of the North Water to Arctic marine mammals. – Ambio 42: 596-610.

Heide-Jørgensen MP, Richard P, Dietz R, Laidre K 2013b. A metapopulation model for Canadian and West Greenland narwhals. – Animal Conservation 16: 331-343 doi:10.1111/acv.12000

Heide-Jørgensen MP, Hansen RG, Westdal K, Reeves RR, Mosbech A 2013c. Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments?, Biological Conservation 158 (2013) 50–54

Heide-Jørgensen MP, Tougaard J, Mosbech A, Nymand J 2015. Summary of environmental studies designed to assess the effects of seismic exploration in the Baffin Bay. Unpubl. report.

Heide-Jørgensen MP, MH Sinding, Nielsen NH, Rosing-Asvid A, Hansen RG 2016. Large numbers of marine mammals winter in the North Water polynya. – Polar Biology (on line) DOI 10.1007/s00300-015-1885.

Inuit Circumpolar Council 2017. People of the ice bridge: The future of the Pikialasorsuaq. Inuit Circumpolar Council Canada / ᐃᓅᐃᑦ ᓯᓚᕐᔪᐊᕐᒥᐅᑦ ᑲᑎᒪᔩᖏᑦ ᑲᓇᑕ / Inuit Issittormiut Siunnersuisoqatigiiffiat, 2017. http://pikialasorsuaq.org/media/efa13559-9221-4407-8583-c47509b56e7b/6CkEoA/Reports/Report%20of%20the%20Pikialasorsuaq%20Commission%20Nov%202017_For%20e-distribution.pdf

IUCN 2017. Canada's newest and largest Marine Protected Area: Tallurutiup Imanga – Lancaster Sound. 31 August 2017 – accessed 31 July 2019. https://www.iucn.org/news/protected-areas/201708/canada%E2%80%99s-newest-and-largest-marine-protected-area-tallurutiup-imanga-%E2%80%93-lancaster-sound

Jakobsen IU 2014. Chapter 10. Marine Protected Areas as Tool to Ensure Environmental Protection of the Marine Arctic: Legal Aspects. In ED. Tedsen E, Cavalieri S, Kraemer RA. Arctic Marine Governance, Springer ISBN 978-3-642-38594-0.

Klein B, LeBlanc B, Mei ZP, Beret R, Michaud J, Mundy CJ, von Quillfeldt CH, Garneau ME, Roy S, Gratton Y, Cochran JK, Bélanger S, Larouche P, Pakulski JD, Rivkin RB, Legendre L 2002. Phytoplankton biomass, production and potential export in the North Water. – Deep-Sea Research II 49: 4983-5002.

Kyhn LA, Mosbech A (eds) 2019. White Paper - North Water Polynya Conference Copenhagen 2017. 152 pp. Aarhus University 2019

Langen PL, Grenier P, Brown R 2018. Climatic drivers. In: Adaptation Actions for a Changing Arctic: Perspectives from the Baffin Bay/Davis Strait Region. pp. [39-76]. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Lovejoy C, Legendre L, Price NM 2002. Prolonged diatom blooms and microbial food web dynamics: experimental results from an Arctic polynya. – Aquatic Microbial Ecology 29: 267-278.

Martin J, Tremblay J-É, Gagnon J, Tremblay G, Lapoussière A, Jose C, Poulin M, Gosselin M, Gratton Y, Michel C 2010. Prevalence, structure and properties of subsurface chlorophyll maxima in Canadian Arctic waters. – Marine Ecology Progress Series 412: 69-84.

Melling H, Gratton Y, Ingram G 2001. Ocean circulation within the North Water Polynya of Baffin Bay. – Atmosphere-Ocean, 39: 301-325

Meltofte H (Ed.) 2013. Arctic Biodiversity Assessment: Status and Trends in Arctic Biodiversity. Conservation of Arctic Flora and Fauna, Akureyri. 560pp.

Merkel F, Labansen AL, Boertmann D, Mosbech A, Egevang C, Falk K, Linnebjerg JF, Frederiksen M, Kampp K, 2014. Declining trends in the majority of Greenland's thick-billed murre (*Uria lomvia*) colonies 1981-2011. Polar Biology 37: 1061-1071.

Merkel F, Tremblay J-E 2018. Living resources. In: Adaptation Actions for a Changing Arctic: Perspectives from the Baffin Bay/Davis Strait Region. pp. [133-200]. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway.

Michel C, Nielsen TG, Nozais C, Gosselin M 2002. Significance of sedimentation and grazing by ice micro- and meiofauna for carbon cycling in annual sea-ice (northern Baffin Bay). – Aquatic Microbial Ecology 30: 57-68.

Michel C, Hamilton J, Hansen E, Barber D, Reigstad M, Iacozza J, Seuthe L, Niemi A 2015. Arctic Ocean outflow shelves in the changing Arctic: A review and perspectives. Progress in Oceanography, doi:10.1016/j.pocean.2015.08.007.

Mineral Resources Authority 2015. Guidelines for preparing an Environmental Impact Assessment (EIA) report for mineral exploitation in Greenland. 23 pp. Government of Greenland. https://govmin.gl/images/stories/minerals/Guidelines_for_preparing_an_Environmental_Impact_Assessment_EIA_report_for_mineral_exploitation_in.pdf

Naalakkersuisut 2014. Skibsfart og klimaforandringer – muligheder for tilpasnings- og reduktionstiltag, Departementet for Miljø og Natur-NAMMCO/JCNB. 2015 . Report of the Joint Meeting of the NAMMCO scientific working group on the population status of narwhal and beluga in the North Atlantic and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Group. Annex 2 in: Report of the 22nd Meeting of the NAMMCO Scientific Committee (p. 94 - 16). http://nammco.no/assets/Publications/Scientific-Committee-Reports/SC-22-Final-Report.pdf

Nettleship DN, Evans PGH 1985. Distribution and status of the Atlantic Alcidae. Pp. 53-154 in: Nettleship DN, Birkhead TR (eds.) The Atlantic Alcidae. – Academic Press, London, 573 pp.

PAME 2015. Framework for a Pan-Arctic Network of Marine Protected Areas. https://oaarchive.arctic-council.org/bitstream/handle/11374/417/MPA_final_web.pdf?sequence=1&isAllowed=y

PAME 2017. PAME MPA network toolbox. Area-based conservation measures and ecological connectivity. https://www.pame.is/images/03_Projects/MPA/Toolbox/PAME_MPA_network_toolbox_Area-based_conservation_measures_and_ecological_connectivity.pdf

Pedersen CE, Falk K 2001. Chick diet of dovekies *Alle alle* in Northwest Greenland. – Polar Biology 24: 53-58.

Prokopowicz A, Fortier L 2002. Population structure of three dominant Calanus species in North Water Polynya, Baffin Bay. – Polish Polar Research 23: 241-252.

Ramsar Convention Secretariat 2007. Designating Ramsar sites: The Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance. Ramsar handbooks for the wise use of wetlands, 3rd edition, vol. 14. Ramsar Convention Secretariat, Gland, Switzerland.

Ringuette M, Fortier L, Fortier M, Runge JA, Belanger S, Larouche P, Weslawski JM, Kwasniewski S 2002. Advanced recruitment and accelerated population development in Arctic calanoid copepods of the North Water. – Deep-Sea Research Part II: Topical Studies in Oceanography 49: 5081-5099.

Sejr MK, Batty P, Josefson A, Blicher ME, Hansen J, Rysgaard S 2011. Box 1. Benthic fauna studies in Baffin Bay assessment area. Pp. 64-67 in Boertmann D, Mosbech A (eds). Eastern Baffin Bay. A strategic environmental impact assessment of hydrocarbon activities. – DCE Scientific Report No. 9, Danish Centre for Environment and Energy, Aarhus University, Roskilde.

Speer L, Laughlin TL 2011. IUCN/NRDC Workshop to Identify Areas of Ecological and Biological Signifi cance or Vulnerability in the Arctic Marine Environment, November 2-4, La Jolla. (https://portals.iucn.org/library/sites/library/files/documents/Rep-2011-001.pdf)

Speer L, Nelson R, Casier R, Gavrilo M, von Quillfeldt C, 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. 112p

Stern HL, Laidre KL 2016. Sea-ice indicators of polar bear habitat. The Cryosphere 10, 20272041, doi:10.5194/tc-10-2027-2016

Robards M, Gilchrist, H Allard, K 2000. Breeding Atlantic Puffins, *Fratercula arctica*, and other bird species of Coburg Island, Nunavut. Canadian Field-Naturalist. 114. 72-77.

Stephenson SA, Hartwig L 2010. The Arctic Marine workshop. – Canadian Manuscript Report of Fisheries and Aquatic Sciences 2934.

SWG [Scientific Working Group to the Canada-Greenland Joint Commission on Polar Bear] 2016. Re-Assessment of the Baffin Bay and Kane Basin Polar Bear Subpopulations: Final Report to the Canada-Greenland Joint Commission on Polar Bear. 31 July 2016: x + 636 pp.

Tremblay JE, Gratton Y, Fauchot J, Price NM 2002. Climatic and oceanic forcing of new, net, and diatom production in the North Water. – Deep-Sea Research II 49: 4927-4946.

Tremblay JE, Hattori H, Michel C, Ringuette M, Mei ZP, Lovejoy C Fortier L, Hobson KA, Amiel D, Cochran K 2006a. Trophic structure and pathways of biogenic carbon flow in the eastern North Water Polynya. Progress in Oceanography: 71, 402-425.

Tremblay JE, Michel C, Hobson KA, Gosselin M, Price NM 2006b. Bloom dynamics in early opening waters of the Arctic Ocean. – Limnology and Oceanography 51: 900-912.

Ugarte F, Rasmussen LM, Heide-Jørgensen MP 2011. The toothed whales. Pp. 133-150 in Boertmann D, Mosbech A (eds). Eastern Baffin Bay. A strategic environmental impact assessment of hydrocarbon activities. – DCE Scientific Report No. 9, Danish Centre for Environment and Energy, Aarhus University, Roskilde.

UNESCO 1996. Biosphere reserves: The Sevilla Strategy and the statutory framework of the world network. Unesco, Paris.

UNESCO 2008. Operational Guidelines for the Implementation of the World Heritage Convention, Link: http://whc.unesco.org/en/guidelines. (27.05.2015).

Ware C, Berge J, Sundet JH, Kirkpatrick JB, Coutts ADM., Jelmert A, Olsen SM, Floerl O, Wisz MS, Alsos IG 2014. Climate change, non-indigenous species and shipping: assessing the risk of species introduction to a high-Arctic archipelago. Diversity Distrib., 20: 10–19. doi:10.1111/ddi.12117